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An integrated systems-design methodology and revised model of sustainable development for the built environment in the Information Age

Submitted by

Marco Macagnano

In partial fulfilment of part of the requirements of the degree of:

Philosophiae Doctor in Architecture

University of Pretoria

Faculty of Engineering, Built Environment and Information Technology

Supervisors: Arthur Barker (Dr), Jeremy Gibberd (Dr)

January 2018

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Declaration

In accordance with Regulation 4(e) of the general regulations (G. 57) for dissertations and theses, I declare that this thesis, which I submit for the degree Philosophiae Doctor (Architecture) at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

I further state that no part of this thesis has already been, or is currently being, submitted for any other such degree, diploma or other qualification.

I further declare that this thesis is substantially my own work. Where reference is made to the works of others, the extent to which the work has been used is indicated and fully acknowledged in the text and bibliography.

This thesis is 118 743 words long (excluding scanned items, and text-embedded imagery).

2018/01/28

Marco Macagnano

Date

Acknowledgements

I wish to acknowledge the input and support of the following persons:

Arthur Barker,

Jeremy Gibberd,

My parents and brother, and

Jessica.

To change the world for the better, one must be prepared to change with it.

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Preface

This thesis was developed to look beyond the current models of sustainable development and architectural working and design processes to respond to the challenges of the current era, defined as the Information Age.

This digital future (present), enabled through Information and Communication Technology (ICT), is dominated by a message of lifestyle improvement through access to information, emphasis on user experience, and convenience. This is presented as a world in which Augmented-Reality ‘glasses’ and other wearable computing can substitute the drudgery of the ‘real’ for a superimposed digital experience. While our senses are kept distracted by artificial electronic impulses, ubiquitous computing is constantly calculating and recalibrating our experience based on interrogation of real-time information. This has a bearing on how we experience our physical surroundings, engage in social interaction, and build knowledge through experience. Architecture no longer has the exclusive mandate to define these aspects and therefore requires an evolution of approach and process.

How is a static building, made of immovable bricks and concrete, and designed for a fixed temporal and spatial scale, expected to overcome potential future obsolescence (partial or total)? Furthermore, how can it compete with a fluid digital landscape into which the world’s connected population has irrevocably immersed itself? This is the reality of the Information Age, and a challenge facing the design of built environments that risk falling behind the technological curve while being potentially limited by a future of technological retrofit and replacement.

Furthermore, as a concept, sustainable development pursues the goal of ensuring that today’s accomplishments are of equal benefit to future stakeholders, promoting quality of life within ecological constraints. Economic, social, and environmental aspects are important factors in ensuring that this goal is met. However, decades of discourse and varying iterations of the concept of sustainable development illustrate that it is easier defined than implemented. This challenge of implementation and appropriateness is also made greater when one considers that sustainable development was conceived of as a concept over two decades before the internet was invented, and the subsequent inception of the Information Age.

The Information Age therefore brings with it a number of challenges to the 21st century architect and architecture operating within the paradigm of sustainable development:

1. The digital world (cyberspace) is actively challenging the physical world as an environment to support our social, recreational and working lifestyles. This is represented by technologies such as social networks, mobile and cloud computing, online shopping, and Virtual Reality.
2. Physical environments are undergoing technological (smart-city) retrofit and augmentation through information-based infrastructure and pervasive digital technologies. This is represented by technologies such as intelligent building management systems, GPS and Wi-Fi-linked navigation and tracking systems (city and building scale), and Augmented (Mixed) Reality.
3. Architectural design process is challenged by an inability to reconcile the concept of sustainable development with the production of static products (buildings) for a specific temporal and spatial scale.
4. Architects are challenged with reconciling the needs of the 21st century building user with the building lifecycle, integrating varying tools for performance simulation and quantification, and planning for future flexibility by considering architectural design as the process of creating systems instead of a product.

This thesis responds to a need to re-define the model of sustainable development to meet the needs and challenges of the Information Age, in order that this may inform a new architectural design methodology to support it. This revised model for sustainable development aligns itself to the 21st Century Information Age, and the evolved human needs of this era, through integration of knowledge as a core criterion. This methodology is developed to guide the architectural practitioner through sequential work stages of an integrated systems-design process. This creates conditions for flexible design, adaptable integration of future technologies and computing, and for the project stakeholders to participate in active knowledge creation, management, and transfer during the project life cycle.

This thesis is therefore developed to advance the concept of sustainable development, propose an integrated systems-design methodology for the architects, as well as provide a basis for future research.

M. Macagnano

Address: PO BOX 915-993
Faerie Glen, Pretoria, South Africa, 0043

Email address: marco.macagnano@gmail.com

Abstract

Full title: **An integrated systems-design methodology and revised model of sustainable development for the built environment in the Information Age.**

Submitted by: Marco Macagnano (Mr)
Supervisors: Arthur Barker (Dr), Jeremy Gibberd (Dr)
For the degree of: Philosophiae Doctor in Architecture
Faculty: Engineering, Built Environment and Information Technology
University: University of Pretoria

This thesis was developed to investigate the current models of sustainable development and architectural working and design practice and process to respond to the challenges of the current era defined as the Information Age. This thesis proposes a new model of sustainable development aligned to architecture and the Information Age, and a new integrated systems-design methodology to support it.

Buildings were defined by le Corbusier in 1927 as ‘machines for living in’[1] on the premise that these buildings facilitated our day-to-day user experience. The role of architecture as a facilitator for a sustainable existence is therefore subject to continued investigation. While there has been an increasing interest in environmental issues and ‘green building’, built environments have consequently failed to effectively holistically integrate core sustainable development principles in architecture. When compared to the definition of sustainable development in the UN Brundlandt Report of 1987, further research into an architectural design methodology is required to enable and plan for the long-term success of our built environments for current and, importantly, future generations.

The practices and production of architecture risk being limited to reactively monitoring the design and construction processes for fixed moments in time, usually after the problem has presented itself. This is representative of localised, yet much publicised trends involving quantifiable rating systems for building performance. This does not

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[1] The phrase by le Corbusier as quoted within the 1927 manifesto *Vers une Architecture* (*Towards an Architecture*).

contribute to long-term sustainability of the architectural product, nor the core principle of sustainable development to adequately meet the needs of current and future generations. The gravitation towards these easily-followed, yet limited-in-scope checklist processes is symptomatic of concepts of sustainable development remaining too broad and fragmented to facilitate focused, industry-appropriate implementation and design.

The digital and information-based revolution has arrived, and humankind has now progressed to the point where constant and pervasive access to information and communication in a world of connected systems has changed the way we live and work. This is occurring at an exponential rate within what have been termed 'knowledge-based societies'. Furthermore, the influence of the Information Age continues to manifest itself in the built environment through advancement of concepts and initiatives such as Smart Cities, intelligent buildings, and the Internet of Things. However, architectural approach and its emphasis on the building as a finite product comes at the expense of a holistic and integrated systems approach, and therefore requires investigation towards a revised design methodology. This thesis will begin by investigating the concept of sustainable development from its original inception to existing interpretations, and will interrogate its continued significance as a decades-old concept to the Information Age. This will be undertaken on the basis that sustainable development primarily aligns itself to the needs of humankind (current and future generations) and as such remains timeless as a core concept. However, the criteria that define sustainable development require investigation based on: a) their suitability towards human need in the context of knowledge-based societies and the Information Age, as well as b) their appropriateness for focused implementation in the scope of the built environment. In this aim, newly proposed criteria will be assimilated into a revised model for sustainable development, from which a methodology for design is developed. This will address the nature of the architectural process towards the creation of sustainable building solutions as a function of a systems approach, rather than a product approach.

An integrated systems-design methodology is proposed, promoting the evolution of sustainable development theory in architecture for greater applicability to the Information Age. This systems-design methodology proactively identifies criteria for solving a given problem and the development of alternative solutions, while the proposed revised model for sustainable development is integrated to achieve a holistic building solution based on a systems process. This is inclusive of product (systems

solution) delivery into the operation phase. The designer and project information model therefore transition into ‘information custodian’ and repository for knowledge gathering and exchange respectively, to the benefit of current and future stakeholders. This is addressed through various stages in design development and implementation, which apply contextually-based requirements of proposed sustainable development criteria, while catering for aspects of future flexibility, user experience, and knowledge-based development. This methodology expects the design practitioner to apply multi-dimensional evaluation and assessment tools at their discretion, and accommodate changing project dynamics over its life cycle. This implementation will benefit from future research and the introduction of new technologies to aid the process. This may furthermore be affected by new regulatory policy and guidelines affecting architects and the built environment.

Keywords: Information and Communication Technology (ICT); sustainable development; intergenerational equity; knowledge-based societies; Information Age; digital age; integrated system-design methodology, architectural design.

Synopsis

The purpose of this thesis is to investigate the origin and evolution of the concept of sustainable development, to examine the continued suitability of the three-pillars of sustainability in architecture comprised of ecological, social and economic criteria, and to understand the evolved needs of our societies in the Information Age that create new requirements for sustainable development and architecture. This investigation will therefore serve as a basis to develop and propose a revised model of sustainable development which is industry-appropriate to architecture, and an integrated systems-design methodology for architects and the 21st century built environment.

The following questions are therefore integrated within the body of research in this thesis:

1. Chapter 3: Are the three-pillars of sustainability still a valid and comprehensive basis for sustainable development, or is there need for further development?
2. Chapter 3: How has the concept of sustainable development, as defined by the UN, evolved since its origin?
3. Chapter 3: Is the concept of sustainable development adequately focused for industry-specific implementation, or is the concept too vague for ease of implementation?
4. Chapter 4: Do the 'knowledge-based society' and 'knowledge-based development' concepts of the Information Age present new user requirements or considerations to be addressed in design for sustainable development?
5. Chapter 4: Does the Information Age and its representative technologies present any new opportunities for human-environment interaction, and what are the implications on architecture?
6. Chapter 4: How has the Information Age and applied ICTs impacted the built environment?
7. Chapter 5: How is the user experience responsibly addressed in a new human-centric sustainable development model?
8. Chapter 5: How important is adaptive and flexible design, in pursuit of prolonging long-term usability, to sustainable development in architecture?
9. Chapter 5: What are the new criteria (pillars) for sustainable development that are aligned to these user requirements?
10. Chapter 6: Can a new sustainable development model be proposed for sustainable implementation in architecture through integration of social (1),

environmental (2), economic (3) and knowledge (4) criteria in a four-pillar approach?

11. Chapter 6: What is the impact of this new model on the architectural design process?
12. Chapter 6: Can architectural design and the built environment benefit from addressing architecture as the creation of dynamic systems rather than the production of static products?
13. Chapter 6: Can a new design methodology be developed on the basis of an integrated systems-design process?

The researcher recognises that, while a variety of concepts and tools exist for sustainable development, current limited application of the three-pillar approach in architecture does not cater for the evolved knowledge-based needs of humankind in the Information Age. An evolved model of sustainable development would benefit from integrating the requirements of knowledge-based development. Furthermore, a new architectural design methodology that supports the proposed sustainable development model is required. This will enable an integrated system of approach which includes criteria for sustainable development and holistic design practices.

The thesis comprises the following sections:

- Description of the problem and its setting as part of the introduction
- Description of the research methodology.
- Division into four key problem statements, each investigated and resolved in the development of subsequent hypotheses.
- Development of a proposed integrated systems-design methodology for the built environment, inclusive of a theoretical case study for the current context of application limited by technological and industry constraints of the time.
- Conclusion and summary and recommendations in which the findings are presented in the context of the problem statements and related hypotheses.

Glossary of terms

Augmented Reality (AR) – A technology that superimposed computer-generated information and imagery onto a user's view of the real world, providing a composite view.

Autopoeisis – A system capable of reproducing and maintaining itself.

Avatar – An icon or figure representing a real-world person in a virtual or digital environment. Avatars often do not have the same name as their owner, disguising the user's identity.

Blockchain - a public ledger of all cryptocurrency transactions that have ever been executed. It is constantly growing as 'completed' blocks are added to it with a new set of recordings. The blocks are added to the blockchain in a linear, chronological order.

Building Information Modelling (BIM) – A digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle.

Building Management System (BMS) – or a Building Automation System (BAS) – A computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems.

CAD (Computer-Aided Design) – Software used by architects, engineers, drafters, artists and others to create precision drawings or technical illustrations. CAD software can be used to create two-dimensional (2D) drawings or three-dimensional (3D) models.

Computational design – The use of computers and mathematical approach to the generation of geometries, objects, and architecture. Benefited through the application of *parametric design* (see below).

Computer – An electronic device for storing and processing data, typically in binary form, according to instructions given to it in a variable program.

Computing – Any goal-oriented activity requiring, benefiting from, or creating, algorithmic processes through use or operation of computers. Computing includes designing, developing and building hardware and software systems; processing, structuring and managing various kinds of information; doing scientific research on and with computers; making computer systems behave intelligently; and creating and using communications and entertainment media.

Cyberspace – A notional domain characterised by the use of electronics to store, modify and exchange data via networked computer systems and associated physical infrastructures. As a social experience, individuals can interact, exchange ideas, share information, provide social support, conduct business, direct actions, create artistic media, play games, engage in political discussion and so on, using this global network.

Data – The quantities, characters or symbols on which operations are performed by a computer, being stored and transmitted in the form of electrical signals and recorded on magnetic, optical or mechanical recording media.

Dialectic process – Reasoning in which a question-answer approach is used to validate or examine and idea or assumption; establishing discourse between two or more parties to establish the truth through reasoned arguments.

Digital – A description of data which is stored or transmitted as a sequence of discrete symbols from a finite set, most commonly binary data represented by using electronic or electromagnetic signals.

Green Building – Both a structure and the using of processes that are environmentally responsible and resource-efficient throughout a building's life cycle.

Generative design – Technology that mimics nature's evolutionary approach to design. The establishment of systems aimed at creating new design processes that produce spatially novel yet efficient designs through computing capabilities. A form, pattern, or object (through parametric modelling) is automatically generated or modified by an algorithm.

Informatics – The science of computer systems and of processing data for storage and retrieval; information science.

Information and Communication Technology (ICT) – A widely used umbrella term for information technology (IT), with a broader scope that stresses the role of unified communications and the integration of telecommunications, computers, as well as the necessary enterprise software, middleware, storage and audio-visual systems, which enable users to access, store, transmit and manipulate information.

Information Age – A period in human history characterised by a shift from industrialisation to an economy based on information computerisation.

Information Technology (IT) – The study or application of computers and telecommunications equipment to store, retrieve, transmit and manipulate data, often in the context of a business or other enterprise.

Intelligent buildings – A building that integrates technology and process to create a facility that is safer, more comfortable and productive for its occupants, and more operationally efficient for its owners; advanced technologies – combined with improved processes for design, construction and operations – provide a superior indoor environment that improves occupant comfort and productivity while reducing energy consumption and operations staffing.

Internet – The global communication network that allows almost all computers worldwide to connect and exchange information. Currently categorised into the internet of everything (IoE), and the internet of things (IoT); these concepts are expanded upon in further detail within the contents of this thesis.

Intergenerational equity – A concept that states that humans hold the natural and cultural environment in common with other members of current and future generations.

Knowledge-based development – A humanistic perspective and development process that uses a variety of knowledge management systems and strategies to capture new opportunities, advance the economy, and achieve progress in the evolution of the human civilisation.

Knowledge-based societies – societies that rely on the knowledge of their citizens to drive innovation, entrepreneurship, and dynamics of that society’s economy, while making available society knowledge that may be used to benefit the human condition. This is based on the vast increase of data creation and information dissemination that results from information technologies.

Multimedia –The field concerned with the computer-controlled integration of text, graphics, drawings, still and moving images (video), animation, audio and any other media where every type of information can be represented, stored, transmitted and processed digitally.

Operating System (OS) – The software that supports a computer's basic functions, such as user interface, scheduling tasks, executing applications and controlling of peripherals.

Open source – Software for which the original source code is made freely available for redistribution and modification.

Parametric design – Use of parameters attached to objects and components, to design things. These parameters are monitored and changed through computational input. If parameters change, the end results change.

Pervasive computing (also called **Ubiquitous Computing**) – The growing trend towards embedding microprocessors in everyday objects so they can communicate information. The words pervasive and ubiquitous mean 'existing everywhere'. Pervasive computing devices are completely connected and constantly available.

Robotics – The branch of technology that deals with the design, construction, operation and application of robots.

Systems design – The process of defining architecture, components, modules, interfaces and data for a system to satisfy specified requirements. **Technology** – The application of scientific knowledge for practical purposes.

Three pillars of sustainability - Sustainability is most often defined as meeting the needs of the present without compromising the ability of future generations to meet theirs. There are three main pillars: economic, environmental and social.

Triple bottom line – A business framework with three parts: social, environmental (or ecological) and financial.

User Interface (UI) – The means by which the user and a computer system interact, in particular the use of input devices and software; this includes everything designed into an information device with which a human being may interact including display, peripheral input devices, help messages and how an application program invites interaction and responds to it.

Ubiquitous computing – See **Pervasive computing**.

Universal access – The ability of all people to have equal opportunity in education and access to information regardless of their social class, gender, ethnicity, background, or physical and mental disability.

Virtual – In computing terms, the quality of effecting something without actually being or creating that something. Not *physically* existing but made by software to appear to do so while being carried out, accessed or stored by means of a computer, usually over a network.

Virtual Reality (VR) – The medium of 'immersive virtual space'. The computer-generated simulation of a 3D image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors.

World Wide Web – An information system on the Internet that allows documents to be connected to other documents by hypertext links, enabling the user to search for information by moving from one document to another.

List of abbreviations and acronyms

AECO	Architectural, engineering, construction, and operations
BIM	Building Information Modelling
BMS	Building Management System
BRE	Building Research Establishment
CAD	Computer-Aided Design
CEN	European Committee for Standardisation
CMEA	Change Mode Effects Analysis
CPN	Change Potential Number
CTAM	Construction Technology Adoption Model
CURT	Construction User’s Round Table
DARPA	Department Advanced Research Projects Agency
DFAD	Designing for adaptability
DOT	Digital Opportunities Task
EIBG	European Intelligent Buildings Group
FAR	Floor Area Ratio
FI	Future Internet
FMEA	Failure Mode and Effect Analysis
GIS	Geographic Information System
HCI	Human Computer Interaction
IB	Intelligent Building
IBE	Intelligent Buildings of Europe
IBI	Intelligent Building Institute
ICT	Information and Communication Technology
IDDS	Integrated Design and Delivery System
IEQ	Indoor environmental quality
IoE	Internet of everything
IoT	Internet of things
IPD	Integrated Project Delivery
ISO	International Organisation of Standardisation
IT	Information Technology
ITIF	Information Technology and Innovation Foundation
ITU	International Telecommunication Union
JE	Joint evaluation
KBD	Knowledge-based development

LOD	Levels of Detail
MEPF	Mechanical, Electrical and Electronic, Plumbing, Fire
MIS	Management information systems
PLM	Product Lifecycle Management
SD	Sustainable Development
SE	Separate evaluation
TBL	Triple bottom line
TFP	Total factor productivity
WCED	World Commission on Environment and Development
WHO	World Health Organisation
WSIS	World Summit of the Information Society
WSSD	World Summit on Sustainable Development
WTI	World Telecommunication/ICT Indicators

1. Introduction

1.1. Statement of the problem

The purpose of this thesis is to evaluate the current understanding and implementation of sustainable development in architecture and to propose advancements to its theory and application. These advancements will address the generic nature of the concept to develop a more industry-appropriate model for application in architecture. Furthermore, since sustainable development is a concept coined at a time that predated the integration of computing into our daily lives, an investigation will be made to determine what evolutions of the concept are required in this new technological era known as the Information Age. These proposed advancements will provide a more appropriate and focused sustainable development model, and an evolved design methodology for architecture in the 21st Century.

For over four decades, numerous and competing theories of sustainable development have been introduced. For the purpose of this thesis, the concept of sustainable development as introduced by the United Nations in 1972, 'the ability of an environment to meet the needs of current and future generations' (WCED, 1987), will be investigated as the basis of sustainable development theory. It is to this theory that varying concepts of sustainable development will be compared.

Sustainable development, as an 'umbrella term' for application to all industries, has proven a successful foundation, yet has resulted in implementation challenges. The concept of sustainable development will be investigated to understand reasons for the perceived generic core concepts and subsequent difficulty of application. A case will be made that evolution of the core concept of sustainable development towards an industry-specific implementation is required for the built environment and architectural practices that shape it.

The purpose of the research will furthermore investigate the evolving needs of humankind within the context of contemporary knowledge-based societies, and the potential for improvements to current concepts of sustainable development in order to cater to the needs and quality of life of future generations. The question therefore remains: since sustainable development's inception, how have the needs of humankind changed in the Information Age?[2]

This new age created a cultural (and technological) shift where the realms of the physical and the digital have merged (pervasive) and been overlaid (augmented). It is, for example, no longer a minimum requirement to be provided with a physical place of work in order to do business, when access to a laptop and internet connection would suffice. The effect of ICT on process and practice has far-reaching consequences for the role of the architect. While there is some inevitable resistance to the pervasive integration of computing into our daily lives, an individual or even a society's success is linked to the ability to access and interpret information effectively. Humankind lives within a context of knowledge societies whereby a sustainable future hinges on the ability to efficiently operate in an ever-evolving, information-charged world. Knowledge is a criterion to which sustainable development and intergenerational equity should be linked.

An understanding of this evolved dependence on information and communication in humankind's daily lives is required. Assimilation of information, and interpretation of this through communication is the basis for knowledge creation. For this reason, this thesis will research trends of access to information, the role of computing as an enabler of enhanced human experience, and humankind's need for information availability. This thesis will also investigate that, while humankind depends upon built environments to contribute towards social, economic and environmental needs, these environments should foster the responsibility to embrace the knowledge requirements of the Information Age. As important as it is to create and support healthy environmental and social conditions in pursuit of a sustainable future, so too is equitable access to knowledge. The reconciliation of human need with the creation of equitable built environments comprised of physical and digital realms is a holistic responsibility of architects. An evolution of approach towards an integrated systems-design process is required through investigation of the knowledge-based requirements of the Information Age. This recognises that knowledge is a core criterion of sustainable development, sharing influence with ecological, economic and social realms.

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[2] Refers to a period in human history characterised by a shift from traditional industry brought about by industrialisation, to an economy based on information computerisation (Castells, 1999).

1.2. Importance of the study

It could be argued that, while sustainability is a globally recognisable concept, it is not always easily understood. In the realm of the built environment, ongoing evolution of the concept fails to provide clarity for (industry-) focused implementation. This causes, in some instances, a splintering of concepts to the point where primary goals and interests are diluted. This often results in the goals of sustainability being abandoned due to complexity, or the re-focusing of efforts to a singular aspect of the greater sustainability goal, such as green building, for reasons of ease of quantification and available scoring tools. This thesis not only re-emphasises the holistic concept of sustainable development, but re-evaluates it for specific implementation in the built environment in the Information Age.

Our urban environment performs an extremely important role in managing and enabling quality of life. Work, play, learning, safety and security are all factors of human existence that have come to define our status as a civilisation, and are all subject, in large part, to the conditions by which humankind interacts with its urban environment.

As technology evolves, human need is affected and evolves with it. For example, it would have been inconceivable half a century ago that humankind would become so dependent on the information phenomenon known as the internet. The advent of the Information Age has brought with it adjustments to the socio-economic, cultural, political and knowledge landscape. Sustainable development in architecture has sought to maintain relevance and responsibility in catering for human needs on a socio-economic basis, within ecological limits. The social impact of the built environment has not diminished in recent years. However, the pace at which its processes have evolved in pursuit of sustainable development presents a significant opportunity for improvement in addressing knowledge-based development and the evolved human needs of the Information Age.

This study therefore identifies proposed criteria for sustainable built environments in the 21st century, through the development of a revised sustainable development model, for inclusion into architectural design processes as a source of reference to architects, urban planners and municipal regulators. The implementation and application of principles contained herein should result in built environments that are sustainably conceived and constructed, suitably responsive to the broader urban and digital context within which they reside. This will provide the basis for greater future adaptability and, by implication, a sustained importance in a future of increased digitisation (representative of the Information Age) wherein the needs of humankind are yet to be fully realised.

It is important to address this problem to bridge the progress gap that has developed between digital and physical landscapes. By investigating, a) how (or if) criteria for sustainable development have changed in the Information Age; b) how the digital age of information has affected our understanding of built environments and the nature of human-product and human-environment interactions; c) how these changed conditions of the built environment and sustainable development can be represented in a logical design process; and d) the nature of the building as a product or as a system and its implications for design methodology, the reader of this thesis will be equipped to function in a design capacity for total integration into a new frontier of knowledge-building and life cycle systems processes typical of the 21st century Information Age.

Neglecting to address this problem comes with risks. Shortfalls in developing understanding and implementation strategies will increase the pace at which architectural processes are losing ground to ICT-based initiatives. This is important as these initiatives seek to advance human experience and convenience in spite of our urban environments, rather than being inclusive of them.

1.3. Intended beneficiaries of the study

This thesis is intended as a means to explore just how truly sustainable solutions can be achieved. Its principal critique is that concepts of sustainability have been largely too vague to allow for effective implementation, and a principal contributor to this vagueness is the lack of contextual applicability and industry focus. As a practising professional architect, the researcher has drawn upon personal experience[3] and empirical evidence within the built environment as a basis to explore this assertion.

The study, while primarily targeting the built environment and architecture professionals as its point of reference, acknowledges that its implications spread well beyond this field. The impact of the Information Age has been profound, and the built environment is significantly affected. Architecture is a clear indicator of the times, where buildings and cities attest to changing social and political climates in more tangible and

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[3] See section 1.4.

observable ways than most artefacts of our evolving civilisation. Architecture is therefore a readily accessible subject matter to which readers of this study, architects and others, can relate. In this context, it is intended that this thesis be of use to architects and built environment professional teams, but also of interest to broader audiences. In establishing that sustainable development is achievable through both physical manifestation and digital enablement, it is possible that further discourse might be stimulated. In understanding the process of investigation, readers may be enabled to investigate which specific criteria for sustainable development might be pertinent to other industries and therefore strive towards providing greater contextual focus to the abundant, antiquated, and generic concepts that seek to solve the problem on combined fronts.

The thesis will advance the existing discourse on the subject of sustainable development and design process methodology. Existing models, and methods for integrated systems-design will be addressed according to their gaps relative to the proposed model of sustainable development. This thesis will also potentially provide a basis to advance and refine architectural software for computational design by creating a framework for integrating external measurement tools and knowledge-building feedback loops into the design process and during the project lifecycle. Furthermore, opportunities for future research are highlighted in order to compensate for future technologies and policy yet to be developed, but which would provide direct benefit to the ease of implementation of the proposed design methodology.

1.4. The researcher's expertise to comment on the topic

The researcher holds formal qualifications in architecture, certified as a Green Star South Africa Accredited Professional for new and existing buildings, and has been practising as a professional architect for over 10 years as project leader and principal designer on projects of varying scale, sector, and complexity, including certified green building design and construction (Green Star). The researcher has over 10 years of experience with BIM and its practical application, and has participated as a speaker at national and international conferences on the topics of green building design, future architectural process, the role of intelligent buildings within the fabric of urban mixed use developments, and the future of city and high density urban environment design in the Information Age.

A study of this nature requires that the researcher be cognisant of the challenges of architectural design and implementation. This pertains to the process of receiving and interpreting a project brief, understanding site constraints, the design process, planning for future flexibility, project costing and feasibility, the construction process, as well as implementation of sustainable and green building design principles.

Hence, the researcher's qualifications, training, the statutory requirements of his profession, experience in practice and recognised pursuits in technological advancement in the profession adequately equip and qualify him to research the topic.

1.5. Assumptions

- The thesis recognises that the most widely accepted understanding of sustainable development is derived from the 1987 Brundtland Report produced for the United Nations World Commission on Environment and Development.
- The thesis accepts the validity of goals and conclusions as included in Agenda 21, the Millennium Declaration and reports emanating from the UN conferences and commissions for Environment and Development, The Sustainable Development Goals, as well as summits on Information Society and sustainable development.
- This thesis accepts that the term 'triple bottom line' was originally coined by John Elkington in 1997 and defines the social, environmental and economic realms as the basis for sustainable development theory. While dated, this term's relevance to subsequent theory is recognised as still important and necessary for interrogation.
- This thesis accepts that implementation or inclusion of technologies and infrastructures is dependent on the economic limitations of the specific building project client or owner, as well as contextual or site-specific limitations.

1.6. Delimitations

- The thesis uses subsequent developmental goals and reports produced by the United Nations following the 1987 Brundtland Report as further basis for evolution of sustainable development goals and recommendations for evolution of the industry, which are current as of 2016.
- Due to the sheer number of sustainable development concepts, theories, models, and derivatives, the researcher will be utilising the core definition of sustainable development as per the 1987 Brundtland report as a basis for concept development. In the same way that technology is ever-changing and thus risking redundancy through focus on a particular application, the thesis is

better served through adherence to timeless core principles, referencing current applications and theory where appropriate.

- Statistics and figures used are current as of 2016.
- Technologies and technological artefacts for built environment applications will be current as of 2016, taking into consideration that reference to future technologies might be highly speculative and subject to corporate secrecy.
- Where technology associated with ICT integration and pervasion is discussed, selected examples with specific reference to current initiatives and applications in the built environment will be used.
- The thesis will be divided between analysis of larger trends, national and industry statistics based on identification of these trends, and a holistic body of research data as opposed to post-implementation project statistical analysis and survey. Theoretical proposals will be investigated and compared to empirical evidence and understanding of implications for individual industry role players.
- The thesis primarily focuses on the value of sustainable initiatives at the scale of direct human interaction with the built environment and a building (micro) scale as opposed to a town or urban (macro) scale.
- This study is intended for global consumption and not subject to regional delimitation.
- This investigation will not document a history of all design processes and paradigms, plot the changing schools of thought, nor favour any approach over the other. Instead, an understanding of the fundamentals of the architectural design process will be undertaken in order to best integrate these into an appropriate implementation strategy. It is understood that design processes, which often possess commonalities in approach, are subjective in nature. Where required, the researcher will therefore apply personal experience of the design process to delineate a path forward.
- The aim of this thesis is not to develop an assessment tool, for example, but to put in place the framework according to which future tools may be developed as a part of the integrated systems-design methodology.
- The proposed methodology is theoretical, requiring that certain external factors of influence such as municipal policy, shift in architectural paradigm, project team and stakeholder technical proficiency and BIM-based protocols be in effect.

- This is a design thesis. As a result, this theoretical proposal is not yet representative of an already documented architectural project or solution that may serve as a scientifically quantifiable case study to be interrogated through statistical analysis or survey. This would necessitate future research once implementation over the period of a project life cycle is possible.

1.7. The purpose of the study

The purpose of the study is to develop an implementable architectural systems-design methodology for a revised model of sustainable development. This will be done by first determining the origin of the concept of sustainable development applicable to the built environment, and examining the goals and implementation methods, and current shortfalls of these concepts within the scope of the Information Age. A revised model of sustainable development will be proposed that is of specific focus for the built environment, and will be inclusive of the evolved needs of humankind represented within the current context of knowledge-based societies.

An integrated systems-design methodology will then be proposed, that will provide architects and built-environment stakeholders with the means to implement a revised model of sustainable development. The parameters for executing a holistic design process will be established for the creation of building solutions that are representative of project life cycle, user experience awareness, future flexibility, and the requirements of knowledge-based development in the Information Age. In doing so, architecture should therefore evolve towards the creation of buildings as open systems processes instead of products.

1.8. The research objectives

The specific objectives of the study are the following:

1. To determine if sustainable development theory provided a logical basis for evolution of the concept since its inception and whether this has contributed towards direct applicability in various industries;
2. To determine what effect the Information Age has on sustainable development criteria, and whether any common goals exist to provide overlap in the formulation of new strategies for execution;
3. To identify specific sustainable development criteria inclusive of the requirements of the Information Age that would have an impact on built-

environment planning processes and a revised model for sustainable development; and

4. To propose (without adhering to any contextual municipal by-laws or specific building regulation) a new model for sustainable development in the built environment to inform the proposed architectural design methodology.

2. Research methodology

2.1. Introduction

Research methodology is the logic behind chosen research methods and techniques. The purpose of this Chapter is to provide the research context and specifically the researcher's paradigm. This study can be classified as applied constructive research with an open-ended approach to the problem. The concepts of applied and constructive research are therefore elaborated in this section.

While research has been frequently undertaken throughout the history of architecture, the conduct of architectural research outside of the confines of specific building projects is a more recent phenomenon, evolving from a focus on product development and building systems design in the 1950s, to include design methods, socio-behavioural issues, and energy conservation in the following two decades (Groat and Wang, 2013:7). International interest in sustainability dating to the 1990s and more recent fluctuations in scope of other substantive topics, theoretical influences, innovations in the design process, and constantly developing building and information technologies mean that architectural research will continue to encompass a broad range of research endeavours (Groat and Wang, 2013:8).

Taking into consideration that different forms of research aid informed decision-making, the researcher firstly acknowledges the importance of applied research for sustainable development in the built environment. Applied research is defined as a form of systematic inquiry involving practical application, and accessing a portion of the community for a specific and focused purpose.

In order to address the research problem effectively in the setting of its application, this thesis proposes the following:

- The model of sustainable development as proposed by the Brundtland Report is in need of elaboration in order to make it applicable to a rapidly advancing and evolving world.
- The role and responsibility of the architect must evolve to successfully integrate information and expertise if the concepts of sustainability are to be successfully applied.
- A new methodology of sustainable design is therefore required for use by architects and other built-environment professionals as a basis for integration in the process.

- Current approaches in design by architects are required to include quantifiable measures of success.

Crnkovic (2010:359) states that constructive research methods are fundamental for knowledge production and concept formulation, and modelling. Constructive research based on ontological realism makes use of existing knowledge in novel ways with the possible addition of a few missing links. This construction advances design thinking, creating future projections of an envisaged solution, embodied as theory or artefact. Conceptual and knowledge gaps are then filled through intentionally engineered building blocks to support the whole construction. Artefacts such as, in the case of this thesis, models and system designs are typical constructs used in research and engineering. Constructivist solutions are therefore designed and developed, and not initially subject to discovery (Crnkovic, 2010: 360).

Constructive research shares parallels with design research, an important component of research traditionally used in engineering since it involves the use and performance of designed constructs in order to explain and improve designed systems. Design research participates in the redefinition of the design process in favour of an integrated system as opposed to a standalone object, yet is the most difficult form of research to categorise since its purpose is to create objects and systems that display the results of project-based research subject to the current state of development at that time (Laurel, 2003: 11). Typical outputs of this research therefore include models, methods, theories and system design methodologies. Design and constructive research therefore represent a bridge between human and natural spheres, producing constructs which are both natural and intentional, implying an understanding of the working of basic mechanisms and the role that a given construct may adopt in the broader context (Crnkovic, 2010: 365).

2.2. The research context

The purpose of this section is to provide the research context with the inclusion of the researcher’s paradigm. ‘Research’ is defined as a process that involves obtaining scientific knowledge objectively by means of scientific methods and procedures to expand knowledge in a particular field of study (Welman et al., 2005:3). There are three manners by which we derive scientific knowledge, namely systematic observation, control and replication (Welman et al., 2005:5). In order to fully satisfy the criteria of scientific research it must be assumed that findings require interrogation, and all evidence pertaining to a claim should be examined.

In determining context, which refers to the physical and cultural landscape within which any building exists, it is proposed that this thesis will determine best practice for the shaping the built environment and user experience.. While context is a contributor to building form and function, it does not necessarily define its design. For this reason, it would be impossible to understand the intricacies of any building or design product without first understanding the human needs that required it to come into being. Context is thus furthermore concerned with historical overview, evolution of concept and status quo of the physical and cultural world within which any product or process resides. The context is therefore broadly assumed at the onset of research and attributed greater focus as research progresses.

Understanding context in the built environment requires consideration of the physicality of a building’s surroundings and the formative non-physical conditions which brought them about. Non-physical requirements may be described as, but not limited to, social requirements, economic factors, architectural theory and design process. Since the evaluation of a product does not easily reveal the developmental process that created it, research into the prevailing societal conditions at the time is necessary to provide some rationale for assumption of decision-making reasoning. ‘Context’ for the purposes of this research is of a similar nature, encompassing both the physical determination of product and its societal influences.

Design is prone to being subjectively addressed and susceptible to personal bias based on context. As with architectural design, research on the basis of context requires a capacity to identify and compensate for contextual influence. In the context of a rapidly evolving technological landscape, for example, the research project executed therein will require adaptability of the process.

2.3. The research paradigm

The research paradigm refers to the point of reference of the researcher. This highlights the frame of mind of the researcher which, in turn, affects the approach to questioning and discovery. This is necessary since the research subject is not investigated in an isolated environment but rather refers to a global body of knowledge, experience and behaviour.

Welman et al. (2005: 6) state that there are two main approaches to research. The first approach is defined as positivistic, which is based on a philosophical approach known as logical positivism. This approach maintains that research must be limited to what we can observe and measure objectively and without bias, and serves as a basis for the natural-scientific method in human behavioural research. This approach is also known as the quantitative approach – observing human behaviour.

In the second approach, anti-positivists maintain that it is inappropriate to follow strict natural-scientific methods when interpreting and collecting data. When studying human behavioural sciences, human-scientific methods are not adequately equipped to study these phenomena (Welman et al., 2005:7). The phenomenological approach understands that human experience cannot, therefore, be separated from the person experiencing it, and thus cannot be separated from the results of objective observation and study. This approach is also known as the qualitative approach – experiencing human behaviour.

Table 2.1: Differences between positivistic and phenomenological approaches of research (Welman et al., 2005: 7)

	Positivistic approach	**Phenomenological approach**
Purpose	Evaluate objective data consisting of quantifiable figures and numbers.	Evaluate subjective data produced by human thought and response. A focus on language.
Process	Researchers use a process of analysis based on complex structure analysis to confirm or disprove hypotheses. Flexibility is limited to prevent bias.	Based on flexible and exploratory methods to allow researcher to change data progressively to obtain a deeper understanding.
Representation	Does not deal with everyday life but rather with an abstraction of reality. Ethical science based on probabilities as derived from the study of numbers and statistics.	Investigate the constraints of everyday life based on results of phenomena and behaviour of people.
Perspective	Understand the facts of an investigation based on an outsider's perspective. Requires an objective view to keep the process hypothetical and bias-free.	Achieve an insider's view by interpreting behaviour of subjects under investigation. First-hand experience of the object under investigation produces the best results.
Rigidity	Research is kept as stable as possible by concentrating on causal aspects of behaviour and collection of facts that are unlikely to change.	Research embraces dynamic and changeable nature of reality.
Control	Control investigation and structure of research through identification of isolated variables. Particularistic approach.	Collect a wide array of data such as documents, records, photos, observations and case studies. Holistic approach.
Focus	Focus on reliability, replicability and stable measurement.	Focus on validity. Objective of the study must be representative of the research subject.
Sample base	Statistical significance based on large numbers of cases.	Small samples of people investigated using in-depth methods.

Welman et al*.* (2005:7) also state that caution should be taken in gravitating towards qualitative methods as the easier substitute for quantitative approaches. Quantitative methods provide an extensive array of checks and balances which may assist researchers in avoiding unjustified conclusions. By contrast, the qualitative researcher constitutes the primary research instrument by essentially taking over the role of the research group to rule out counter arguments, to observe without affecting that which is being observed, and to manage personal expectations.

In the context of a phenomenological research paradigm, constructivist epistemology emphasises the fact that scientific knowledge is constructed through scientific exploration with the assistance of cognitive tools. It therefore stands in contrast to the strictly positivist epistemology which relies on the creation of scientific knowledge through discovery. In the positivist approach scientific facts are discovered, establishing a unique connection between the world and the fact. Constructivism, however, entails that there is no single valid methodology for construction of scientific knowledge, unique prescribed method to establish the facts and provide data, and therefore no guarantee for consensus (Crnkovac, 2010:365). As further stated by Crnkovac (2010:365), constructivism in research is more inclined towards establishing the mechanisms for theory building while positivism is intent on describing the state of theory where one dominant framework has been established among competing approaches.

In further understanding the specific characteristics and varied approach between positivistic (quantitative) and phenomenological (qualitative) research, the researcher is thus in a position to establish in which direction the research approach is inclined when attached to the previously defined research objectives. Table 2.1 has been adapted in Table 2.2 to communicate the researcher’s normative position regarding a comparison between quantitative and qualitative research design paradigms. In doing so a list of research objectives as previously identified in this chapter is outlined to serve as a basis to describe the applicable paradigm.

- A continuum scale was introduced between the two research approaches to which the research paradigm is introduced. The scale is balanced, with measurements of scale assigned as neutral, or as a record of support for quantitative or quantitative approaches respectively.
- The normative position of the researcher is described for each research objective.

Table 2.2: The researcher's paradigm

Research Paradigm: Predisposition of the researcher						
Research objectives	**Positivistic** Quantitative, scientific, reductionist etc.			**Phenomenological** Qualitative, holistic, descriptive, etc.		**Normative position of the researcher**
	Strongly Agree	Agree	Neutral	Agree	Strongly Agree	
Purpose				▨		The researcher believes that investigation cannot be separated from human thought and response to subject matter.
Process				▨		The nature of the investigation recognises that flexibility and exploratory re-evaluation will be necessary in order to represent developing trends and technologies.
Representation				▨		The Investigation will lend itself towards human-centric experience and the constraints of everyday life based on results on phenomena.
Perspective				▨		Impartiality will be required to maintain an objective investigative mind set when observing the status quo and representation of statistical data, while the researcher will accept a bias towards developing hypotheses based on heuristic approach via first-hand experience and interpretation of behaviour.
Rigidity			▨			An effort will be made to maintain stability of research through analysis of causal aspects of behaviour and collection of facts, while maintaining flexibility for dynamism within selected aspects of the reality being observed.
Control		▨				The structure of research will be particularistic through identification of isolated variables within a larger scope based on decided need for implementation on a specific scale and industry.
Focus			▨			The nature of research is required to be replicable and reliable, hence investigations should be responsibly undertaken to achieve this. The researcher recognises too that the research must be valid and representative of the subject matter.
Sample base			▨			The sample base will be divided between analysis of larger trends, national and industry statistics based on identification of trends, and holistic body of research data. This will be investigated and compared to empirical evidence and understanding of implication for individual industry role players.

In the book *Research methods for construction*, Fellows and Liu (2003:8) state that pure research aims to contribute to an already existing body of knowledge, developing knowledge in search of 'truth'. Pure research asks the question 'is it true?'. Applied research, however, attempts to solve a practical problem in a manner where addition of knowledge is more incidental. The researcher acknowledges the description of applied research and certain principles of sustainability. Applied research therefore asks the question ‘does it work?’. Furthermore, a construction, either theoretical or practical, constitutes a new reality against which an existing one can be interrogated and understood, thereby offering an undeniable epistemological value (Crnkovic, 2010: 360).

The research conducted in this study is classified as applied constructive research with an open-ended approach, in recognition that research is never a closed system but instead an open system which should allow for flexibility and the establishment of criteria for future study.

2.4. The research design and method

Constructive research implies the building of an artefact (practical, theoretical, or both), theory, model, or methodology that solves a domain-specific problem in order to create knowledge about the potential solutions for that problem, which is communicated through understanding, explanation, and modelling. The results of constructive research can therefore have practical and theoretical relevance, while considering novelty, feasibility, and improvement. The emphasis is therefore on the theoretical relevance of the construct by determining the elements of the solution that are central to the benefits and how these can be presented in a condensed form (Crnkovac, 2010:363).

The structure of this thesis, indicated in Figure 2.1, as a derivation from the research structure by Welman et al. (2005), is developed to incorporate a combination of qualitative and quantitative research approaches. Originating with a delineation of the aims of the research, the process then sets out to identify the research topic and problem. Having set the scene and identified the need for research into this topic, the literature review is undertaken in order to inform and support the theoretical construction of knowledge and hypotheses.

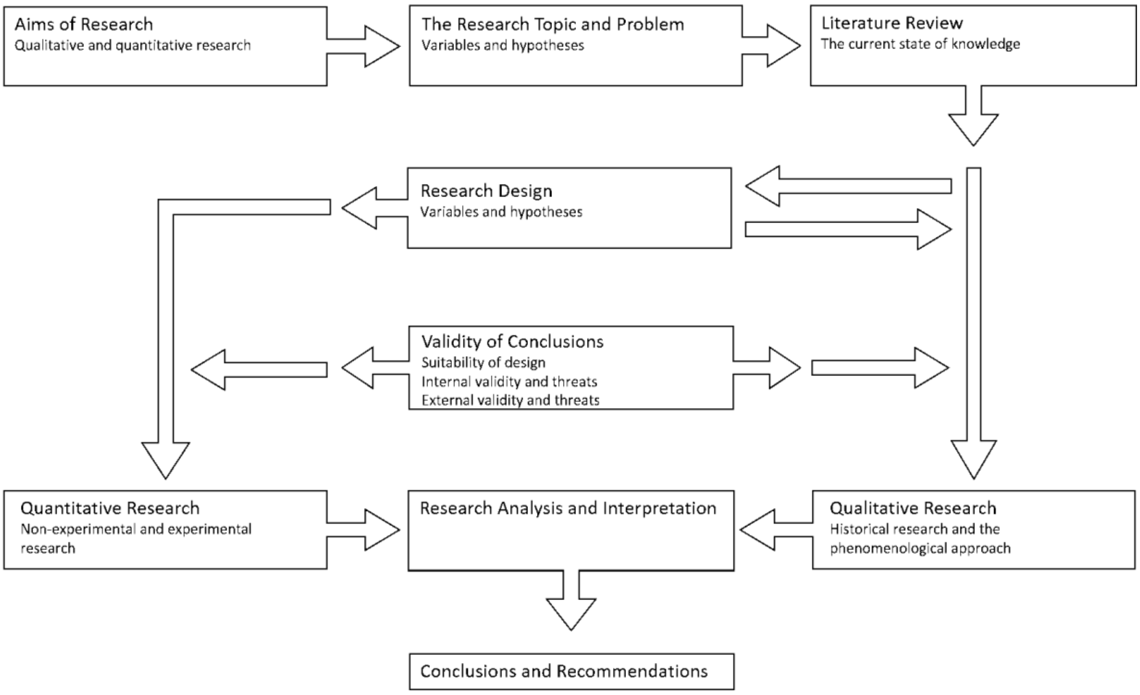

Figure 2.1: The typical research structure, as derived from Welman et al. (2005)

This thesis is further developed to support the theoretical construct as follows:

- Identifying a practical problem and its research potential (Chapters 1 and 2);
- Assimilating, processing and disseminating deep knowledge in the research theme (Chapters 3 to 5);
- Creating an innovative solution and developing a construct of use (Chapter 6);
- Theoretical implementation and testing of the solution (Chapter 7); and
- Identification and analysis of the theoretical contribution (Chapter 7).

The organisation of this thesis therefore follows the scientific procedure of first introducing all of the background of sustainable development in Chapter 3, continuing with the description of the study of the problem and aims of the study. This thesis is based on four hypotheses, which will be presented in each chapter that follows.

Therefore, chapters relating to the advent of the Information Age (Chapter 4) the interrelationships that exist between it and sustainable development (Chapter 5) will be presented in this order. However, the methodological considerations and criteria for the research on this new phenomenon of sustainable design in the Information Age will also be defined in Chapter 5. Once established, the framework for development and proposition of an architectural design methodology will be proposed in Chapter 6.

Constructive research, comprised of combination of qualitative and quantitative research approaches will be undertaken to formulate a systems-design process for specific application by built-environment professionals. This theoretical methodology will be the product of evaluation and extension of the causal and symbiotic relationships that exist between applicable tiers of sustainable development. While deductions will be made from empirical sources and experience in keeping with broader industry trends, observations through literature review will largely contribute to data-gathering processes while heuristically interpreting that these relationships are affected by societal and contextual influences.

The research strategy will be additionally structured including the following types of research design:

- Content analysis: Associated to the examination of preserved records in written or multimedia format to discover the non-obvious meaning contained in the record. Research methods used are quantitative, although qualitative judgments are required to be made. This will contribute to theory building research as the basis for all assumptions and hypotheses made in the course of this thesis. Hypotheses will be derived following identification of the problem and iterative research pertinent to the topic of this thesis, by means of referencing publications and other resources.
- Critical theory: Takes a critical perspective on an aspect of society in order to question the assumptions that form the basis of our understanding of the status quo. Theory testing research is undertaken by placing the collected data into context for theoretical evaluation of the implied successes and shortcomings, as well as practicality of application.
- Theory development: Tests an aspect of an existing theory and expands its applicability. Various methods are used to achieve this aim, making use of content analysis and critical theory, as well as deductive logic and reasoning in order to develop a theoretical model with future applicability. Theory application research is undertaken through the production of a new theoretical model and methodology for the purposes of advancing architectural product and architectural process.

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The available research methods can be described as:

- Exploratory: Associated to content analysis. The formation of a hypothesis within an applicable context. The theory is then tested via a process of data collection, analysis and interpretation.
- Explanatory: Associated to critical theory. Specification of a relevant phenomenon of the hypothesis is tested with expansion upon the exploratory phase.
- Interpretive: Associated to theoretical development. The implementation of a heuristic model where variables are interrelated according to assumed relationships.

The constructive method of approach proposed for this topic of research begins by defining the problem, deducing hypotheses, collecting data and evaluating it, and introducing of a new model and system design methodology.

Where a model and system design is to be proposed on a theoretical basis, as with this thesis, reproducibility of results and assertions remains an aspect of importance in order to contribute to the greater body of knowledge as well as provide a basis for future research to develop. Realist constructivism relies on the observations of a stable world with which we interact and about which we develop future knowledge. However, Crnkovac (2010:361) states that reality exists independently of any mind, and is subjective in the epistemological sense, reconstructed in the mind of the observer through their specific interactions with the physical world and other stimuli. Reproducibility requires unambiguous and repeatable connections between an observer and reality in any experiment under certain conditions.

As physical reality presents fundamental constraints for knowledge construction, an epistemic community creates additional constraints through the process of interaction. However, while scientific study is defined by the interactions between members of the research community, and as such the result of a collective effort, it is a strictly regulated social system for knowledge creation and sharing. The result, while not absolute, is still the highest state of knowledge in the context of the research problem (Crnkovac, 2010:362).

The proposed methodology, as a construct of the research, is developed in a scenario where it is context-free and is best described in a voice that is unbiased and objective. Information and findings represented in the study assert themselves to be accurate and reliable through analysis of current industry standards and phenomena, yet generalisations are to be accounted for to provide a basis for prediction of applicable future trends and feasibility of the contained hypotheses. Predefined categories are established from the onset, but these categories are general enough to accommodate an ever-changing and evolving scope of applicable innovations and technologies pertinent to the topic.

The scope of technology is constantly evolving and innovations are being introduced into the market on a daily basis in terms of product and applications, as well as innovations and advances in the architectural process, as will be investigated in Chapter 4 sections 4.1.7., 4.1.8., and Chapter 5 section 5.2.3. It is for this reason that while the generic direction is set, a degree of re-tracing of steps is required throughout the execution of the thesis. Literature review and identification of applicable technologies will therefore be an ongoing process throughout the documentation process. Likewise, in order to best filter out the necessary technologies in a world where access to information is limitless, the proposed methodology is designed utilising data gathered from the literature review process in order to substantiate its proponents and composition.

2.5. Research instruments

Data collection will be made through literature review, as published by industry specialists and formalisers of related evaluation models and methodologies. Selection of this data-gathering method is due to the fact that a theoretical model is proposed. Therefore deductive reasoning on the part of the writer is required to be implemented on a basis that incorporates a combination of a descriptive analysis of current environmental conditions of varying contexts, as well as normative interpretation for evolution of those contexts.

Due to the particular emphasis on literature review as the basis for theory building and of theoretical constructs within this thesis, it is important at this stage to discuss the potential challenges when applied with a constructivist research approach. Literature review requires a comprehensive study of the subject matter through published content, disseminated and synthesised to address those aspects which are of direct consequence to the subject at hand. As knowledge is gained, theoretical constructs are developed. Literature review as a basis is therefore presented with the following potential challenges:

- Comprehensive synthesis of themes within literature applicable to the topic of research and the defined research questions;
- Effective substantiation of deductive logic used in establishing the conceptual framework of the study; and
- Epistemological value of derived theoretical constructs according to which this new reality is created.

This thesis will as a theoretical basis for continued research, remaining open-ended to accommodate new theory in constant development while establishing new knowledge. Synthesis of literature requires assessment of existing perspectives while offering new ideas (Groat & Wang, 2013:142). This new knowledge informs theory building which is systematically constructed through a deductive process. Using this deductive process the researcher identifies the main players (the ‘what’) and their working principles in order to lead to a theoretical prediction of results. This form of reasoning is core to the context of discovery in the sciences and the basis for which hypotheses are formed. By contrast, while inductive reasoning (explaining the ‘how’ when the ‘what’ and the results are known) informs the ‘discovery’, deductive reasoning informs the ‘justification’ (Groat & Wang, 2013:34).

Databases consulted in the literature review include, but are not limited to, various online digital databases such as the University of Pretoria E-reserves, Scopus, ProQuest, Science Direct, QUT Digital Repository, ResearchGate, London School of Economics (LSE), Research Online, and Google Scholar. Search phrases were extensive and highly varied, ranging from broad term search phrasing such as ‘applied architectural design methodology’, ‘sustainable development in the Information Age’, ‘ICT and the built environment’, ‘integrated systems design’, and ‘smart cities and intelligent buildings’, to more specialised concepts as knowledge deepened, extending towards search phrases inclusive of, but not limited to ‘design for flexibility’, ‘change mode analysis’, ‘digital and physical place-making’, and ‘knowledge-based development’.

2.6. Determination of problem statements addressed in the research process

Following the statement of the problem in Chapter 1 section 1.1, aspects contained in the main problem are summarily divided into the sub-problems and related hypotheses listed below. This is an accepted 'Pretoria' method. These inform the research process, providing spheres for literature review and concurrent deductive logic, thereby linearly progressing constructive theory:

Sub-problem 1: Are current theories of sustainable development adequately focused for industry-based implementation?

Hypothesis 1: Industry-specific interpretation of sustainable development is required for appropriate implementation in the built environment.

Sub-problem 2: How have the needs of 21st century societies changed in the midst of the Information Age and how is this applicable for future sustainable development?

Hypothesis 2: Sustainable development and its criteria require alignment and redefinition according to the needs of the Information Age and knowledge-based societies.

Sub-problem 3: What are the aspects of ICT that align it with the goals of sustainable development and the triple bottom line in the context of the built environment?

Hypothesis 3: Alignment of the goals of sustainable development and ICT provides a basis for advancement of sustainable development principles in architectural design process and product within the Information Age.

Sub-problem 4: How can architectural approach in design and implementation towards sustainable development in the built environment be improved to meet the needs of the Information Age and knowledge-based development?

Hypothesis 4: A new integrated systems-design methodology for architectural design is required, implementing the integrated systems-design process and the proposed new model of sustainable development.

2.7. Organisation of the study

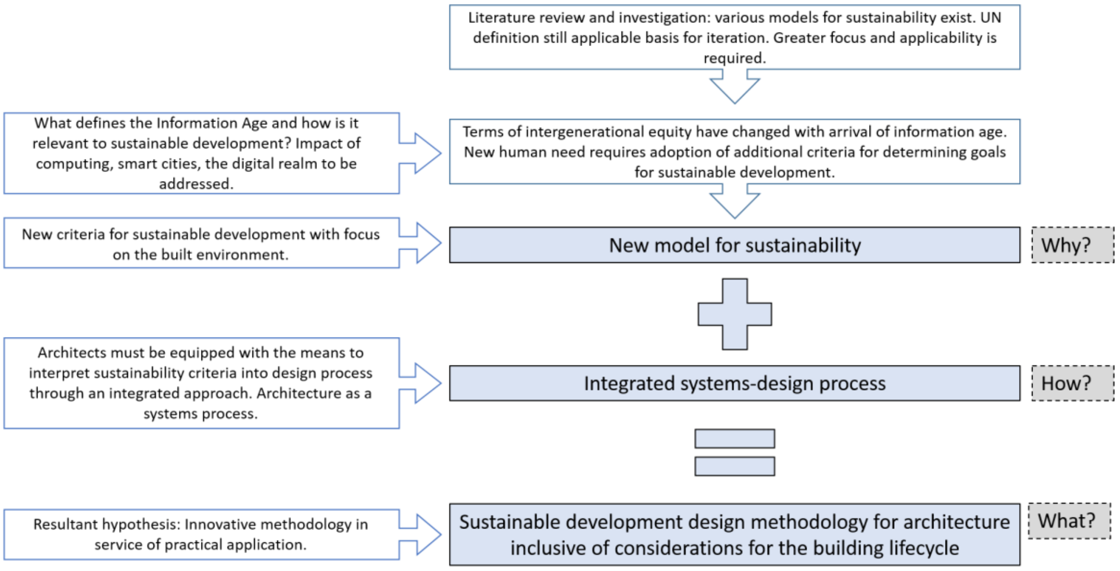


Figure 2.2: Structure of approach

Figure 2.2 represents a graphical representation of the researcher's thought process in addressing the problem. This consists of a 'why', 'how', and 'what' process and progression of investigation. This approach has been adopted for the purposes of primarily establishing the need for the study by identifying the principle problem that requires attention. In this thesis, the researcher questions the applicability of a concept of a systems-design design approach for architects, the success of its general implementation, and the conditions that present challenges. This is informed by a rigorous literature review to ascertain existing theory and the extent of applicability. Furthermore, this approach enables the researcher to question the context of the problem, addressing societal and technological changes that affect human development.

The process of investigation concerned with literature review is therefore quantitative, addressing and outlining historic and progressive rationale, and global schools of thought in order to reach objective conclusions. This is done with the aim of evaluating the need for future intervention, new technological opportunities, and the establishment of supporting hypotheses to advance architectural capacity and capability.

Following the establishment of the 'why', 'how' the problem to overcome is then addressed. This process targets the problem, and seeks to understand its primary challenges within a particular scope of implementation, and investigated with the aim of understanding current and new opportunities. Previously identified factors determined to be of necessary consideration for the solution, are combined and a process of integration is undertaken to establish a framework for implementation.

Having established the systems-design process, the researcher defines the ‘what’. This step is concerned with addressing previous hypotheses within a defined methodology of approach, representative of previous research and substantive in its formulation.

The study is therefore divided into the following sections:

Chapter 3: The status quo of sustainable development theory in the built environment.

This chapter reviews the international sustainable development context in order to understand its origins, as well as its impact on societal and institutional policy. This chapter also concerns itself with understanding its role, the nature of its ongoing redefinition and exploration, and methods of application. This research furthermore seeks to establish that implementation is hampered by inherent vagueness in the concept, prompting the need for greater focus of goals and an industry-specific approach.

Chapter 4: Sustainable development in the Information Age

This chapter reviews the current development of humankind, by investigating the most recent technological revolutions and the effects on our existence, needs, and potential for future development. This provides greater clarity on the pervasive effect of ICT, and defines the means by which abundance of information and the formulation of knowledge societies has changed the nature of sustainable development in the 21st century. This chapter also reviews the continued applicability of a triple bottom line approach, suggesting the expansion and alteration of sustainable development theory.

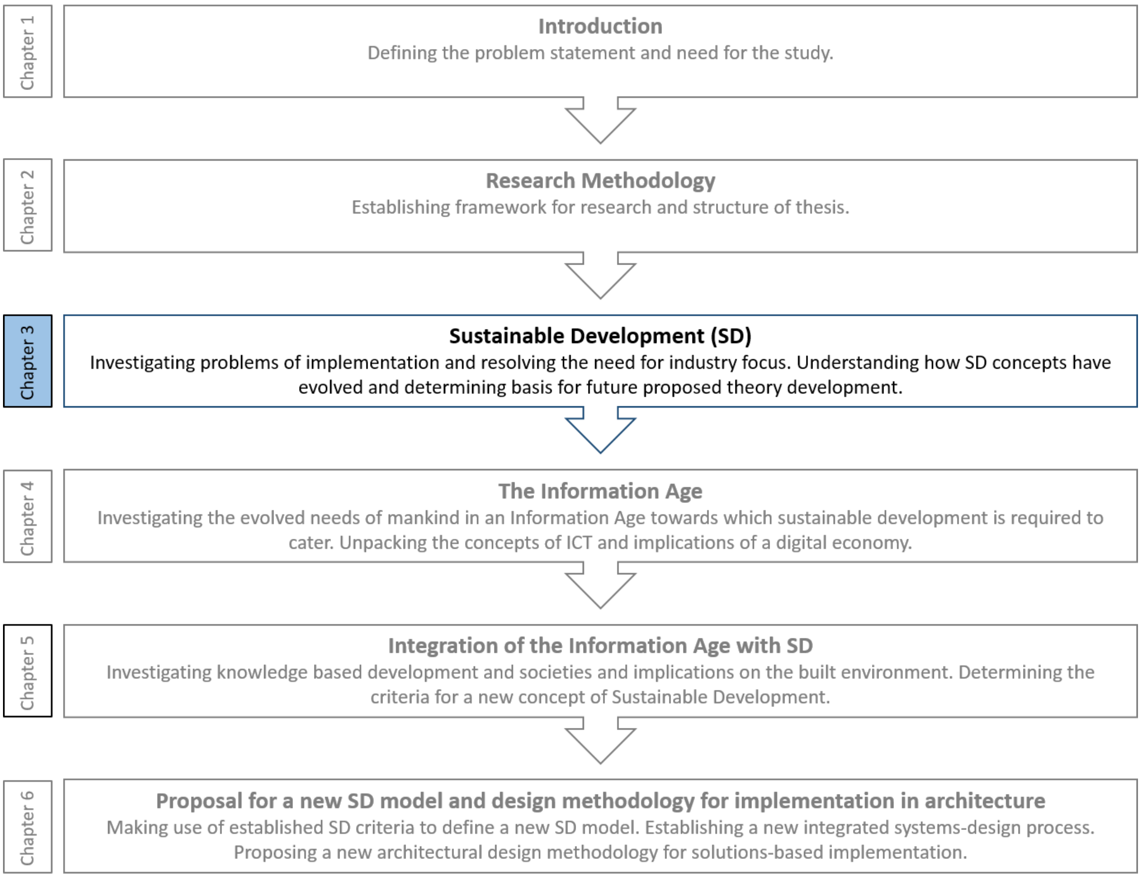
Chapter 5: Establishing criteria for integration of concepts of ICT, knowledge-based development and sustainable development within the built environment.

This chapter reviews and investigates the changed technological landscape of the Information Age, and the creation of digital and physical ‘place’. Research is undertaken into the effects of the digital realm on human-environment interaction, and the implications for architectural systems-design process. Based on the established research of the previous chapters, criteria for achieving and implementing sustainable development intervention in the built environment needs of humankind and knowledge-based development are presented and discussed.

Chapter 6: Proposal for a new sustainable development model and architectural design methodology

This chapter addresses all research of the previous chapters: the need for updated sustainable development theory, the classification of contributing criteria, and the means for architectural specificity, and combines these into a revised model for sustainable development, inclusive of knowledge as a core criterion. Following this, a methodology of approach is devised based on an integrated systems-design process allowing for implementation of sustainable development principles according to formulated criteria of success. This is furthermore designed for practical use in the industry, providing the means to execute a project holistically from point of inception, as well as during operations. This is importantly cognisant of the fact that what is being delivered is not a finite product, but a persistent process and systems-based architectural solution.

3. Status quo of sustainable development theory in the built environment



Chapter 1 — **Introduction**
Defining the problem statement and need for the study.

Chapter 2 — **Research Methodology**
Establishing framework for research and structure of thesis.

Chapter 3 — **Sustainable Development (SD)**
Investigating problems of implementation and resolving the need for industry focus. Understanding how SD concepts have evolved and determining basis for future proposed theory development.

Chapter 4 — **The Information Age**
Investigating the evolved needs of mankind in an Information Age towards which sustainable development is required to cater. Unpacking the concepts of ICT and implications of a digital economy.

Chapter 5 — **Integration of the Information Age with SD**
Investigating knowledge based development and societies and implications on the built environment. Determining the criteria for a new concept of Sustainable Development.

Chapter 6 — **Proposal for a new SD model and design methodology for implementation in architecture**
Making use of established SD criteria to define a new SD model. Establishing a new integrated systems-design process. Proposing a new architectural design methodology for solutions-based implementation.

3.1. Sub-problem One:

Sub-problem: Are current theories of sustainable development adequately focused for industry-based implementation?

3.1.1.1. Introduction

Not since the 1970s, in a period commonly referred to as the period of ‘environmental crisis,’[4] has the long-term well-being of the environment featured so prominently in the media and social consciousness. The global awareness currently being experienced can ultimately be attributed to a shift in political attitudes regarding climate change, yet

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[4] ‘THE ENVIRONMENTAL CRISIS: An unprecedented crisis’, Environmental Science and Management. http://www.soas.ac.uk/cedep-demos/000_P500_ESM_K3736-Demo/unit1/page_11.htm - accessed 9 May 2016.

including, more importantly, social and economic impacts (Barr, 2008: 3). Recently, for example, the British government has been shifting emphasis for action towards sustainable future building from an environmental case towards an economic argument, as is evident in the Stern Review of the Economics of Climate Change (HM Treasury, 2006).

Derived from the Brundtland Commission's Report for the UN in 1972, this concept of sustainability is broadly concerned with ensuring that decision making meets the needs of current and future generations. In the context of this thesis it is thus necessary to explore various popular models of sustainability by understanding the progression of this concept over time.

This chapter seeks to provide a constructive perspective on the origin and development of the more popularised concepts of sustainable development, and their application in the context of the built environment. The evolution of concepts in sustainability will be plotted against a timeline factoring in political, non-governmental and built-environment paradigm shifts. This timeline will therefore seek to highlight the progression of importance of the concept and the source of influence that would determine furthering of policy and understanding. Evaluating the chronological evolution of this concept in this way will seek to highlight the evolution of sustainable development from a political tool, to that of a social tool.

Following an understanding of motive, evolution of the paradigm will be outlined through documentation of the various trends followed and set, including its role in green building design.

3.1.2. Historical overview of the concept of sustainable development

The emergence of humankind as the dominant species on this planet is the result of ingenuity, intelligence and an innate ambition. This ambition, however, has not been without its costs to the planet. Expending resources and natural material became necessary for a cause far greater than that of sustenance but in the pursuit of progress, both individualistically as well as collectively. Human beings sought to elevate themselves to heights of operational and lifestyle comfort that freed their minds to concentrate on innovation and progress.

As humanity's comfort level and access to information grew, so too did the capacity for self-interrogation and evaluation of actions. A product of this paradigm resulted in a growing social awareness of the ecological constraints of the planet, following reports of environmental crises such as the degradation of the ozone layer and ice-cap melting.

The Club of Rome, a convening of intellectuals in 1972, produced a report titled ‘The Predicament of Mankind’ whereby it sought to evaluate the current trends of existence and resource dependency proportional to the human population and the limits in capacity of our planet to support them (Barr, 2008: 13). This saw the formulation of a predictive tool which served to spark the debate of a sustainable future by drawing attention to a direct relationship between societal practices and the environment. While it was understood over time to be valuable in its intentions, it contributed to the rise of the environment as a socio-political subject of discourse. The resulting momentum of the topic instigated the formation of the UN Man and Biospheres Programme, which ultimately evolved into the now renowned Brundtland’s Commission (UNCED, 1981).

> ‘The last thought we wish to offer is that man must explore himself – his goals and his values – as much as the world he seeks to change. The dedication to both tasks must be unending. The crux of the matter is not only whether the human species will survive but even more whether it can survive without falling into a state of worthless existence’ (Meadows et al., 1975:205).

The Limits to growth (Meadows et al., 1975), can be seen as the tangible pinnacle of the ‘environmental crisis’. The Stockholm Conference on Human Environment and Development of 1972, when presented with the problem of Earth’s capacity, sought to draw a clear relationship between the contributing factors between human growth and demand for resources. A link between environment and economy could be seen as the critical breakthrough of the conference (Barr, 2008:22), and in doing so ensuring that the profile of the environment was never higher on the agenda. The Brundtland Commission’s Report had earlier changed the perception of ecological responsibility by reinforcing the concept that, at the centre of sustainable development, resides a responsibility to meeting human needs.

However, if human need was to truly form the central point around which sustainability principles were to be constructed, socio-economic factors needed a larger role to play. Efficiency of implementation was the goal, and the means to achieve greater efficiency was widely interpreted to be greater investment in technology as a means to adaptive solutions.

The concept of the ecological footprint which was developed by Rees and Wackernagel in 1994[5] was but one of many concepts to highlight that the Earth's capacity to sustain life was limited. Ecological responsibility had inevitably dawned on humankind as a matter of fundamental importance if following generations were to be assured of a prosperous existence.

The Word Conference on Environment and Development, more commonly referred to as the Rio Earth Summit (UNCED, 1992) was the first major conference to set the agenda for institutionalisation of sustainable development. 'The shift from 'environmental crisis' of the 1970s to the political mainstreaming of 'sustainability' has proved to be a process which has reflected the growing importance of citizen and participatory discourses in the environmental arena' (Barr, 2008:17).

Brundtland's proposition for sustainable development had proven to be the subject of much theoretical debate since, while it seemed a simple concept superficially, it remained practically complex (Barr, 2008:21). What was emerging was an acknowledgement that without clearly quantifiable methods of approach and evaluation, sustainability implementation debate would become repetitious, and remain an unanswerable debate. A core basis for departure was therefore sought.

'Business executives wanting to grasp the full scale of the emerging challenge must audit current performance and future targets against the triple bottom line' (Elkington, 1997: 69).

According to the United Nations Resolution 60/1, released as part of the 2005 World Summit outcome, the 'three pillars', namely ecological, social and economic, are widely accepted as the basis for a quantifiable and measurable concept of sustainability. The triple bottom line, coined by John Elkington in 1987, was the first public account that drew specific reference to these pillars. Although it was originally devised to serve an economic context due to its feature in Elkington's book *Cannibals with forks: The triple bottom line of 21st century business*, the possibilities for broader focus quickly led to its adoption in most spheres of human sciences, as well as the built-environment industry. Over time the idea has been expanded upon and integrated into a variety of tools and

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[5] Rees, W.E., Wackernagel, M., 1994. Ecological Footprints and appropriated carrying capacity: measuring the natural capital requirements of the human economy. In: *Investing in Natural Capital: The Ecological Economics Approach to Sustainability*. Washington DC: Island Press.

field guides for implementation such as the Sustainable Building Assessment Tool (Gibberd, 2003).

3.1.3. Timeline of events in the formulation of the sustainability concept

The following is a study of the evolution of an idea. The idea is one that many have pondered and sought to address, and it has manifested itself in the pursuit of ensuring that current actions achieve justice, equity, alleviation of poverty, and contributed to redistribution of opportunity (Elkington, 1997; 6) ‘without compromising the ability of future generations to meet their own needs’ (UN Brundtland Report, 1987). What could be seen in the early 1990s, however, was that a shift in power was emerging. As big business grew so too did its public influence, and pressure for change became a balance of political, business and social factors.

Figure 3.1 draws attention to series of occurrences that have, as Rose and Millar (1992) state, projected the concept of sustainability into the everyday consciousness by stipulating the main contributors to introduction of policy or behavioural change on a broad scale as either political or non-governmental (public). Since these behavioural and political shifts could not occur without tangible implementation, the progression and invention of concepts of built environment design are similarly incorporated to draw specific reference to the relationship between concepts of sustainable development and evolving architectural paradigms.

This figure illustrates occurrences within a 70-year period, from 1948 to 2015, selected for the purpose of identifying observable trends in the social or political pressures over periods in human history that included post-war rebuilding, economic recessions, social uprisings for independence and emancipation, as well as the arrival of the Information Age. The period is determined by the researcher to extend over noteworthy disruptions in human history to confirm that observable shifts in pressure exist, and that these shifts will continue. Additional research could be extended to include future occurrences within the proceeding decades to document and confirm the continuation of these trends.

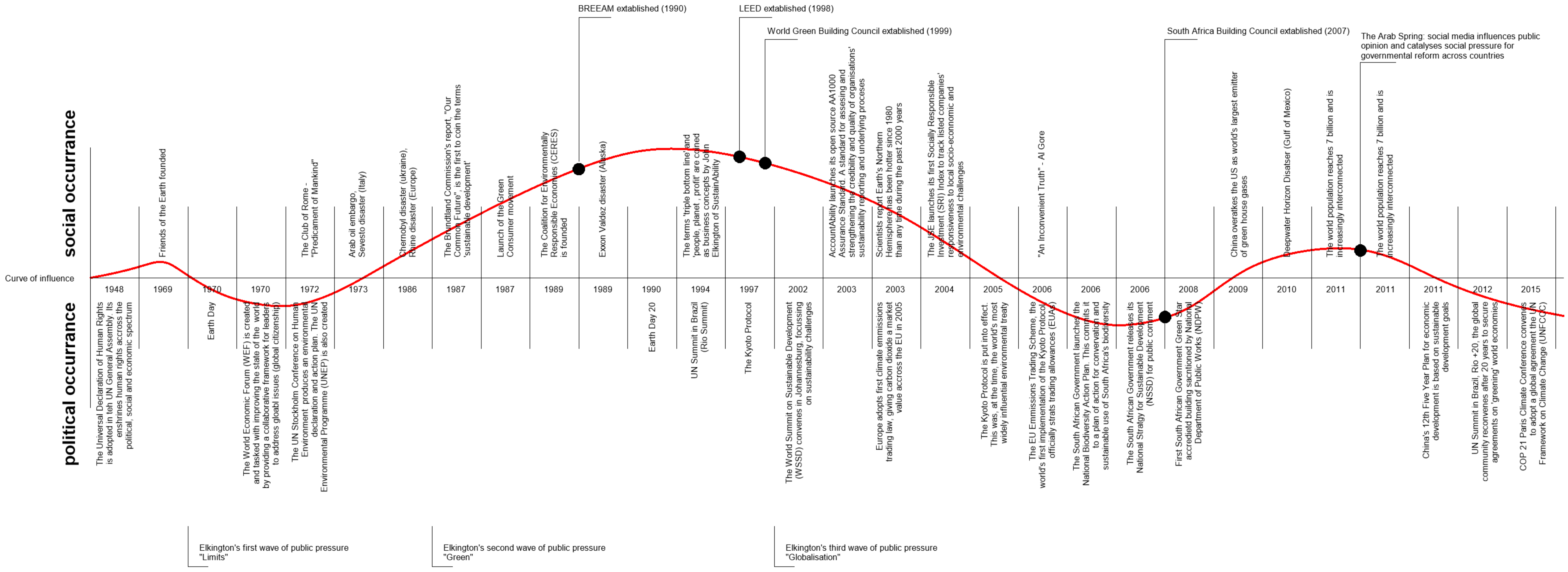

Figure 3.1: A timeline of waves of political and social pressure relative to sustainability principles

Elkington's observations reinforced trends shown in the graph. Major political and social events and elevated public consciousness of matters of sustainability, apply to Elkington's analysis of increased reference to the term 'sustainability' over time. In this method, a curve is plotted indicating the shifting importance of sustainability as catalyst for change from that of a political tool, to a social tool. By plotting significant architectural events along this curve, it is also possible to gain perspective on the motivations for emergence of certain concepts and models of sustainability for the built environment.

3.1.4. Observing a pattern of influence

Through interrogation of the graph in Figure 3.1, a pattern of influence can be observed. It is evident through the indicated 'curve' of influence that the main protagonist for action in the first 30 years of sustainability as an emergent concept was through the channels of political institutions. The concept was yet to be instituted with any great structure, but drew relevance on an international scale in generating awareness and evoking action in preservation of global ecology and social opportunity.

As Figure 3.1 indicates, influence of policy can be seen to be swayed in 'waves'. Definite periods of influence of either political or public pressure can be seen to be in effect for many years at a time, with political will influencing industry and those that work within it, while access to information similarly informed public opinion and enshrined influence on global trends through big business initiatives and adjustment in economic priorities. While matters of ecology remained prevalent in the first 30 years of developing concepts of sustainability, it was not until the 1980s that business and economics took to the stage by introducing numerous models for evaluating of life cycle cost relative to long-term benefits for current and future generations.

Current thinking with regard to sustainability has been further summarised to be the result of three predominant 'waves of public pressure' (Elkington, 1997:7). Each wave can typically be seen to be reactionary to contextual events of their time.

The first wave emerged in the 1960s, giving rise to a spike in international legislation. Rising awareness with regard to ozone depletion and rainforest destruction can be seen to have played a role in the emergence of the second wave of public pressure, giving rise to a paradigm of green consumerism. The third pressure wave – globalisation – began in 1999, represented most typically by protests against the World Trade Organisation, the World Bank, the IMF and others, highlighting the emerging role and importance of the public and international institutions in promoting concepts of sustainability.

As the global village becomes more interconnected and access to information grows, it can be seen that impetus for human progress is increasingly proactively, driven by public pressure, with political will following a reactionary role of conditional support. Franks (1996) and Harris (2012:3) argue that in lieu of social aspects, the influence of political institutions and business must be considered in their pivotal ability to induce paradigm change and 'cultural shifts'.

Human perception of threat is largely dependent on the scale of direct influence of a particular occurrence. In general the larger the space and the longer the time associated with a particular problem, the smaller the number of people that are generally concerned by that problem (Meadows et al., 1975:9). Furthermore, developments in technology have insulated us from the environment and as a result we have become particularly desensitised to the problem of environmental change.

The capacity of 'citizens' to appreciate a global issue at a scale they can appreciate can be typically observed in the changes to the typical householder's approach to energy consumption through energy saving devices and consumables for immediate gain. Public-realm investment in environmental technology or sustainable infrastructure fluctuates depending the political context of the day (Barr, 2008: 6). This has created a clear tension over time between the individual citizen's and societal interests pertaining to issues of sustainability due to the varying levels of temporal and spatial influence and their relative derived sensitivities. The value of sustainable initiatives in the context of this study will be primarily focused on the scale of direct human interaction with the built environment and a building (micro) scale as opposed to a town or urban (macro) scale.

The majority of current global environmental problems are described by Barr (2008:8) and Harris (2012:4) as a result of exploitation of resources by the individual, yet manifest themselves on a global scale. As discussed previously, the temporal and spatial context disconnects the problem from our day-to-day activities and priorities. This disconnection gives a sense of the 'abstract' to the problem, hence requiring a need to place quantifiable value on the effects in order to bring the problem into a context comprehensible by the individual. Brundtland's proposition for sustainable development had been the subject of much theoretical debate, since while it seemed a simple concept superficially, it therefore remained practically complex.

Every significant trend-setting item of policy that emerged could be represented in definitive adjustments in built-environment design and construction, based on the holistic evolution of the concept of sustainable development, while the effect on the built environment has been reactive to these trends of influence. The changing paradigms of built-environment design could therefore be interpreted as a measure of the influence of current policy. Over time, however, as the public demanded greater innovation in the preservation of our planet and the lifestyles of those who occupy it, it became desirable to substantiate decisions pertaining to the design of built environments based on a quantifiable evidence of approach, such as international green building ratings tools, for example. These various methods to validate architectural approaches were developed as architects and their clients sought to ensure feasibility beyond the foreseeable future. These aspects will be addressed in greater detail in Chapter 3, section 3.1.7.

3.1.5. Sustainability defined?

Sustainability has come to be defined in an almost infinite number of ways (Elkington, 1997:vii). The concept of what we have come to accept as sustainable development is one of the dominant political discourses of the early 21st century. This concept has been accepted by a multitude of sectors of society from political institutions and community organisations, permeating academic as well as socio-political networks, encompassing all while proving significant even at the individual sector level. The general and overarching nature of sustainability at an academic level proves difficult to research and teach due to the overlapping agendas of both the social and natural sciences (Barr, 2008:21), and herein the difficulty of defining this concept clearly lies (Eden, 2000:111). Politically, the concept of sustainable development poses difficulty for implementation through reconciliation of social, economic and environmental agendas (Barr, 2008:21). What is clear, however, is that these three sectors prove to be the common ground for interpretation of the concept, regardless of scope and scale of intended implementation.

The lack of any single definition and the resulting multitude of conceptual models, frameworks, and policies means that sustainable development continues to emerge as a concept to which most can subscribe and conduct themselves accordingly at one level, yet hold different opinions on a range of socio-economic and environmental issues at another (Barr, 2008:21). From the scale of perspective of citizen engagement, these conceptual differences do not create a clear distinction between optimum and inefficient practices, but an ‘overlapping set of discourses which sometime reflect contradictory positions' (Barr, 2008:22). In general terms, it appears that without specific context for implementation, the discourse is destined to perpetuate itself.

Due to the fact that the nature of research in areas of sustainable development (Brundtland's Report and Agenda 21) has provided researchers with a wealth of theoretical and conceptual material to interpret, an understanding of sustainable development at this point reveals that there are multiple discourses surrounding this concept, with each discourse motivated by its own contextual priorities and disciplinary agendas.

This thesis therefore acknowledges that a single 'truth' cannot exist in the quest for sustainable development, but rather that findings are generated specifically for the applicable context. Spatial and temporal factors play a significant role in both the manner in which a problem is deemed important, as discussed previously, but so too in the manner with which a sustainable agenda is likely to be adopted by a particular discipline in both implementation as well as operation. It is for this reason that sustainable development in the scope of the built environment is both required and most suited to be addressed in isolation, as the conclusion achieved herein may not be suited for implementation in alternative industries.

In order to proactively support sustainable development, it is widely understood that, if possible, development should occur without detriment to the natural environment. In other words, development should occur in such a way that a reduction in the Earth's natural capital does not occur in a manner which cannot be recovered. As a result of this thinking, two doctrines of thought emerged at opposite ends of the spectrum. The first was deemed the 'ecocentric' approach. This approach acknowledges that the potential for human growth and reliance on resources is finite, and based on a limited capacity of the Earth to sustain our population. Alternatively and contrastingly, a second paradigm exists. The 'technocentric' approach regards the environment as a resource available to be exploited as long as human interests are not compromised. In this manner, the environment contains economic value only, and should be maintained in a manner that supports human growth.

As mentioned above, the technocentric approach does not advocate compromising the environment as it too recognises the social, environmental and economic bedrock upon which sustainable development as a concept is built, but places emphasis on human development and applied technologies to support its continued progression. A middle ground is therefore sought. Much research has been conducted on addressing the importance of the environment as both a resource and a cost. Of the research conducted, the reports on developing a ‘Green Economy’ such as the ‘Blueprint for a green economy (1989)’, and ‘Green economics’ (1992), and recently ‘Blueprint2: greening the world economy (2013)’ as produced by Pearce et al. have proved to be some of the more prolific. In this research, it is proposed that technological innovation and modernisation could be a way to offset any incurred or potential environmental consequences while maintaining growth trends (Barr, 2008:35).

In order for this to occur, a shift in behaviour is required, whereby those that seek to implement sustainable development can be made to remain open to change by predictable analysis on the cost and benefit of such behaviour. In the context of the built environment, the issue of temporal and spatial scale is required to be addressed directly. This forms a principle critique of sustainability definitions in this thesis. Spatial and temporal scale affecting sustainable development is therefore applicable to additional criteria such as physical and spatial context, technological and infrastructural requirements, statutory and regulatory limitations, as well as cultural phenomena of the time.

The value of interpreting sustainable initiatives from the point of view of the built environment is that this contextual scale is readily defined. It is possible to attribute definite long-term goals to a project, to predict the lifespan of a project, the focus of implementation and to predetermine the required durability of any such implementation over time. The ability to appreciate impacts on the environment reduces when we move beyond the local scale. As stated by Redclift in his paper ‘The multiple dimensions of Sustainable Development’ (1991:36), sustainability at one scale may not imply sustainability at another. Therefore, when approaching sustainable development from the point of view of built environment, contextual parameters and restrictions are required for adequate substantiation of decision making. It is based on this delimitation of scale that it is possible to quantify the achieved and potential successes of any implementation. This need for ‘quantification’ to better establish cost and value of the environment, in the context of socio-economic development has given rise to a series of models and applications over time. While each deviates from the other, all can be seen to share the same common ground. Although geared towards implementation on a holistic level and therefore not specifically to a particular context for implementation, the triple bottom line has been recognised as guiding principle and subsequent point of departure.

3.1.6. Varying concepts of sustainable development

'If it cannot be measured, then it cannot exist.'

– Professor H. J. Eysenck

Prior to embarking upon specific models for implementation of sustainability principles for the built environment and architecture specifically, it is necessary to understand the varying concepts at a holistic level. In order to provide a focused approach and understand the specific models for implementation of sustainability in the built environment, the reasons and principles of the guiding models must be taken into consideration at all spatial and temporal scales (Barr, 2008:38).

The first model to consider is that of Khan, published in 1995. His triple bottom line scenario implies that the Earth's natural capital must be maintained in equal proportion both as provider and as input, as well as a 'sink' for waste. The regenerative capacity of the environment must be matched by the expenditure of its resources. The triple bottom line represented in this model therefore boasts a linear dependency and responsibility between each dimension.

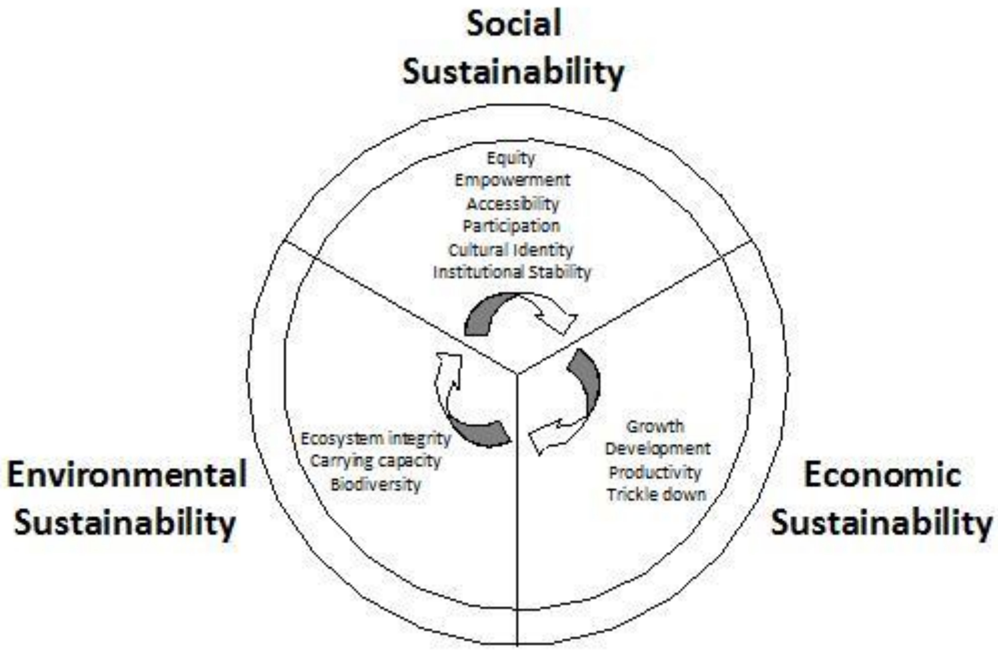

Figure 3.2: Khan's Model of sustainable development (1995)

In the economic dimension, the model refers to a production process that satisfies current levels of consumption without compromising future needs. This would later be revised on the finding that this was based on the assumption that, in the interest of economic stability, business would support technological innovation to increase efficiency and reduce expenditure of natural capital. Although there has been significant innovation, it can be seen that the rate of technological growth is slower than the rate of exploitation of resources. The social dimension and its stability is a matter more prevalent in developing contexts in order to promote equity and empowerment, yet proves to be the most problematic to measure, as with most social sciences (Barr, 2008:38).

Based on this model a series of alternatives had emerged over time, and many did in fact seek to alter or add to the triple bottom line, or ‘three pillars’, as the fundamental basis for departure. The most notable of these was the model proposed by Basiago (1995:115), known as the ‘Four Lens Approach’.

In this model, emphasis is placed on the following dimensions:

- Biodiversity sustainability
- Economic sustainability – addressing five specific contexts:
    - Environmental context – physical aspects of the Earth and solar system
    - Human context – knowledge, skill and motivation
    - Socio-organisation context
    - Manufactured context – products and environment (including built environment)
    - Context of credit – money and debt
- Sociological sustainability
- Planning – addressing future perspective regarding humans and their environment.

Basiago’s model differs to that of Khan in that it seeks to provide at its core a response to context, yet without establishing the order of interrogation. Additional to this model, sensitivity to future planning is prevalent, which is assumed to apply only to the dimensions of economic and sociological sustainability, as the Earth’s biodiversity capital is limited. Instead it may be determined that the effect of future planning is therefore to equate expenditure with regeneration of natural capital. This model at its core thus expands upon the triple bottom line approach by understanding that each dimension intrinsically overlaps the others, particularly the concept of economics. This model reiterates the concept that the environment has value, and with it poses its own economic considerations. Where it is similar to the model of Khan is that it places equal importance on each dimension, without making reference to any limit that each might place on the other.

The third model of significance is the ‘Three Rings Model’ by Giddings et al. (1996). This model takes into consideration that each dimension has an influence over the other, that each share common ground which needs to be examined in greater detail. They argue, however, that to address each dimension as being of equal significance, or as being balanced, is misleading. Barr (2008:42) states that ‘acknowledging the difference in the three sectors (dimensions) implies that there is prioritisation’ and that to actively seek balance means to encourage a compartmentalised view of sustainability without addressing the ‘overlap’ between dimensions. ‘Trade-offs’ are thus accepted, and these in turn require adaptive and ‘technical fixes’ to make them work, resulting in inefficiency in the system, as processes for implementation are continually under correction.

Giddings et al. (2002:187) further examine the problem, and furthermore establish that a ‘political reality’ plays a role in current decision making. As alluded to previously in this study, the paradigm shifts and evolutions of concept have been born out of institutional pressure, which in turn responds to societal pressure. In order to ‘render’ a problem into the conscious thought of the masses, the scale of the problem must be of temporal and spatial significance.

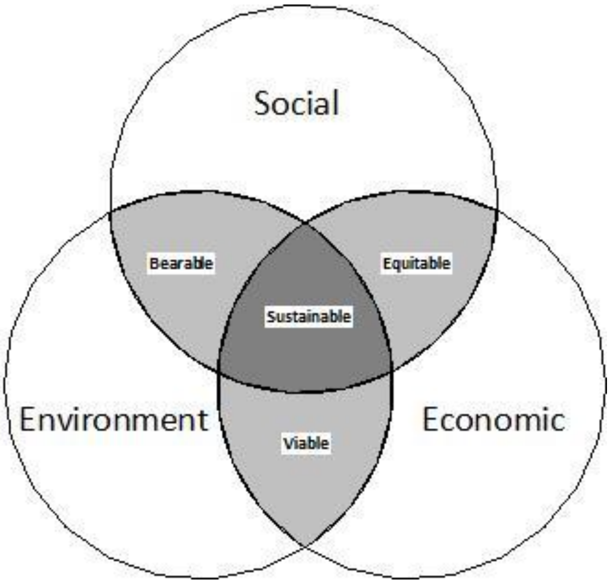

Figure 3.3: Giddings et al. (2002:189) ‘Three Rings Model’ of sustainability

From the understanding that striving for equity of the dimensions represented in the triple bottom line is not necessarily the optimal approach, the linear and linked theories are again adapted to produce 'nested theory'. This theory recognises that humans are dependent on our natural environment, and that we are irrevocably bound within it. By emphasising that the relationship with our environment occurs on the surface at a societal level, this process thus works in a two-way fashion, prescribing limits of human activity regarding environmental exploitation as well as the impact on the environment in isolation. In this model, the economy is placed at the centre, implying a reliance on social exchange and networks.

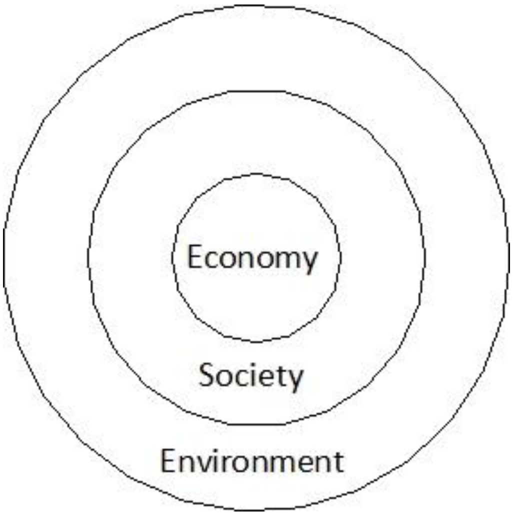

Figure 3.4: Giddings et al. (2002:192) 'Nested Sustainability Model'

This model therefore gives a hierarchal structure to the models that are formed at their basis by the triple bottom line. It places greater emphasis on social needs as opposed to those of economics, all the while operating under the assumption that the natural capital of this planet is a finite commodity capable of being used over a range of scales (Barr, 2008:43).

In 2004, Williams and Millington contested these models by stating that the application of these lacked flexibility as interpretive tools. To interpret the wide scope of assumptions in sustainability policy, a more sophisticated manner was required. This gave rise to 'weak' and 'strong' sustainability. Weak sustainability, or 'shallow environmentalism', refer to a scenario where trade-offs exist. In a world whereby contribution and exploitation between the triple bottom line dimensions can be measured in theoretical 'capital', the weak approach looks only at the total amount of capital passed on to future generations as a combination of all three dimensions combined. This means that it is plausible that environmental capital could be reduced while economic capital increases. There is some measure of sustainability here, but it is clearly and understandably defined as weak since the capacity of environmental capital to support future growth is compromised, instead relying on technocentric approaches to facilitate greater efficiencies of a social and economic nature. There is little or no repayment to the environmental dimension. A strong approach, to the contrary, recognises that growth is required, yet focuses on maintaining proportional growth in all dimensions as implementation is passed on to future generations (Barr, 2008:44). Thus the critical levels of environmental capital are always maintained.

What is clear in the evaluation of these models is that their derived implementations are conceived at a generic level. In order to achieve sustainability on a focused scale, a synthesised approach pertinent to a particular field needs to be derived. In terms of the built environment, the scale, impact and lifespan of a particular implementation is available for scrutiny. Utilising the nature of the relationships between dimensions as indicated above, a series of implementation tools have been devised. Although widely accepted by the industry, it is evident in most that the link or even hierarchy between the three pillars has been forgone in order to focus on the dimensions which are most easily quantifiable or serve to provide greater political momentum.

3.1.7. Existing models for application of sustainable development principles in the built environment

The many available models, definitions and applications of sustainable development contribute to the term remaining vague and, at times, largely abstract. As can be determined from Table 3.1. below, this often affects and limits its implementation as a holistic concept by focusing instead on more easily quantified sustainability issues in isolation, such as *principles of ecology*. This can typically be observed in a predisposition towards ‘green building’ in the industry and the accreditation processes involved with organisations such as that of LEED and the Green Star Rating System. These rating tools are devised with a mandate to ensure that a building is designed and constructed with a goal to be ‘energy efficient, resource efficient and environmentally responsible’ by incorporating ‘design, construction and operational practices that significantly reduce or eliminate the negative impact of development on the environment and its occupants’ (GBCSA, 2012).

The following section represents an overview of a selection of popular assessment tools used in the built environment. This overview seeks to identify the aims and objectives of each method, the areas of focus, and the actual response to, and integration of, the aforementioned ‘three pillars’ of sustainability. The assumption made at the outset, however, is that the process and evaluation is limited to the architectural intervention in isolation. It is assumed that government is responsible for the planning, design and construction of all infrastructure and the policy framework that supports our society. The term ‘infrastructure’ includes a variety of factors, including urban planning, roads, public transportation and information networks. Each is independently administered and thus the responsibility of different governmental agencies. However, it is important that all be designed holistically in order to optimise their collective efficiency. For the purposes of this thesis, the nature of design of infrastructure is not critiqued, but assumed to be of an adequate nature to not inhibit built environment development at a building scale.

Table 3.1: Comparison of popular global methods for sustainable intervention by architects in the global construction industry

Method		**Aims and objectives:**	**Main drivers and areas of focus:**	**Triple bottom line inclusiveness:**
BREEAM, UK, 1990	The Building Research Establishment (BRE) Environmental Assessment Method (EAM)	Environmental assessment. Applicable to new and existing non-residential buildings in the UK.	• UK and European regulations • Legislation and planning • Private sector companies - • Public sector – institutional mandate. Investigates: Management, health and well-being, energy, transport, water, minerals, waste. Land use and ecology, pollution	Environmental
LEED, US Green Building Council, USA, 1994.	Leadership in Energy and Environmental Design (LEED)	Environmental assessment. The design, construction and operation of new and existing high-performance green buildings, homes and macro-scale environments, with five overarching categories pertaining to industry specialities. LEED also forms the basis for other sustainability rating systems such as the EPA’s *Labs21.*	• American ASHRAE standards • Private sector companies - • Public sector – institutional mandate. Investigates: sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality.	Environmental

Green Star, Green Building Council of Australia, 2003.		Provides multi-category scoring for investigation into building performance at *design* and *as-built* stages of completion.	• Public sector – preference and responsibility Investigates: energy efficiency, indoor environmental quality (IEQ), water, Transport, ecology, materials, innovation	Environmental
SBAT, (Gibberd) South Africa, 2003	Sustainable Building assessment tool,	Performance criteria that acknowledge social, economic and environmental issues. Divides 15 performance areas into five performance criteria. Integral part of a building process based on the typical life cycle of a building.	• Private sector companies • Public sector – preference and responsibility Investigates: materials and components, occupant comfort, inclusive environments, access to facilities, participation and control, education, health and safety. Local economy, efficiency, adaptability, ongoing costs, capital costs, water, energy, waste. site.	Environmental Social Economic

Within the comparison above, it is observable that while some are inclusive of triple bottom line factors, the focus of the most popular tools, namely: BREEAM, LEED and GreenStar is predominantly environmental. This focus limits the capacity of the tool to correctly inform the suitability and sustainability of the proposed intervention. These tools focus attention on the building product primarily as a measure of efficiency and resource allocation, while remaining 'light' on the end user and societal level. SBAT, by comparison, represents a more holistic approach to building performance evaluation by including social factors of inclusiveness and accessibility. Economic factors are also addressed in gaining insight into operational costs and initial expenditures; however, economic feasibility relative to building performance and function still requires further investigation during operations and building life cycle, while all remain light on the assessment of user experience during occupation (sustained usefulness). Furthermore, it can be seen of all the represented tools that they are conducive to an assessment at a selected and fixed point in time, represented in either design, construction or operation. These assessment tools will again be revisited in Chapter 6 section 6.1.7

whereby their effectiveness and shortcomings in response to revised sustainable development success criteria will be investigated.

Further to these tools, standardisation of building products and construction is guided by organisations such as the International Organisation for Standardisation (ISO),[6] and the European Committee for Standardisation (CEN).[7] These global standardisation bodies offer guidance in general principles and objectives in the production of sustainable building products. In establishing the use and development of a framework for use of sustainability indicators, ISO21929-1, for example, takes these into account with the aim of assessing the sustainability performance of buildings.[8] However, the standards do not provide levels or benchmarks that may serve as the basis for sustainability claims, thus necessitating the inclusion of multi-tool analysis in project development and execution. Furthermore, these standards ascribe to the triple bottom line indicators of sustainable development as a basis for interrogation of methodological basics while transitioning into an environmental-centric emphasis in product life cycle, as can be observed in Figure 3.5 below, thus limiting holistic implementation of sustainability principles.

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[6] ISO 15392:2008(en) Sustainability in building construction – General Principles. https://www.iso.org/obp/ui/#iso:std:iso:15392:ed-1:v1:en [Viewed on 2017-03-07].

[7] CEN/TC – Sustainability of construction works. https://standards.cen.eu/dyn/www/f?p=204:7:0::::FSP_ORG_ID:481830&cs=181BD0E0E925FA84EC4B8BCCC284577F8 [Viewed on 2017-03-07]

[8] ISO 21929-1:2011 Sustainability in building construction – sustainability indicators. https://www.iso.org/standard/46599.html [Viewed on 201-03-07].

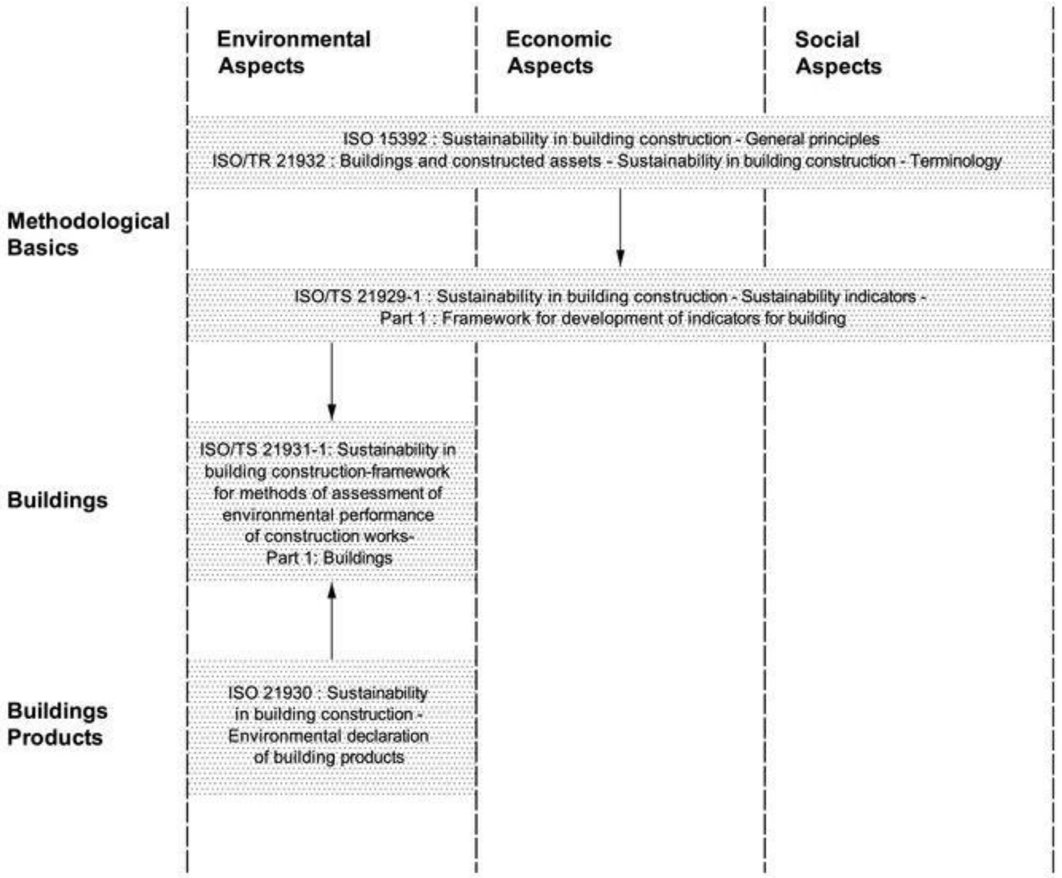


Figure 3.5: Suite of related International Standards for sustainability in buildings and construction works
Source: https://www.iso.org/obp/ui/#iso:std:iso:15392:ed-1:v1:en [Viewed on 7 March 2017]

As stated by Trinius and Chevalier (2005:4622), the utilisation of the aforementioned construction standards and the inherent listing and aggregation of performance criteria at a product level is not yet a sufficient basis to express sustainability aspects of buildings. In order to consider the full-life-cycle application of these standards, theoretical scenario-building is required for which the methodological framework does not sufficiently allow for, thus challenging adequate implementation. Furthermore, these standards are based on modules, which is prone to creating silos of approach. These standards therefore enable later refinement and the development of additional modules for fields that are not yet adequately addressed (Trinius & Chevalier, 2005:4633).

3.1.8. Summary

This section investigated the origins of sustainable development theory and the factors that contributed to its emergence. The arrival of the argument concerning humankind's limits to growth and the ecological capacity of the planet brought about a new consciousness into humankind's future. If we were to progress as a species, and do so without detrimentally affecting the planet's ability to accommodate our basic needs, a sustainable approach was necessary.

It was observed that increasing social and political pressures, often alternating in waves of influence over time, reactively gave rise to newer sustainability policies as well as industry standards of approach. The levels of pressure exerted were a function of the perceived level of threat, and as such influenced the interventions to manage these threats. The premise of threats is perceived at a specific temporal and spatial scale, therefore prioritising actions in response.

Spatial and temporal scale is what provides scope for intervention, without which the concept remains vague and, at times, abstract. This has been a contributing factor to the perceived ambiguity and vagueness of sustainability theory to date, resulting in an appreciation for the core concept and goals to which it strives but lacking a clear framework for intervention. The spatial and temporal scale of pressure is the dominating paradigm that has established preference to green building design approaches, by attributing principles of approach to scales that are identifiable. By introducing a scale of approach, clear goals and steps are possible to attach to a process, thereby better enabling implementation.

Furthermore, it was observed that since its inception as a concept, sustainable development has been the focus of a triple bottom line. This bottom line sought to adequately cover all aspects of development in order that a harmonised and balanced approach could be sought. These pillars of the triple bottom line, namely social, environmental and economic, would be subject to much conjecture, as well as the development of varying models describing their relationship. While various models were identified, these remain broad in scope to be used across various industries, but as a result remaining challenging for focused and holistic implementation. This continues to prompt development of variations and alternatives, furthermore addressing the issue that sustainable development as a core concept requires focus of scope (industry) and scale if it is to be adequately implemented. Attributing an industry focus to a particular scale (temporal and spatial) of intervention, could create conditions of quantifiably facilitating sustainable development theory implementation and make the process more accessible as has been demonstrated with green building design tools. This creates the conditions for additional criteria to be integrated within sustainable development theory while improving the focus of application.

3.2. Addressing hypothesis one:

Hypothesis: Industry-specific interpretation of sustainable development is required for appropriate implementation in the built environment.

3.2.1. Understanding the importance of sustainable development theory for the architectural profession

Architecture requires a sustainable approach in design and implementation; this is already an established canon. It must be reiterated, however, that design for sustainable development requires a deeper investigation into, and beyond green design. A critical element in achieving sustainable living is therefore in how built environment professionals practise design towards a sustainable future.

Typically sustainable development is illustrated as three intersecting circles connecting community, economy and the environment. However, the overwhelming majority of problems, issues and corresponding solutions are three-dimensional. As three-dimensional problem solvers, architects are therefore very well suited to lead the change and resolution of nonlinear, spatial challenges affecting sustainable development. Most professions do not work this way, and most people do not think ‘spatially’. The three spheres of sustainable development, much like the three elements in Vitruvius’ principles – firmness, commodity and delight – must be solved simultaneously and spatial thinkers are well equipped to accomplish this. Since these spatial relationships are essential and connected parts of sustainable design, spatial thinkers are best equipped for the responsibility, challenge, and custodianship of multidimensional solutions (Williams, 2007: 14).

Design and planning at the regional scale have the greatest impact on sustainable development. The layout of utilities, services, and infrastructure has significant impacts on sustainable development, such as transmission loss due to the length of lines delivering electricity. The local, regional and national layout of highways, roads and zoning patterns dictate whether land use is compatible with natural and sustainable patterns. When planning creates a system in which roads and highways are the only linkages to personal necessities, the planning itself creates unsustainable conditions. Urban sprawl, in which development extends further and further from the core business district, leads to a greater dependence on automobiles, both in the number of trips required and in the length of the trips (Williams, 2007:24).

According to Williams (2007:26), the universal lack of long-term, large-scale planning is not due to a mistrust of the design and planning profession, but to the fear that people have approached the unknowable – embarking on a process they do not understand. By working with communities, teaching the process and creating illustrated, community-based visions, architects can help communities define their desired future and establish the next steps to implement their vision.

Birkeland (2005:5) furthermore states that some designers take the position that environmental design cannot influence human attitudes and behaviours. While physical determinism (the belief that the built environment influences social behaviour) is overly simplistic, so is the view that it has no discernible effect. This latter view conveniently absolves designers of responsibility for presenting their public or private clients with the wider social and ecological implications of their proposed projects or investments. For design to become relevant to social and environmental problem solving, design education and the design process itself must be transformed.

Throughout this thesis it is apparent that architecture cannot exist in isolation, and that our environment affects, and is affected by, the actions of humankind. What is also apparent is that the needs and wants of humankind are dynamic and ever-changing; hence a mechanism for reacting to, as well as predicting, behaviour is required for sustainability to be achievable. In addition, a view of design that does not consider the political nature of designed environments and objects is a very partial analysis, neither integrated nor holistic – and is therefore not compatible with systems design.

Based on these problems, it is the opinion of the researcher that architectural practice and related design process may still be improved to better integrate ideology pertaining to sustainable principles. This is in recognition that a comprehensive and systems-design methodology is, for the time being, the most appropriate mechanism to achieve this.

3.2.2. Evolution of the concept of sustainable development

As previously discussed in this chapter, sustainable development is the subject of many opinions and model-based variations. At the core of the debate lies the issue of capacity versus potential. Should sustainable development be characterised by seeking to define the limits that ecology poses to humankind within this planet of finite resources, as Meadows et al. postulated in *The Limits to growth* (1972), or should the concept be driven by the potential for contribution to this planet and its inhabitants? To comply with the former argument, as stated by Gibberd (2005:300), sustainable development can be described as a state in which humankind is living within the carrying capacity of the Earth. The UN-commissioned Brundlandt Report of 1987, however, based its approach on de-emphasising the environment while underlining human need to be realised through development. This created an ethical paradox by virtue of the understanding that sustainability describes the characteristic ability to maintain a process indefinitely, while development inherently relies on environmental modification and utilisation of natural resources to occur. Sustainable development was therefore introduced as a concept in order to seek moderation of this paradox (Jabareen, 2008:181). As furthermore stated by Jabareen, sustainability was originally devised as a concept to represent the field of ecology and ecosystem longevity without alteration. Upon inclusion of the scope of development, the concept was advanced to include the values of society and the capital economy (2008:181).

Design for sustainable development, be it in the creation of a product or system, has been understood to represent an effort to consider both environmental and socio-economic systems. Fiksel (2003:5334) states that while it is not possible to design a perfect natural environment or society, it is instead possible to modify the controllable characteristics of our designed artefacts and interventions, and in this way derive environmental and social benefits. A product therefore contributes to sustainable development if it constrains environmental resource consumption and waste generation to an acceptable level, supports satisfaction of important human needs, and provides enduring economic value to business enterprise (Fiksel, 2003:5330).

This frame of thinking sets the tone for a common trend through alignment of sustainability principles to ecology, economy and society, more commonly referred to as the triple bottom line or three pillars. The majority of practitioners are accustomed to relating to the triple bottom line theory in developing business strategies and formulating long-term goals (Yang, 2005:x), while many environmentalist scholars equally believe that sustainability is achievable through effective balancing of the three-pillar objectives. The most frequently quoted definition of the concept is seen to be derived from the Brundtland Report which drew emphasis towards equity between generations (Jabareen, 2008:183) through balance of these three pillars. The triple bottom line approach has been the guiding principle of sustainable development in many countries and sectors of the industry (Yang, 2005: xiii) facilitating improved analysis via the three-pillar approach due to the fact that traditional methods for analysing cost, benefits and risks are often overwhelming (Fiksel, 2003:5330).

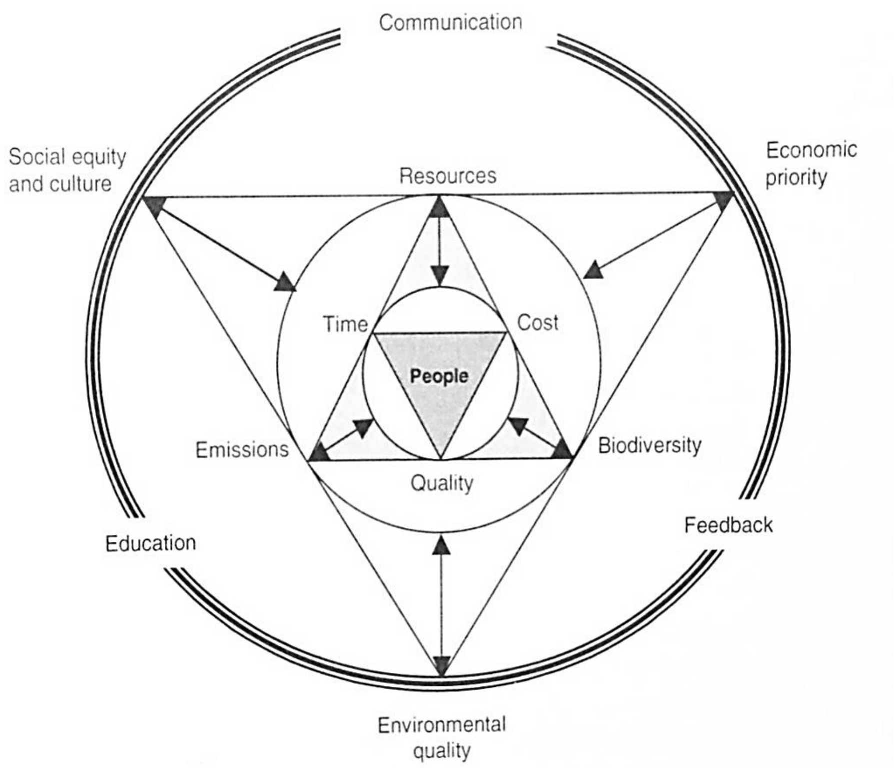


Figure 3.6: **An integrated approach to key issue of smart and sustainable built environments (Yang, 2005: xii)**

The paradox of sustainable development is a theme that has given rise to a multitude of varying theories and approach within many industries. Yet while there are models that are more or less inclined to emphasise capacity of ecology or delivery to the needs of humankind, a deeper understanding of an integrated systems approach has emerged. Gibberd (2005:310) states that sustainable development cannot be seen in isolation from users and their social context and should be responsive to local needs and opportunities. This development should thus be seen as 'systems of physical and non-physical aspects to work together in an efficient and integrated way'. The success of sustainable development therefore relies on the continued success of humankind. Sustainable development concepts centre on people and will have the same underpinning of time, quality and cost as with key management principles (Yang, 2005:xiii).

Triple bottom line is understood to emphasise that success in society is influenced by success in ecology as well as economy. As Jabareen (2008:182) states, capitalism and ecology are no longer contradictory. Limits to growth are manageable and SD 2001, the European Council 1993, the United Nations Conference on Environment and Development (UNCED) 1992, the United Nations Framework Convention on Climate Change (UNFCCC) 1992 contribute to global belief that an integrative and holistic approach is required. The evolution towards sustainability and sustainable development as an integrative systems approach can be derived from Meadows and Randers' definition of a sustainable society as one that has in place informational, social and institutional mechanisms that keep check on one other through feedback loops. By means of this approach, a framework for sustainable development through integrative management is developed, one that seeks to achieve social development, economic growth and environmental protection (Jabareen, 2008:185) through establishment of systems for integrated environmental and economic accounting.

In the realm of the built environment, while it can be seen that industries are keen to advance in search of appropriate mechanisms for delivering a final outcome that is environmentally sustainable (Yang, 2005:xii), a recent trend has emerged in the form of Green Design. The establishment of 'eco form' is represented in the applied technologies and ideas relating to ecology and sustainability such as alternative building materials, renewable energy, organic foods, conservation and recycling. The predominant view among scholars, planners and policy makers is that energy efficiency is key to achieving ecological form through design (Jabareen, 2008:185). This approach has been somewhat contradictory to the holistic vision embraced by the greater community because design for energy efficiency emphasises ecological capacity. Cole (2012:40) states that 'Green Design' has been used fairly consistently over the past decade or so to emphasise the environmental performance of a building and is primarily directed at reducing the degenerative consequences of human activity on the health and integrity of ecological systems. Performances are evaluated relative to a benchmark, rather than their absolute consequence on human and natural systems. Process-related criteria are incorporated alongside performance issues (2012:41) to be applied to a specific product or intervention.

When comparing Green Design with the accepted definitions of sustainable development:

- A sustainable society is one that continues to satisfy the current needs of its population without compromising quality of life for future generations.
- A sustainable enterprise is one that continues to grow and adapt in order to meet the needs of its shareholders and stakeholders. A sustainable product is one that continues, possibly with design modifications, to meet the needs of its producers, distributors and customers.
- Green design is an element of sustainable design (Williams, 2007:16).

- Sustainable design differs from Green Design in that it is additive and inclusive – it includes continuing, surviving, thriving and adapting (Williams, 2007:16).
- Green Design incorporates ecologically sensitive materials and creates healthy buildings and processes that do not negatively affect the environment before, during or after manufacture, construction and deconstruction (Williams, 2007:16).
- Sustainable design integrates the principles of Green Design and goes further to become a passive and active structure (Williams, 2007:16).

As architects and planners, we are taught to work on a project until it is done, then move on to the next one. But design, like the concept of sustainability, is dynamic and it is better thought of as a continuum**,** where design and planning are constantly approaching sustainability. A design is sustainable, or it is not. If it is not sustainable, changes can be made to make it sustainable. If it is sustainable, by necessity it will be changing and evolving. Sustainability is therefore not static, it is iteratively changing, based on evolving knowledge that connects science and design' Williams (2007:16).

The above definitions imply that social responsibility is a characteristic of the enterprise, not of the product or service, and requires constant adaptation to ensure transparency and responsiveness to the changing needs of its stakeholders. Ecological integrity and quality of life are often influenced by characteristics of a product or service and thus can be addressed through sustainable design principles (Fiksel, 2003:5332).

3.2.2.1. Investigating resilient and regenerative theory

A parallel trend to Green Design in the built environment is thus focusing on the holistic approach once more through endeavouring to achieve sustainability through creation of open and adaptive systems. This approach is embodied in the form of two complementary concepts: design for resilience, and regenerative design. The researcher recognises that these theories represent a contingent of contemporary thinking in multiple industries, including the built environment, and will be investigated as such.

In designing for resilience, it is understood that complex systems are dynamic, non-linear and capable of self-organising to sustain their own existence. The law of thermodynamics states that closed systems will gradually decay from order into chaos, tending towards maximum entropy. However, living systems are open in the sense that they continually draw upon external sources of energy and maintain a state of low entropy. The essence of sustainability is resilience, the ability to resist disorder. Characteristics of resilient systems (Fiksel, 2003:5333) are:

- Diversity – existence of multiple forms and behaviours;
- Efficiency – performance with modest resource consumption;
- Adaptability – flexibility to change in response to new pressures; and
- Cohesion – existence of unifying forces or linkages.

The evaluation of systems quantifies selected performance criteria that portray consequences of design choices through quantifiable performance indicators as part of its guideline for sustainable reporting (Fiksel, 2003:5337). Through designing for adaptability (DFAD) products are conceptualised and modelled as dynamic systems with feedback control strategies to respond, or adapt effectively to changes in product performance criteria. This approach takes into consideration changing performance requirements based on physical, cultural, environmental or economic considerations among others (Kasarda 2007:727). Through the introduction of adaptability as a key feature of product design it is assumed that this inherent ability to resist obsolescence in an extended lifecycle would have a high impact on sustainability goals. DFAD seeks to characterise a product as a dynamic adaptable system, and models the product as a controllable system with a feedback loop. Control and feedback can therefore be used to modify system performance. Considerations relating to adaptable products can be seen to include building material, potential for remanufacture, smart materials, nano-technology and building inputs (Kasarda 2007:727).

‘Regenerative’ design and development, by comparison, emphasise a co-evolutionary, partnered relationship between humans and the natural environment, rather than a managerial one, and in doing so build rather than diminish social and natural capital (Cole, 2012:39), placing emphasis on the carrying capacity of the environment through creation of products and systems that require little, or no (net zero) ecological input to be self-sustaining.

While resilient and regenerative design are actively pursued, other research under the sustainable design umbrella includes focus on increasing product life through flexible design, design for remanufacture, design for disassembly, and product reliability (Kasarda, 2007:728). This takes into consideration the fact that a design product should not solely be in a position to ‘resist chaos’, but be sufficiently self-diagnostic in order to validate its continued existence.

The principles of regenerative and resilient design are appropriate to be incorporated into a revised model for sustainable development in the built environment, particularly when enhanced through additional investigations into system flexibility. However, an emphasis on matters of ecology limits the holistic appropriateness of their implementation on the basis of attending to evolving human need. For this reason, the researcher recognises that pursuit of a revised model for sustainable development and the criteria that define it remains necessary.

3.2.3. Challenges of implementation

The nature of sustainable development is such that since its inception as a globally accepted concept there have been and continue to be many attempts to provide a theoretical framework for implementation. This thesis has investigated some of the prevalent established and contemporary theories by selection due to the sheer number. The fact that newer concepts are emerging, and evolving, demonstrates the difficulty for implementation that the concept poses to practitioners, professionals and scholars in their respective fields. For example, while a number of definitions of sustainable development are currently used, many convey the notion of a state in which humankind lives within the carrying capacity of the earth (Cole, 2012:44), while others refer to the common contribution possible to the three pillars. The influential but ambiguous Brundtland Report has also allowed for general interpretation on a policy level by giving governments and businesses the means to be ‘in favour’ of sustainability without fundamental change to the current course (Hopwood et al., 2005: 40). Du Plessis (2012:7) furthermore argues that the current and dominant concepts of sustainability have instead reached a limit to their usefulness due to their conceptual foundation in an inappropriate mechanistic worldview and their tacit support of a modernisation project that prevents effective engagement with a complex, dynamic and living world.

‘Our Common Future’, the 1987 UN-sponsored WCED report’s definition of sustainable development, despite its well-known vagueness and ambiguity, has been highly instrumental in developing a ‘global view’ with respect to our planet’s future (Mebratu, 1998: 494). However, expanding the framework to include social, cultural and economic considerations moves the assessment into areas where there is greater difficulty and less consensus regarding performance metrics (Cole, 2012: 44). Critical review shows that definitions of sustainable development are vague, and lack operative definitions fraught with contradictions over what should be sustained (Jabareen, 2008:179). The inherent vagueness of the concept of sustainability and sustainable development has resulted in a political battle for influence by attaching varied interpretations to the concept (Mebratu, 1998:503). This has resulted in a large variety of definitions that are personalised and specific towards institutional and group requirements rather than a pursuit of the general essence of the concept (Mebratu, 1998:493).

Based on a literature study within all fields that concern sustainable development, including social sciences, philosophy, ethics and ecology following the Brundtland Report, Jabareen ascertained that a lack of a comprehensive theoretical framework for understanding sustainable development and its complexities is evident, furthermore stating that there is currently no general agreement over how the concept should be translated into practice (2008:180). Beatley and Manning similarly argue that there is a general sense that sustainability is a positive concept worth pursuing, but requires further definition and elaboration to be effectively implemented (1998:3).

In order to propose a better path for implementation, it has been proposed that a suitable alternative to the pursuit of a generic ideal is to design a resilient system by taking advantage of fundamental properties such as diversity, efficiency, adaptability and cohesion (Fiksel, 2003:5330). However, as encountered and stated previously, the actual development of sustainable systems remains challenging because of the vaguely defined and broad range of economic, environmental and social factors that need to be considered over the system life cycle (Fiksel, 2003:5330). The basis for sustainable development upon the three-pillar approach remains an accepted constant in most intended approaches as a basis for departure, however, and environmental protection and social responsibility are regarded as important to shareholders and other stakeholders. Yet, despite heightened awareness, companies have continued to find it difficult to translate broad goals and policies into day-to-day decision making (Fiksel, 2003:5330).

The concept of sustainable development is often associated with resource constraints and maintenance of status quo rather than with opportunities for continued innovation, growth (regeneration) and prosperity. Instead, the widely accepted concept of the triple bottom line implies that economic profits are required to be considered as inseparable and contribute collectively to environmental and social benefits (Fiksel, 2003:5334). In addition, when comparing these difficulties to the implementation of sustainable development principles to the built environment, the useful effective life of a building or other asset in the past has been particularly difficult to forecast because of premature obsolescence (Conejos, 2012:97) due to infeasibility of one or more of the three pillars.

Considering this, it is stated that sustainable development is often interpreted as a goal to which we should collectively aspire. It is not an end-state that we can reach; rather it should be considered to be a characteristic of a dynamic, evolving system (Fiksel, 2003: 5330). For sustainable development to remain meaningful, it must act as an integrating concept, requiring tools that are integrative and synthetic, not disciplinary and analytic (Cole, 2012:43).

3.2.4. Striving towards industry-appropriate implementation

While the goals of sustainable development are agreed to be of importance, the generic nature of these goals inhibits an appropriate approach at the scale for which the sustainable intervention is intended. In this case, it is stated that appropriateness surpasses performance as a key to technological success. According to McCullough (2004:3), this is further understood through the fact that appropriateness is almost always a matter of context as ‘we understand our better contexts as places, and we understand our better design for places as architecture’. A product, therefore, cannot be sustainable in an absolute sense. Rather it must be considered in the context of the supply chain and the market (Fiksel, 2003:5330).This evolution of thought means that sustainable development is best achieved when specific understanding of what is required is linked to the context for which it is intended. While the basis for departure is agreed based on the previously discussed broader goals, versions of sustainability theory are thus required to be developed.

Within the industry of the built environment and architecture, Cole (2012:43) reiterates a concept brought forth by Gibberd in stating that it is inappropriate to consider buildings as being sustainable. A building is an element set within wider human endeavours and is necessarily dependent on this context. Thus, an individual building’s performance is more substantially understood by the contribution it makes to the social, ecological and economic health of the place it functions. This places the built environment in the category of approach of sustainable development that is not bounded by limits of growth or capacity, but rather in the context of a system and its potential contribution to continued human and ecological benefit.

Buildings are designed and then assembled through a rigorously controlled series of processes, yet we participate in social and ecological processes that are not at all designed. The requirement is thus to design policies and interventions that influence system behaviour and evolution (Fiksel, 2003:5334).To bridge current gaps, the next stages of development must incorporate a more integrated approach (Yang, 2005:xiv) which requires an understanding of the contextual contribution required. With the aim of an appropriate systems-design approach for sustainability, Fiksel (2003:5338) lists the following:

- Requirements will include system behaviours rather than just outcomes.
- Productive modelling will give way to exploratory scenario building.
- Design strategies will rely on intervention rather than control.
- Robustness will be achieved through resilience rather than resistance.
- Risk management will draw upon new concepts such as adaptability and diversity.
- System state indicators will be based on fundamental energy attributes.

‘The old Newtonian view of an orderly, machine-like world is giving way to a new view of a chaotic, evolving world. Designing systems that are inherently resilient will support our collective quest for sustainability in this ever-changing, unpredictable universe’ (Fiksel, 2003:5338). The increasingly seamless debate and investigation of scale and industry-specific performance issues and the development of tools to evaluate them has strengthened the need to understand buildings and their physical, social and ecological context as a nested system with intrinsic hierarchy (Cole, 2012: 42). Additionally it is stated that the design of future buildings with embedded adaptive re-use potential is a useful criterion for sustainability and self-regulation. Criteria can be weighted according to physical, economic, functional, technological, social, legal and political categories to calculate adaptive re-use (Conejos, 2012:95).

Cole furthermore states that in the pursuit of sustainable and regenerative design through consideration of the unique social, economic and ecological context, a fully matured global information system and culture may instigate and permit the creation of regionally and place-based practices that are central to the notion of ‘glocal’. ‘Glocal’ recognises the need for balance between the invisible forces and the actual sense of place and culture (Cole, 2012:48). It is here that the first indication of response and reliance is made to the information infrastructure of our time, and the importance of its consideration is observed. Yet, without upgrading of skills, a considerable number of practitioners are struggling with the new concepts and will be reluctant to change the way that they conduct their professional routines (Yang, 2005:xii).

The way forward will require a new philosophical and comprehensive approach, as opposed to existing technical approach to the phenomena of sustainability. A rationalised, structured and integrated approach should replace ad-hoc applications and impatient deployment of technologies aimed at immediate benefits and returns. Along the way, practitioners require a knowledge upgrade and stakeholders require communication. The public requires education (Yang, 2005: xvii). The stage is thus set through a recognised need for advanced approaches to sustainable design within the industry.

3.2.5. Summary and resolution of hypothesis

> ‘In sum, the TBL [triple bottom line] agenda as most would currently understand it is only the beginning. A much more comprehensive approach will be needed that involves a wide range of stakeholders and coordinates across many areas of governmental policy, including tax policy, technology policy, economic policy, development policy, labour policy, security policy, corporate reporting policy and so on. Developing this comprehensive approach to sustainable development and environmental protection will be a central governance challenge – and, even more critically, a market challenge – in the 21st century’ (Elkington, 2004:16).

The quotation above suggests that even by the account of its inventor, the triple bottom line theory is incomplete. It is a theory that has developed out of a reactionary process to respond to public pressures, and that these pressures are symptomatic of information and events pertinent to their time of emergence. In keeping with the societal pressures for an evolution of the concept of sustainable development for the current world in all its complexity, and with specific reference to the built environment, there is sufficient scope to assume that the model of sustainable development is primed to be further modified to cater to the evolved human-centric (information and knowledge) requirements of the 21st century.

Elkington (2004:4) refers to our current time in the third pressure wave as the ‘chrysalis economy’. This economy, in his opinion, will actively seek to embed a basis for sustainable development through an intense technological, economic, social and political metamorphosis. Furthermore, he refers to a need for the public sector to evolve in the same direction as the private sector, by embarking upon a typical corporate learning flywheel:

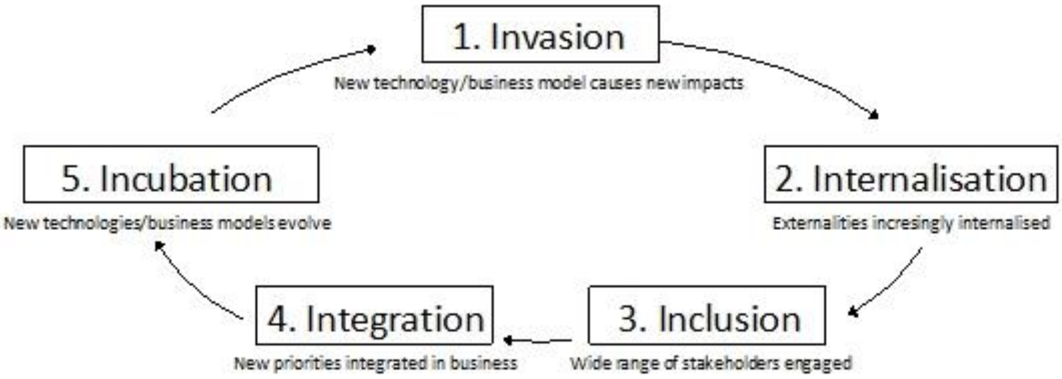


Figure 3.7: 'The Learning Flywheel' (Elkington, 2004: 4)

Although the model above is specifically developed for an economic context, it is no less applicable to other contexts, including the built environment, since it refers to a process followed by contemporary implementations seeking sustainable results. This is also particularly evident when considering the varying spatial and temporal scales of developed and developing contexts, since these developing contexts have the benefit of learning from the lessons of the developed while seeking to elevate their own people to greater heights of self-sufficiency and productivity.

Sustainable development has evolved in the 50 years since it was brought into our consciousness as a society, but so too has society and human need. To operate and enforce 50-year-old concepts of sustainability through minor iterations and adjustments is hindering the ability of practitioners in all fields, including the built environment, to achieve implementation that is truly future-proofed.

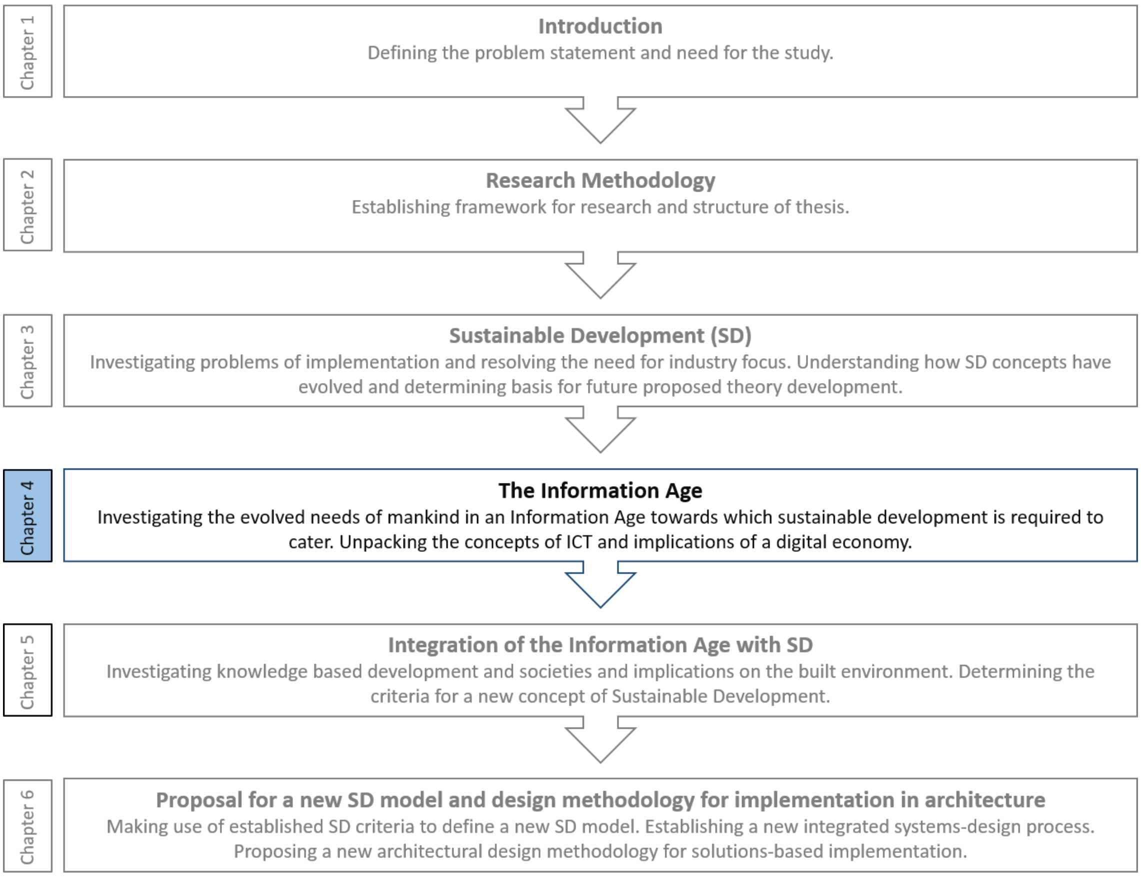
In the context of the built environment, implementation is afforded the benefit of tangible constraints. Range of influence, initial capital expenditure and cost of operation, intended beneficiaries and life span can all be moderately predicted and planned for. In the context of a developing country, this carries with it a greater responsibility since the range of social and cultural interoperability, educational background, operational proficiency and potential for rapid social and economic improvement place increased stress on infrastructure and the buildings themselves. The social dimension and stability therein is a matter more prevalent in developing contexts in order to promote equity and empowerment.

These tangible constraints offer great opportunity to conclusively determine if all factors are being considered in the pursuit of ensuring future efficient operations of any built-environment implementation. What is proposed, however, is that a range of renewed considerations must be present in the fabric of the architectural design for implementation and operation should future-proofing be a feasible objective:

- Increased efficiency
- Minimised expenditure
- Environment as enabler
- Adaptability
- Connectivity.

Sustainable development has been subject to reinvestigation and re-formulation of models of approach, confirming that it is a pliable concept and fit for purpose. The nature with which architectural process is required to address environmental and human need and do so with a view towards long-term responsibility, therefore requires an evolution of approach that removes the vagueness of previous sustainable development theory in favour of contextual focus and applicability (temporal and spatial scale), and an actionable design methodology. This therefore creates the basis for the re-evaluation of the concept at an appropriate scale of implementation for architecture and its end users.

4. Sustainable development in the Information Age



Introduction
Defining the problem statement and need for the study.

Research Methodology
Establishing framework for research and structure of thesis.

Sustainable Development (SD)
Investigating problems of implementation and resolving the need for industry focus. Understanding how SD concepts have evolved and determining basis for future proposed theory development.

The Information Age
Investigating the evolved needs of mankind in an Information Age towards which sustainable development is required to cater. Unpacking the concepts of ICT and implications of a digital economy.

Integration of the Information Age with SD
Investigating knowledge based development and societies and implications on the built environment. Determining the criteria for a new concept of Sustainable Development.

Proposal for a new SD model and design methodology for implementation in architecture
Making use of established SD criteria to define a new SD model. Establishing a new integrated systems-design process. Proposing a new architectural design methodology for solutions-based implementation.

4.1. Sub-problem Two:

Sub-problem: How have the needs of 21st century societies changed in the midst of the Information Age and how is this applicable for future sustainable development?

4.1.1. Introduction

In this chapter, the introduction and impact of ICT is investigated as the advent of a new era in human societal evolution. The term ‘Information Age’ will be unpacked, firstly establishing the criteria for defining a new *age*, how this concept has been attributed to ages of the past, and by understanding what the perceived impact of this age has on humanity and our built environments. Understanding the Information Age will furthermore be addressed by interrogating the importance of transferring, assimilating and interpreting information. The various forms of information will furthermore be defined, highlighting the various possibilities for application. The Information Age has been the subject of much discussion globally, and catalysts for its growth, e.g. computing, the invention of the internet, the establishment of global communications networks, will be addressed in explaining just how interwoven and pervasive the information revolution has become to everyday life.

The effect of the Information Age will be investigated for its role in defining societal and cultural change, namely in the establishment of knowledge societies. Previous discussion in this thesis shows that sustainable development is reliant on social and cultural factors, knowledge societies form a part of the essential fabric for which development of the future must be designed. The role of information in development, and in particular sustainable development, will be explored, from which the feasibility of a process based on commonality of goals will be determined.

ICT will be defined, illustrating practical and current examples of their implementation on macro and micro scales. The scale of implementation will vary between such concepts as the IoE (‘Internet of everything’), the IoT (‘Internet of things’), smart cities and intelligent buildings. With each scale of implementation the nature of information in its various forms will be explored.

Establishing the importance to architects is then explored, querying the impact that this digital information revolution has, and will yet have, on the profession, both in process and product. The new evolution of approach in architectural process, namely BIM, will be investigated to establish whether this process is aligned to allowing architects to attend to the complex nature of sustainable design in the Information Age, as well as what opportunities are made available through pervasive embedding of data into virtual design. In recognising that sustainable development has now evolved in meaning and definition, the researcher broadly investigates how architects are placed not only to service the digital era, but also to contribute.

4.1.2. The arrival of the Information Age

In the context of this thesis, the term ‘age’ is recognised by the researcher to refer to a distinct period of time within which human capability has been affected by technological development of a particular nature. This definition can be similarly compared to the term ‘revolution’, which also features in this chapter. It can be observed that numerous *Ages* of significance have predated our current society and shaped our evolution as a species, opening the door to advanced methods of living and operating. Historical societies are seen to have been a part of a three-part system, namely the Stone (ending between approximately 8900 BC and 2000 BC), Bronze (2900 BC), and Iron Ages (ranging between 1200 BC and 600 AD),[9] with each being particularly affected by technological advances in the areas as defined in their names. These various ages spanned human evolution and brought with them various advances in technological application for the materials and tools of the time. Advances in metallurgy, for example, brought with them increased capability for subsistence farming, warfare and exploration. With each age, an increase in humankind's operational effectiveness and efficiency, came an increase in capability for learning and innovation.

The Industrial Age (also referred to as the Industrial Revolution) began in the mid-18th century, where a new reliance on mechanisation for manufacturing and production arose, changing from manual methods to processes of mass production through machinery.[10] The life-blood of this machinery, over and above electricity, took the form of water and steam power and unleashed production capabilities that were previously impossible. By removing hard labour and the associated time constraints, humankind was freed to improve on technologies through research and experimentation and invest further time in increased innovation. The first Industrial Revolution came to an end approximately 100 years after it began, at which point it evolved into the second Industrial Revolution of 1840. This second revolution brought with it advances in travel and mechanisation in the form of steam-powered boats, railways and ships, as well as steam-powered factories and ever-increasing mechanisation.

While the first three 'ages' of humankind can be observed to have occurred over many thousands of years, human technological progress is increasing at an exponential rate. The Industrial Revolution brought with it the most significant advances in modern mechanised-assisted living, and within just a few hundred years we find ourselves firmly within the next revolution of human capability, the information and communication revolution.

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[9] 'THE STAGES AND AGES OF MAN ON EARTH', by Dodd, J. https://anthropology.knoji.com/the-stages-and-ages-of-man-on-earth/ [Viewed on 2016-06-06]

[10] 'INDUSTRIAL REVOLUTION'. http://www.history.com/topics/industrial-revolution [Viewed on 2016-06-08]

We exist in the midst of a new Post-Industrial Age, one that brings with it the benefits of advances in communication and availability of information for purposes of empowerment and growth. This age is demonstrative of the understanding that humankind now exists in a world of ever-increasing connectivity, often defined as the 'global village'. At the end of the second millennium a number of significant social, technological, economic and cultural transformations combined to give rise to a new form of society, the network society (Castells, 2010:1986). The shift from traditional mass media to a system of communication networks organised around the internet and wireless communication has introduced a multiplicity of communication possibilities and patterns at the source of a fundamental cultural transformation (Castells, 2010:1986). For the purposes of the thesis, this age will here be referred to under the popularised term of the 'Information Age'.

4.1.2.1. Understanding of the term: The Information Age

The Information Age encompasses the economic, social and cultural changes brought about by access to information through transformed communications technologies and processes. In most global societies more people are employed collecting, handling, and distributing information than in any other occupation and while networks are an antiquated form of organisation, digital networking technologies – characteristic of this Information Age – powered social and organisational networks to foster limitless expansion and adaptability (Castells, 2010:1969).

Keohane and Nye (1998:83) describe the early days of the information revolution, stating that this has seen the drastic reduction in cost of communicating over distance, resulting in an almost negligible transmission cost and an effectively infinite amount of information that can be transmitted. In keeping with expectations as derived from Moore's Law,[11] computing power is observed to have doubled every 18 months for the last 30 years, costing less than one percent of what it did in the 1970s. Internet traffic doubles every 100 days as communication bandwidths expand and communication costs continue to fall. In 1980 copper wire phone lines could transmit one page of information per second, while today a thin strand of optical fibre can transmit over 90 000 volumes in the same time.

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[11] Moore's Law is a computing term which originated around 1970; the simplified version of this law states that processor speeds, or overall processing power for computers will double every two years. Source: http://www.mooreslaw.org/ [Viewed on 09 May, 2016].

Since the emergence of various platforms for information sharing, it has become increasingly difficult for central governments to restrict or control the flow of information to the individual. In the current evolving technological environment, the increasing complexity of the sector continues to alter the conditions of governance – defined as the making of decisions that affect others in important ways, and includes government, corporate systems, international organisations, and NGOs (Samuels, 2002:156), with an apparent trend for easier implementation of policy instruments prevalent at the micro level (Bauer, 2004:22). The 2003 World Summit on the Information Society expressed hope that effective governance structures could assist in harnessing the benefits of digital information availability, while ‘cyber libertarians’ have maintained for many years that these advanced information networks should not be subject to any form of governmental oversight (Bauer, 2004:3). This is the mark of a cultural revolution that is fuelled by open access to information and communication, freedom of speech and (largely) unrestricted knowledge exchange. Evolving economic, political and technological factors have transformed information network infrastructures over the past three decades from a relatively closed to more open system (Bauer, 2004:3). From a systems perspective, however, it has been observed that Information Age technologies do not move in a predictable state of equilibrium, therefore hampering the effective implementation of traditional regulatory theory (Bauer, 2002:22).

The opportunities and benefits of the information revolution are not easily overstated. As the global population (consumers) are observed to have become digital producers in certain contexts, to ensure that the information revolution is fully embraced and taken advantage of requires collaboration and participation by citizens in the digital economy (Atkinson, 2007:6). The ability to participate will be discussed in more detail in Chapter 5 of this thesis where criteria for compliance in the information-based societies today are investigated. These criteria range from matters of contextual limitations extending to policy, literacy, infrastructure, economy and available technologies, to name a few.

To expand on the concept of the ‘digital economy’, this represents more than just an economy conducted on the internet, but instead is defined in the pervasive use of ICT in all aspects of the economy, including organisational and inter-organisational operations and transactions. ICT serves as the enabler of the digital economy and the Information Age, providing the means to create, manipulate, organise, transmit, store and act on information in new ways (Atkinson, 2007:7).

In an opinion piece titled ‘Managing the fears that define the Information Age’, May (2011:14) describes a parallel between the fears of the Malthusian-styled ‘limits to growth’ and the trepidations associated to the evolving digital landscape. As has been widely stated that the population of this planet is rapidly exceeding the capacity of the Earth to support it, so too a fear exists in the ‘big data’ ecosystem that the volume of information that must be known is growing faster than an organisation’s capacity to know. ‘Failure to embrace new technologies and new information management practices is predicted to doom us to a form of cognitive starvation’ (May, 2011:14).

It is the opinion of the researcher that the Information Age requires comprehensive stakeholder participation in order to maximise the potential offered to the global population. As has been commented on in Chapter 3 pertaining to the concept of sustainable development, general concepts of a broad nature are easily acknowledged, but implemented with far greater difficulty. In the case of the Information Age, it becomes necessary to understand the parts of the whole in order to focus understanding and strategy. As with the pillars of sustainable development, the Information Age is given form by a number of key contributors. These contributors are summarised as, but not limited to the digital economy, knowledge-based societies and ICTs. The latter two contributors will be discussed in further detail in the next section. In identifying and understanding the building blocks of the Information Age, greater focus may be placed on specific implementation and therefore narrowing the scope of ‘big data’ and the volume of information associated with it.

4.1.3. Unpacking the concepts of information and communication

In previous ages of humankind, production and automation carried with it industry-based economic opportunity. Material and product trade and transport held with them the means to empower and enrich, offering new avenues of production and operational efficiency. Yet the world of material trade is now evolving into a world whereby the importance and value of the ‘physical’ is being transcended by the ‘abstract’ and ‘intangible’. In his book, *The coming of the post-industrial society*, Daniel Bell (1974) posits that we now live in an age in which information has succeeded raw material and energy as the primary commodity of value (Bradfield, 1983:v). Information is the foundation upon which service delivery is based, and it can be seen that large components of our economies are dominated not just by trade of goods, but by trade of services.

In his book *Disconnected: Haves and have-nots in the Information Age*, Wresch identifies five basic types of information (Wresch, 1996:8): public media, personal, organisational, professional and commercial. Each form is subject to various challenges with regard to transmission and reception. These challenges range from governmental interference with the public media, to the user's level of education and access to means of communication when relying on personal information. Organisational information is restricted by the willingness of an organisation to release information of its own accord. Professional data, while increasing at an exponential rate, is not always adequately inclusive of global research, while commercial information is available to those who are in a position to pay for it (Gregory, 1997:56). Within these types, the forms of information vary widely, from contextual and briefing data, to legislation, standards and product information, to name a few. In addition to this, changing techniques for implementation can bring with them an increased emphasis on technical data, depending on the industry (Bradfield, 1983:2). These challenges and limitations therefore bring with them a realisation: information itself is of no use without the capacity to communicate, organise and present it (Bradfield, 1983:1). The quantity of information in cyberspace has little meaning on its own, whereas the quality of information and distinctions between the types of information are more important. Information does not just exist it is created (Keohane, 1998:84).

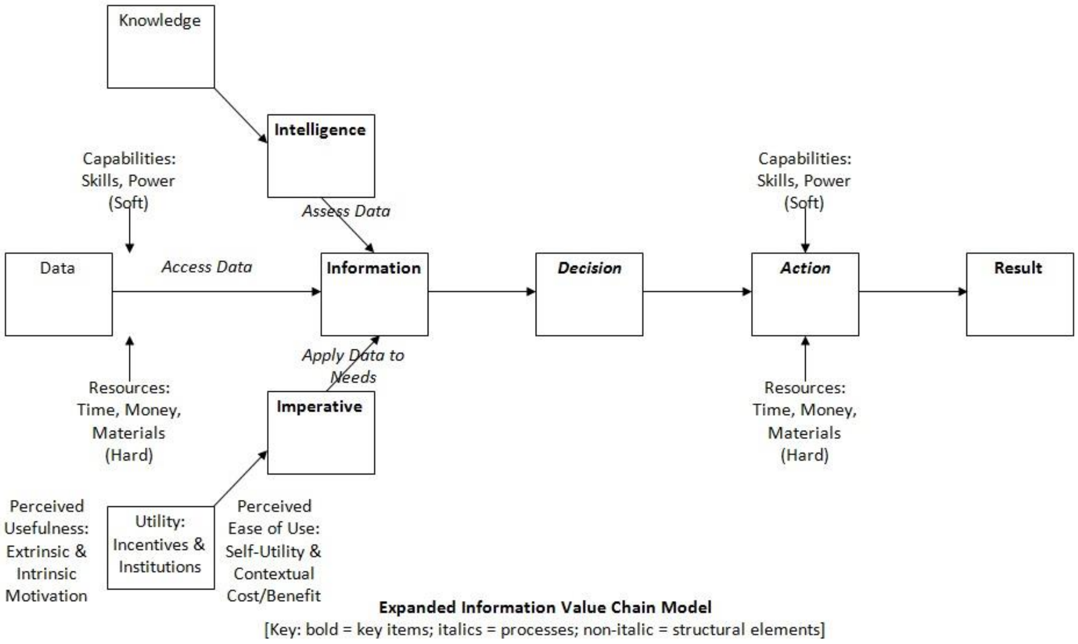

Figure 4.1: Information Value Chain Model
Source: https://ict4dblog.wordpress.com/author/richardheeks/ [Viewed 10 January 2015]

Figure 4.1, representing the information value chain, reinforces this concept that data *per se* is worthless. Value can only be derived once data is given scope and resources, thereby altering its form to that of *information*. This, in turn, is used in enabling decision making that is ultimately implemented as action (development). In order for this value chain to succeed, the process requires on-the-ground intelligence to process the data into information; the human urge to motivate the process's completion; and the soft capabilities and hard resources to access the data and take action (Heeks, 2014).

Information and knowledge are tools of high value in the present age (Lennon, 1999:285). In exploring the value of information, it is important to ascertain to whom this value is attributed. 'Informational value' is important as a concept as long as there is party for whom this information is important. Stakeholders in the information value are therefore required to be identified at the onset. These can range from individuals to collectives, but all are observed to reside within a network through which information transfer is possible. In their paper interrogating network communities and the network structure of communication, Zubcsek et al. (2014:53) posit that the intensity of communication between individuals within information communities is greater than when compared to other areas of the communication network.

In determining the manners with which information may serve as a form of currency, Lennon (1999:286) identifies a hypothesis, namely: What are the common characteristics of money and information? In answering this, Lennon states that information can be traded, information is a store of value, and information can be invested in order to create more value. The importance of this is the understanding that information contains intrinsic value that is linked to real-world economic advantages, making information an irrevocable feature of the future economy.

By providing 'information value' a context of community within which to operate and exist, the concept of value transcends that of information as 'social capital'. Social capital refers to informational resources embedded within a social structure which are accessed or implemented in 'purposive action' while characterised by relational, structural, and cognitive components (Zubcsek et al., 2014:57). The term 'social capital', as introduced by Coleman, defines three categories: obligations and expectations; the information-flow capability of social structure; and emergent group norms (1988:95). In his paper, Coleman recognises that the application and interrogation of social capital is most suitably achieved when evaluating its impact on the two intellectual streams of sociology and economy.

The sociological stream recognises that the 'actor', while shaped by the environment, is still required to generate some form of impetus to generate purpose of action. The economic stream recognises that an individual's actions are shaped, directed and constrained by the social context. It is furthermore stated that norms, interpersonal trust, social networks and social organisation are important contributors to the overall function of society as well as the economy (Coleman, 1988:96). Social capital additionally plays an important role in defining the concept of environment, particularly in the sociological stream, by abandoning the traditional views of locally-rooted communities and instead focusing on the structure of primary links between individuals. The environment is therefore embodied in the network structure – active community ties – between individuals and not solely in physical proximity or social similarity (Zubcsek et al., 2012:58). Identifying information communities also allows for identification of regions of the social network where information exchange is more likely and the attention that knowledge receivers give to this information (Zubcsek et al., 2012:63).

Information forms an important part of knowledge development; however the transfer of this information requires a conduit through which to pass. This conduit for information is communication.

> 'The communication realm is the social sphere where values and interests of conflicting actors are engaged in struggle and debate to reproduce social order, to subvert it, or to accommodate new forms resulting from the interaction between the old and the new …' (Castells, 2013:xxii).

Any person acting communicatively does so by raising claims of validity with the aim of being ratified or vindicated by the recipient. This participatory process known as communication is aimed towards achieving understanding between two or more persons (Habermas, 2015:2). In communication theory, the issue of capacity is addressed by stating that communication limits the quantity of information which can be transmitted through a given channel at any given moment in time (Broadbent, 2013:5). The aim of communication is thus to provide clarity and focus to information, delivering only that which is deemed pertinent to the intended message, deliberation, hypothesis or problem. Castells (2013:xviii) states that the foundation of institutions that are responsible for organising society are mental constructs as a result of communication processes, comprising interpersonal communication or mediated communication. Mediated communication constitutes the symbolic environment in which people receive, process and project information that has specific meaning to them. Mediated communication, however, is dependent on the culture, organisation and technology of specific communication systems.

The term ‘mass communication’ refers to the extended circulation of symbolic form and information through linguistic and qualitative expression (Thompson 2013:1). Mass communication furthermore refers to the establishment of institutions for cultural transmission, oriented towards broad-based production and diffusion of commodified symbolic forms (Thomson, 2013:16). However, the Information Age has had a profound effect on communication, causing a shift of mass communication to mass self-communication. Mass self-communication, according to Castells (2013:xviii), is the process of interactive communication that can potentially reach a mass audience in which production of the message is self-generated, the retrieval of the message is self-directed, and the reception and interpretation are self-selected. This pattern in the digital age, facilitated by the internet and mobile communications devices, has given rise to new social structures known as network societies. It is through communication processes that humankind interacts with its natural and social environments, and mediates the way in which power relationships are formed in the domain of social and political practice. This process of power relationships has subsequently been transformed in the organisational and technological context created by global digital networks (Castells, 2013:4). Mass communication is supported in three identifiable degrees of media (Jensen, 2013:4):

- The first degree: intended to articulate an understanding of reality for a particular purpose and with intent to engage with others. This is represented in the form of verbal language and speech.
- The second degree: technically produced forms of representation and interaction which support communication over space and time. This is represented, for example, in the form of the written word, and broadcast messaging through radio and television.
- The third degree: digitally processed forms of representation an interaction, reproduced and recombined in a single platform. An example of this is the networked personal computer.

In addition to the above-listed degrees of media, Jensen (2013:8) furthermore states that communication is also represented in various social levels which involve various stages, agents and forms of feedback. These, in turn, offer humanistic and social-scientific approaches across these levels. Figure 4.2 represents the different social levels of communication, as proposed by Jensen (2013), indicating that while mass-mediated communication is representative of one type, other types of communication may be more appropriate to different scales or evolving structures of society.

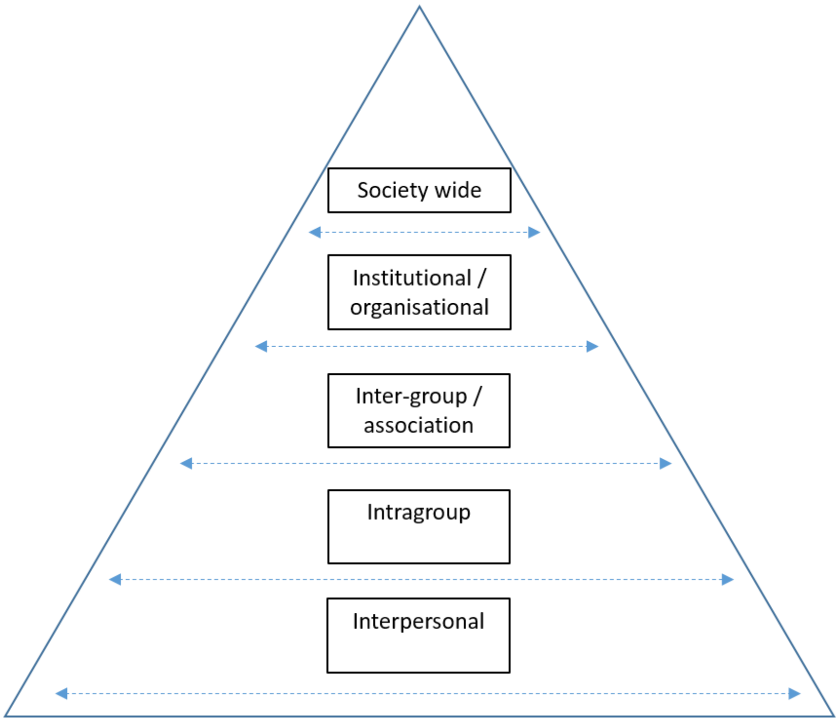

Figure 4.2: **The levels of communication (Jensen, 2013:9)**

Information and communication therefore represent the accumulation of a wealth of data and the ability to limit, filter and selectively apply this data to be actionable and facilitate decision making. It is for this reason that the concept of IT has been expanded to include communication. ICT is representative of the means of deriving meaning in a digital age comprising mass information and communication. ICT provides focus in the Information Age which in turn empowers its users to derive maximum benefit pursuant to knowledge generation and acquisition.

4.1.4. Understanding ICT

According to the Information Technology Association of America, Information Technology refers to the ‘the study, design, development, implementation, support or management of computer-based information systems, particularly software applications and computer hardware’ (Dyson et al*.*, 2000:1).

ICT, which later saw evolution of the concept of IT to include ‘communication’ within its structure, is concerned with access to information and facilitation of knowledge transfer, and for this reason the human element cannot be excluded from the broad definition. ICT represents more than computers and the internet, as was understood when the digital divide and issues of internet governance were much of the focus since the first World Summit of the Information Society (WSIS) in 1993. The WSIS declaration states that this summit was committed to building a

> 'people-centred, inclusive and development-oriented information society, where everyone can create, access, utilise and share information and knowledge, enabling individuals, communities and peoples to achieve their full potential in promoting their sustainable development and improving their quality of life, premised on the purposes and principles of the Charter of the United Nations and respecting fully and upholding the Universal Declaration of Human Rights' (WSIS, 2003:1).

Applications of ICT are divided into two broad categories. The first category refers to those ICTs that are dependent on traditional telecommunications networks that enable on-demand communications to provide information tailored to the user's convenience and needs. How the information is processed and whether it is transformed into knowledge is left to the human user who asked for the knowledge in the first place. The second group of ICT applications can be termed 'human dependent', where information is processed and decisions are arrived at based on pre-set criteria without human intervention at the time of decision making. These can be nearly passive systems, or embedded as a part of a larger system. A major challenge is how to design both ICT and other complex systems (engineering or societal) where the two categories can be integrated (Tongia, 2004:19).

The application of ICTs as a means for development offers opportunities to reduce existing disparities in income distribution and quality of life in both a social and economic context, These innovations of systems and products are contributing to knowledge-based development, improving social, economic and environmental conditions in developing countries (Mansell, 1998:3) and generating new social and technological capabilities such as beneficial ways of learning, governing, conducting business and occupying leisure time. Social capabilities complement technological capabilities and they combine in many different ways to generate economic growth (Mansell, 1998:10). This contributes to improving quality of life for citizens with special emphasis on health, special needs – enabling technology to provide location-based targeted information to the elderly and unemployed (Hine, 2000:1760) – education and environment, and access to public information (Mansell, 1998:82). A global information infrastructure is taking shape, and ICTs are becoming more and more pervasive

(Mansell, 1998:3) by seamlessly blending into humankind's daily routines and operations. It can thus be seen that ICTs fill the gap between the three pillars of influence – the requirement for provision of resilient systems capable of sustainable implementation. It is not possible to evaluate the suitability of ICT in design without equally considering the accepted three pillars of sustainable development.

In their study, *Digital prosperity*, produced for the Information Technology and Innovation Foundation (ITIF), Atkinson et al. state that in the new global economy ICT is the major driver, not just for improved quality of life, but also of economic growth (2007:3). Atkinson et al. furthermore outline a global economy whereby IT is a driver not only of quality of life, but also of economic growth. The integration of ICT into all aspects of society and the economy is observed to serve as a catalyst for the majority of today's economic growth and prosperity (Atkinson et al., 2007:3). ICT is furthermore recognised for its contribution to the global economy by:

- Contributing indirectly to boosting growth by facilitating the emergence of more globalised markets (2007:29);
- Increasing the capacity of organisations to make faster and better-informed decisions (2007:30), assisting in market stability through greater financial innovation and improved inventory management (2007:33);
- Assisting market efficiency through expansion of consumer information and assisting with making better purchasing decisions (2007:41);
- Boosting economic output and people-based productivity (2007:35);
- Enabling greater participation and productivity for persons with disabilities (2007:36);
- Introducing new market signals and boosting goods and services allocations in production (2007:39);
- Enabling higher quality products and services (2007:43) through advanced quality monitoring and capabilities for mass customisation; and
- Driving innovation (2007:47) by expanding research and development capabilities, including the end user in a greater capacity, and boosting organisational transformation.

As a mechanism through which ICT is pervading global business, increasing numbers of businesses are investing in the development and management of online resources directed to consumers, influenced by the World Wide Web, which is perhaps the most rapidly developing new medium in history, proving also to be the most democratic medium through the ability to use and host content at relatively low cost.[12] The capacity to not only provide information to website visitors but also to immediately exchange information with visitors on an individual basis is a communication approach unique to the Information Age. The World Wide Web is unique in its role simultaneously as a mass medium and interpersonal communication (Eighmey, 1998:187).

> ‘You can see the computer age everywhere but in the productivity statistics’ Robert Solow, *New York Book Review*. July 12, 1987.

While the relationship between ICT and economic achievement has been explored extensively, the above quote from Robert Solow is reference to his famous ‘productivity paradox’ (also known as the Solow computer productivity paradox) which argues that the exact dimension of the impact of ICT in economic growth and productivity remain contentious (Myro et al., 2009:2). Solow states that it can be observed that investments in ICT and supporting infrastructure can, in some instances, be seen to cause a decline in productivity when comparing economic output to investment (MacDonald, 2000:601). In their paper, MacDonald et al. observed that the productivity paradox progressed in the past five decades through five stages (2000:603):

1. Early adoption of IT in the 1970s represented a broad notion that IT would displace labour, resulting in an assumption that labour productivity was the unit of measurement in establishing the impact of IT.
2. The late 1970s produced the first real observations that IT investment was yielding lower than expected results. This did not dissuade many global companies from making large investments in IT, with only a limited percentage attempting to validate expenditure through return on investment calculations.
3. The early 1980s was marked by a realisation that is was a mistake to exclusively use IT in terms of productivity. Instead, some companies began to think of IT in radically new terms, and employ it in strategic use applications, yielding a significant competitive advantage.
4. The late 1980s gave rise to IT investments migration towards management information systems (MIS), which could be understood as surveillance and

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[12] ‘INTERNET GROWTH STATISTICS: Today's road to e-Commerce and Global Trade’, Internet Technology Reports. http://www.internetworldstats.com/emarketing.htm [Viewed 09 May 2016].

control systems. It was at this time that the productivity paradox emerged, since IT was no longer expected to be directly 'productive'.

5. Following this period, it could be seen that the majority of investment in IT was within telecommunications. This new advent of investment further reduced expectations of productivity increases.

In concluding the assertions of the paper, MacDonald states that the emphasis has long been on using IT for efficiency in order to achieve competitiveness and that it may be time to redirect this emphasis to flexibility, to gaining competitiveness through the ability to change, and to innovate (2000:612). In referring to the paradox, MacDonald furthermore states that its existence has value as an enduring reminder that the impact of IT is inherently complex and subtle. Concern with measuring or managing IT is therefore misplaced in neglecting those characteristics (2000:613).

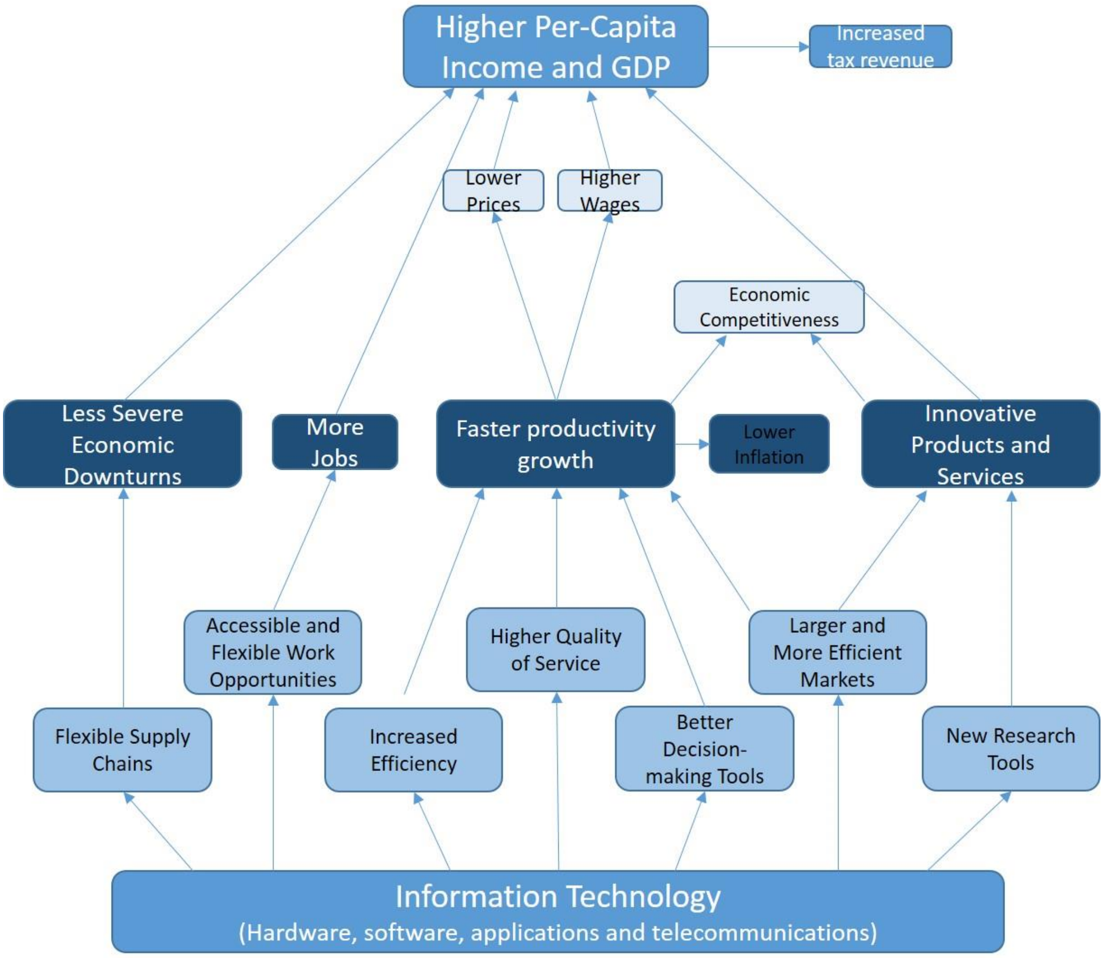


Figure 4.3: The path from information technology to prosperity (Atkinson, 2007:4)

In some contrast to MacDonald, investment in ICT hardware and software is later observed by Atkinson et al. to be a powerful driver of economic growth, with an impact on productivity up to five times that of non-ICT capital, with observable influence in the building sector as an example. For most industries and organisations ICT has become the principal tool relied on to increase productivity and innovation (2007:3). The effects of ICT on productivity, and as such on the economic prosperity of an initiative or activity, is observed in two forms: capital deepening, and total factor productivity (TFP). Capital deepening refers to the concept that greater productivity is generated through increased capital reward for workers, while TFP refers to increases in productivity where the same amount of capital is used more effectively (Atkinson, 2007:20). In establishing the reasons for ICTs' observable impact on greater TFP, Atkinson et al. refer to three indicators (2007:20). Firstly, ICT enables capital equipment innovations (such as advanced mechanisation and automation) to improve efficiencies and productivity. Secondly, ICT proves that it not only provides the means to automate tasks, but provides widespread complementary effects by allowing companies and individuals the means to re-engineer processes. The result of this is that a re-organisation is often required in order to make changes to service output and processes to leverage possible benefits to new ICT integration. The technology alone cannot produce productivity and efficiency gains. Thirdly, ICT provides what is termed 'network externality', which refers to the establishment of a larger communications network and therefore a greater basis for knowledge exchange and communication (Atkinson, 2007:21).

4.1.5. Knowledge societies and information cities

In an era of globalisation and competition, governments, organisations and individuals are turning to knowledge as a strategic asset to drive economic advantage. The value of knowledge is enhanced when it is created, shared and re-used within a critical mass of society that has the capacity and ability to understand and apply it. The knowledge society is furthermore an integral feature of the knowledge-based economy, comprising a community of people. (Sharma et al., 2012:24). A knowledge society is different from an information society since information may be structured or shaped in its consumption by society. However, knowledge is transformed by the active participation of those people who comprise the society (Sharma et al., 2012:25).

Knowledge is acquired in two forms: primary experience whereby we know the subject for ourselves, and through secondary experience whereby we know where to locate the information pertaining to the subject (Bradfield, 1983:v). Knowledge may subsequently be defined as information acquired through learning, while experience as information acquired by applying knowledge in practice (Bradfield, 1983:3). A new challenge has emerged, however, as we presently find ourselves in an age of excess of information and sources of information (Bradfield, 1983:v). This is as a result of computers having increased the opportunities of information availability, not only by serving the role of information stores and providers, but also providing a platform for manipulation of data so as to synthesise new information depending on the criteria for investigation (Bradfield, 1983:vi). Knowledge is constantly being updated and augmented and its correct ownership and utilisation enables the user to formally recognise any need for additional knowledge and more precise information (Bradfield, 1983:3).

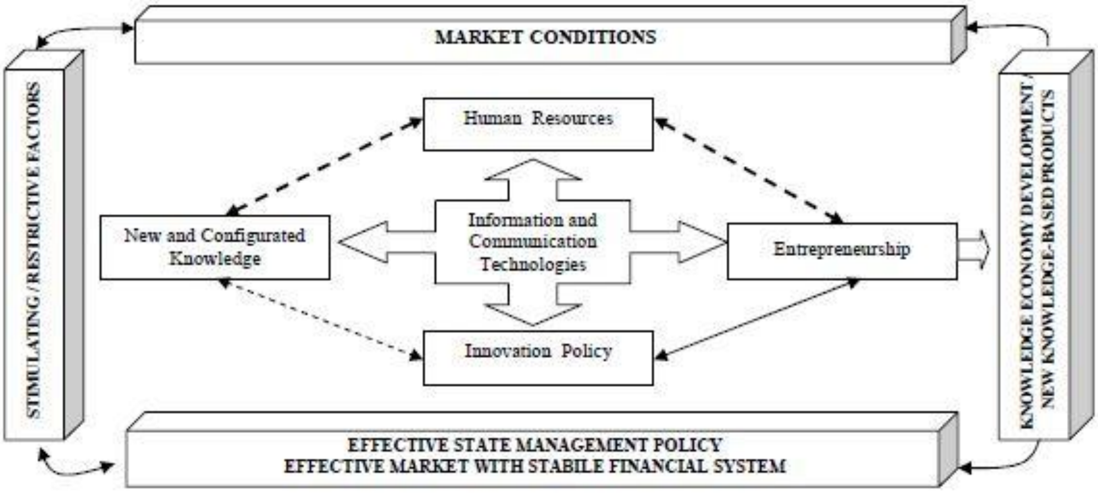


Figure 4.4: The structure of Knowledge-based Economy Expression (Kriscrunas, et al., 2015:37)

Individuals, companies and communities are now linked through worldwide systems of communication, transportation and commerce. Access to information has thus resulted in the formation of a new paradigm of society known as the ‘knowledge-based society’ (Mansell, 1998:1). Knowledge societies, which it is possible to define as an ‘era’ of human development (Stock, 2011:965), are network-based societies which have been empowered in the Information Age by becoming information networks powered by information technologies (Stock, 2011:964).

Stock (2011:965) furthermore refers to ‘knowledge societies’ as societies:

- in which innovations are carried by resource information;
- in which digital information and networks play important roles;
- in which information contents of any nature are available at any place and at any time for the purposes of being accessible and taken advantage of; and
- in which lifelong learning is necessary.

The 2005 WSIS defined four dimensions of knowledge societies: freedom of expression and information, universal access to information and knowledge, quality education for all, and respect for cultural diversity (Mansell and Tremblay, 2013:1). Knowledge societies are therefore concerned with human development, not only on technological innovation. In a report prepared for UNESCO's 2013 WSIS (Mansell and Tremblay, 2013:1), the goal of knowledge societies is outlined as fostering peace and sustainable development. Knowledge and universal access to information is a basic requirement in the creation of knowledge societies. Knowledge, as a concept, furthermore implies meaning, appropriation and participation. It is a means to achieve social and economic goals while remaining essential to cultural socialisation, political participation and integration. The full potential of digital networks and information applications can therefore only be realised if a balance exists between private and public interest in knowledge.

In a review of Hert's 1997 book *Understanding information retrieval interactions: Theoretical and practical implications*, Myburg states that human interaction is mediated by an individual's particular state of knowledge (1999:1257). However, according to Hert, information retrieval and seeking is a part of a larger process, and for this reason it is impossible to specify principles of systems design without specifying context (Myburg, 1999:1257).

Informational cities are the prototype cities of the knowledge society, consisting of creative clusters and spaces for personal contact for sharing of implicit information (Stock: 2011:963). Urbanised developments and cities offer a unique space for interaction of knowledge-intensive activities that contribute to making economies more resilient to external change as well as a means to accelerate social progress and human development (Carillo et al., 2014:xv). Carillo (2015:2) states that knowledge-intensive areas, such as technological districts, university campuses, innovation hubs or science parks catalyse urban and national competitiveness. Yet knowledge-based development has a wider meaning than intensity of cutting-edge ICT. It is also represented by the ability to integrate and encompass the various dimensions of urban knowledge, such as peer-to peer and social sharing, and collaborative consumption. The role of ICT is also not to be understated as it contributes to big data analysis and, in the case of our urban environments, extensive grid management. The dominant infrastructure in information cities and the knowledge society is therefore supportive of space and flow, representative of ICT, as well as representing cognitive infrastructure and explicit knowledge (Stock, 2011:963).

Knowledge-based development is represented in three forms, namely (Carillo, 2015:3):

1. Object-centred approaches: focusing on object attributes such as media, data and knowledge;
2. Agent attribute approach: concerned with structure, roles, hierarchy and competencies; and
3. Knowledge context: providing cultural significance and economic relevance, focusing on meaning and value, taking into account the tangible (physical) or intangible (intellectual capital) value.

Therefore in addressing context and the urban environment, specifically the embodiment of knowledge societies through informational cities, Fiksel argues that design teams of today must additionally consider a broad range of system-level issues, including safety, security, manufacturability, serviceability, material and energy efficiency, end of life recovery, environmental emissions and long-term impacts upon quality of life for future generations (2003:5330). To attempt to achieve this is to understand the realm of intervention through which this systems approach is possible.

The concept of knowledge-based development and its influence on the formulation of our urban context will be further explored in section 4.2.4, while knowledge creation, transfer and management will be addressed in Chapter 6 section 6.1.4 as a function of integration within architectural process.

4.1.6. The digital divide

ICTs are at the heart of recent social and economic transformations in both industrialised and developing countries. There have recently been many initiatives at the highest levels of government and industry to promote the construction of global information infrastructures so that they can participate in knowledge-based development and experience the predicted social and economic benefits (Mansell, 1998:1). As has been shown previously, it is widely understood that the diffusion of technologies is extremely uneven throughout the world. This brings with it a very high risk that these technologies and services will deepen the disadvantages of those without the skills and capabilities to make investments required for building innovative knowledge-based societies (Mansell, 1998:1).

The digital economy and the Information Age present new opportunities and challenges to the design and commercialisation of new systems. One such challenge is the characterisation that we live in a divided world: between rich and poor, healthy and sick, literate and ignorant, between empowered and deprived. A new label of our time which threatens sustainable development is the 'digital divide' which describes the development of countries and groups within countries in terms of their 'capacity to harness the power of Information and Communications Technology' (Tongia, 2004:15).

Norris (2001:3) provides scope to the discourse by referring to three distinct aspects that comprise the multidimensional phenomenon of the digital divide. Firstly, the *global divide* refers to the divergence of the internet access between industrialised and developing countries. Secondly, the *social divide* refers to the distance between the information rich and the information poor in each country. Thirdly, the *democratic divide*, which affects the online community, identifies users of the available digital resources as being able to engage, mobilise and participate in public life. The digital divide, thus defined as the gap between those who have access to ICT and are able to participate in network and knowledge societies, and those who do not, has been an issue on the scholarly and political agenda since the end of the 1990s (van Dijk, 2006:221). It is argued by Selwyn that, while ICT has the ability to empower, increase levels of social interaction and civic involvement, as well as increase access to widespread education and information, should individuals or groups be inhibited from the use of ICT they will be deprived of these benefits (2004:342). The digital divide is not static, nor is it impossible to bridge. However, the inequality symptomatic of the digital divide is not limited to the technological, but is also inclusive of immaterial (freedom, life chances), material (capital, resources), social and educational factors (van Dijk, 2006:223).

The digital divide continues to be an important factor for consideration both in social awareness as well as in government policy, with many nations declaring 'universal access' as a necessary prerequisite towards equitable living. Counties such as the UK, France and the US have, since the 1990s, introduced various forms of socially inclusive agendas and policies (Selwyn, 2004:343). However, the digital divide is not simply defined as a dichotomy between the 'haves' and 'have-nots'. As stated by Selwyn, a more sophisticated dialogue concerning the digital divide is required, addressing it rather as a hierarchy of access to various forms of technology in various contexts (2004:351).

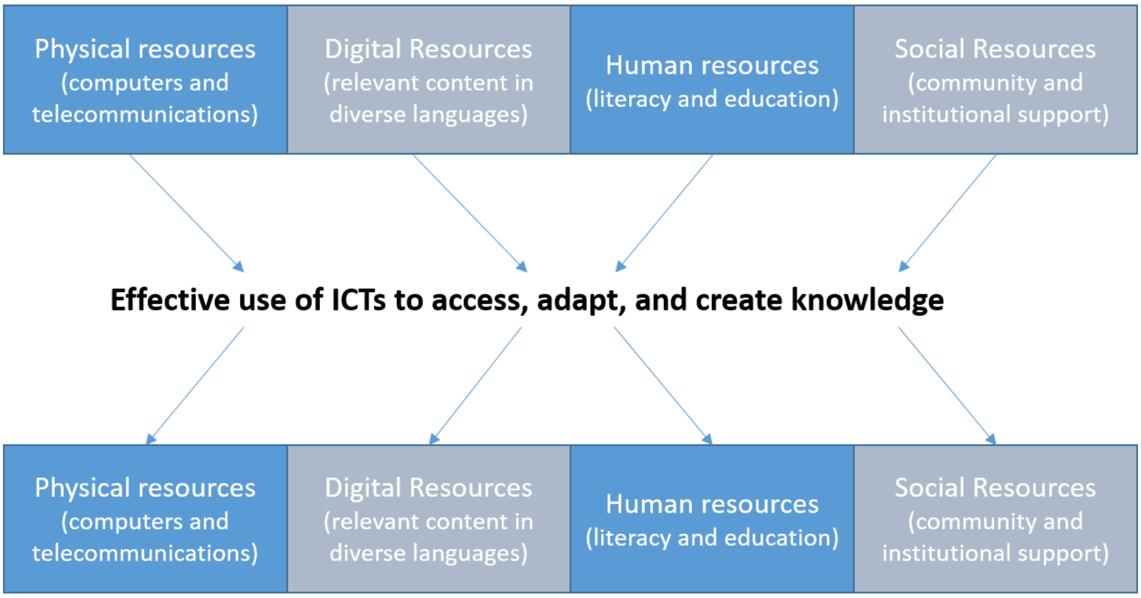


Figure 4.5: Effective use of ICTs (Warschauer, 2002:2)

The issues of the digital divide are therefore not exclusively technological but instead related to social, political, economic and cultural issues. The digital divide is not a feature of technology, but a function of technological capital. This is defined as the fundamental differences in the cultural, economic and social resources available to communities and individuals when engaging with technology (Selwyn, 2004:355). This argument is similarly addressed by Warschauer (2002:2) in stating that the digital divide framework provides a poor roadmap for utilisation of technology to promote social development since it overemphasises the importance of computers and connectivity to the exclusion of these other resources. Furthermore, ICT is not available as an external variable that can be simply introduced (proactively or retroactively) from the periphery to bring about better results. It is instead required to be integrated inclusively in a complex manner within social systems and processes. While the digital divide is a problem born of the digital age, it requires more than a technological solution. The problem is a symptom of knowledge inequality and as such, is benefited by a holistic approach towards sustainable development.

4.1.7. Exploring the applications of ICT

The researcher recognises that identifying all possible examples of ICT integration in the Information Age would be of interest to this investigation; however, as stated by Atkinson et al., the role and continued evolution of ICT in the Information Age is so expansive – based on a digital economy – that to attempt to catalogue even a fraction of the new applications for ICT today in its wide array of application areas and sectors would be a monumental task (2007:6). As observed by Fellenz and Brady (2007:29), the questions of which ICT is deployed in practice, as well as when, where and to whom are not generally considered from the perspective of the affected stakeholders. This results in 'uni-dimensional' answers to these questions that ultimately limit the value of the ICT deployment.

As stated by Wright et al. (2004:2), technology is not just used or appreciated by humankind, but it is something we live with. It is deeply embedded in our everyday experience. For these reasons, a select range of examples of ICT integration and pervasion will also be discussed in this chapter with specific reference to current initiatives and applications in the built environment. These applications are summarised into the following categories:

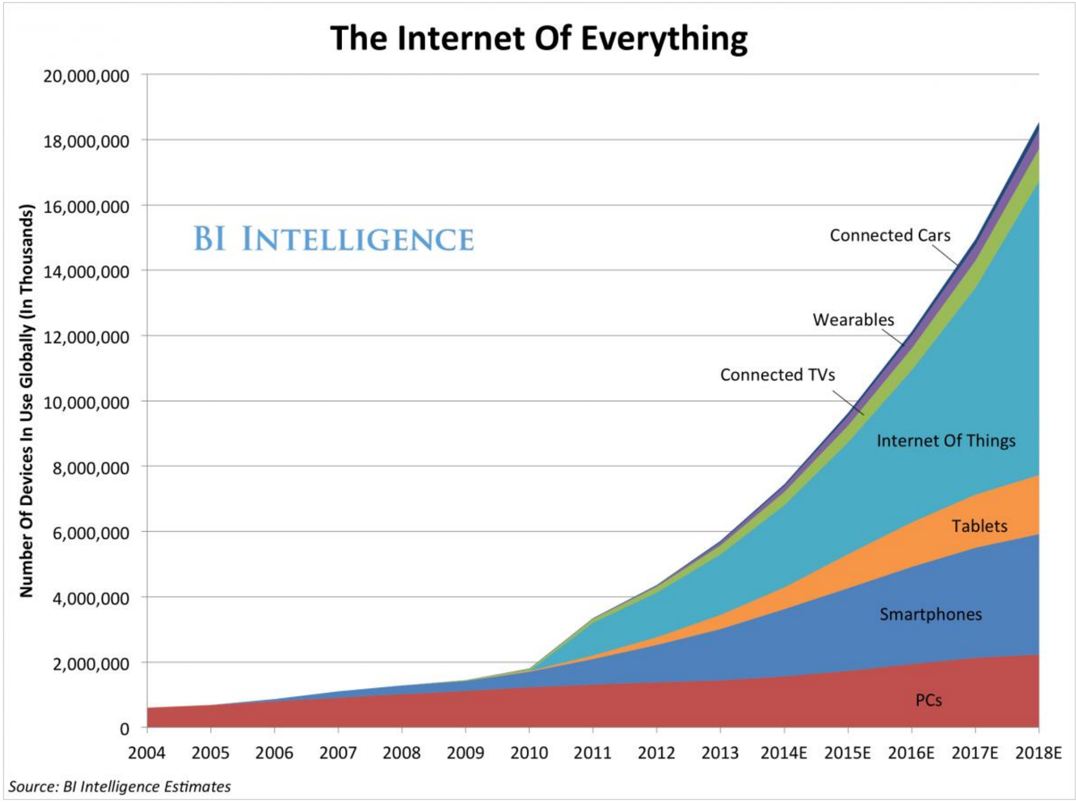
- the IoE
- social networks
- ubiquitous and pervasive computing
- smart cities and intelligent buildings
- BIM.

In understanding these categories, it will become possible to discern a reality whereby our lives are now completely immersed in a digitised information landscape whereby things, people and processes are completely intertwined through constant and, in some cases mandatory, access to the internet and digital databases. Through this immersion, our patterns of behaviour and preferences are mapped and catalogued, providing us with passively-presented (not derived by intentional search) and customised online experiences from which we establish social connection and derive important information and news. As our experiences mould to our digital profile, so too do our physical environments and the products we use. So hidden from view is this process that it continues to compute and predict our needs in the background, ubiquitously catering to our individual circumstances, growing as we do, supplementing and enabling our existence a billion calculations a second at a time.

4.1.7.1. The Internet of Everything

The IoE represents an evolution of the IoT. More specifically, IoT refers only to the manifestation of the global database of the internet in its inanimate technological devices and hardware periphery. A 2013 online article published by Dave Evans,[13] chief futurist for Cisco, states that the IoE instead brings together the four pillars of people, process, data and things. These pillars and their connections create vast amounts of usable data (Clarke, 2013:3).

This makes networked relationships more valuable than ever before, turning information into action, creating new capabilities, richer experiences and greater economic opportunities for business and individuals. To elaborate further, the IoE refers to a world where virtually everything will be connected to the internet.



Source: BI Intelligence Estimates

Figure 4.6: The current and projected scope of the IoE by BI Intelligence. Source: http://www.businessinsider.com/the-internet-of-everything-2014-slide-deck-sai-2014-2#-1 [Viewed 2016-09-07].

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[13] 'Beyond things: the Internet of Everything takes connections to the power of four', by Evans, D. 2013. http://blogs.cisco.com/digital/beyond-things-the-internet-of-everything-takes-connections-to-the-power-of-four - [Viewed 2015-08-11].

This is not future theory, however; this is current reality. Today, more and more is being linked to the information superhighway that is the internet, from cars, to household appliances, to schools and even internal body functions. The world is an interconnected database, and the IoE provides a blanket term to define the abundance of information that, if harnessed correctly, can provide unprecedented value from the connections created. The harnessing of these connections therefore remains an important aspect to this thesis and the proposal for integrated knowledge feedback loops within a supportive architectural design methodology.

In a later article, Evans[14] furthermore predicts that the IoE will continue to evolve over the next 25 years, specifically:

- The IoE will contribute to increased economic opportunity as governments and organisations deploy internet-enabled technology across various industries.
- The IoE will become more personal and predictive, merging the physical and virtual worlds to create more individual and personalised experiences.
- The IoE will drive an intersection of technology and humanity through enabling greater control of our global management processes, ultimately intelligently monitoring precious resources at a higher capacity and benefiting quality of life.

Clarke states that while less than one percent of things that could be connected to the internet or intelligent systems are connected today, by 2017, 3.5 billion people will be connected to the internet. Clarke furthermore predicts that human life will significantly be affected by the IoE in three ways (2013:4):

1. The IoE will automate connections, removing the need to proactively connect or communicate information, instead transmitting data automatically. An example of this would be transmitting personal health information, such as heart rate, to doctors.
2. The IoE will enable fast personal communications and decision making by integrating intelligence into the data analysis process. In this way, large

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[14] ‘Answering the two most-asked questions about the Internet of Everything #IoE’, by Dave Evans, 2013. http://blogs.cisco.com/ioe/answering-the-two-most-asked-questions-about-the-internet-of-everything – [Viewed 15 May 2015].

amounts of data will be able to be filtered for specific information as deemed important by a specific data-gathering technology, device or software application. This embedded intelligence allows for real-time decision making.

3. The IoE will provide an opportunity to uncover new information through the deployment of sophisticated sensors and information-gathering devices. This allows city managers to understand cities as never before by providing an ability to monitor and data gather through means such as acoustic sensors (to detect audible distress incidents such as gunshots), traffic flow monitoring (to better analyse and alleviate commute times by intelligently adjusting traffic light intervals), among many others.

4.1.7.2. Social networks

The increasing growth and popularity of social networks has created a new world of collaboration and communication. Over a billion individuals around the world are now observed to be connected and networked together with the aim of collaborating, creating and contributing their knowledge (Cheung et al., 2010:1337).

Social networking websites constitute virtual communities which allow people to interact and 'socialise' online (Cheung et al., 2010:1337). In a non-academic study by internet analyst company Shareaholic, as reported on by the *Search Engine Journal* (Wong, 2014), it was determined that social media sites such as Facebook, Pinterest, Twitter, LinkedIn, and Google+ accounted for approximately 20% of overall driving of internet traffic to sites. In the later part of 2014, this figure further grew exponentially after it was reported that this figure had grown to 31.24%, replacing search engines and organic search engines such as Google, Bing and Yahoo! in dominating global internet traffic (Wong, 2015). This is an incredible increase in global usage considering that social networking accounted for just 6.5% of all internet traffic in 2007 (Cheung et al., 2010:1337). Facebook alone constituted 15% to 18% of the overall social network share of the internet, making it the most influential social networking platform on the planet by a significant margin (Wong, 2015).

Many analysts attribute the global upward trend of interest in social networking to the rise of access to internet and information via mobile devices and supporting networks (Lenhart et al., 2010:5). What this trend implies is that global internet usage is relying less on homepages and search engines, with internet users instead discovering news and personally pertinent information through social media.

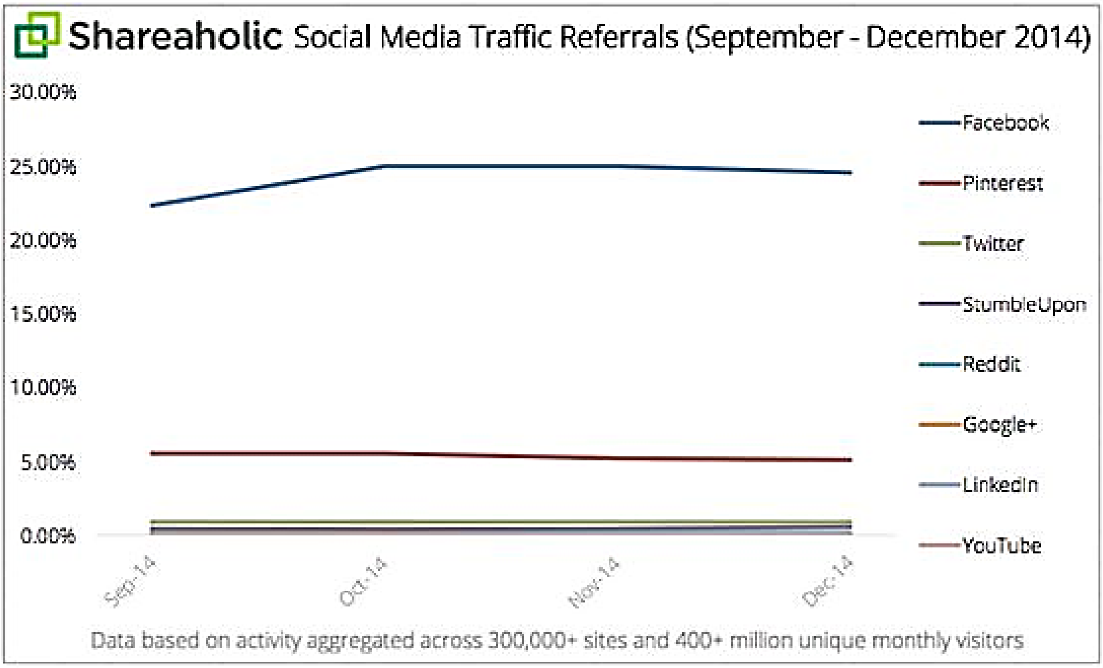

Figure 4.7: **Social media traffic referrals for Q4 2014 (https://blog.shareaholic.com/social-media-traffic-trends-01-2015/)**

The trend in information gathering via social media highlights a fact that information is more conveniently obtained through customised suggestion rather than primary search. Social networks such as Facebook have invested billions of dollars in research and development in past years in order to devise systems that customise the user experience to provide information about people, news and general internet content based on personalised preferences through automated statistical analysis and personal profiling. What this allows is for news feeds to be automatically generated based on usage trends, inclination of interest in certain internet content (derived from digital cataloguing of frequency of visits, pattern of commenting and sharing, and ‘likes’). This system also understands with whom you share common interests, and proposes internet content based on shared preferences.

This highly sophisticated ‘push’ of information based on personal profiling across its billions of users not only ensures that the social network becomes a digital landscape within which we can become immersed almost indefinitely, but provides immense monetary potential to the parent companies and hosts of these social networks by virtue of the fact that just as information may be intentionally directed towards discerning individuals, so too can advertising. This means that product placement may thus be targeted at those persons that are most likely to find interest in the product, as opposed to a generic ‘hit-and-miss’ approach of online ‘digital billboard’ advertising on websites.

Recognising these statistics of internet usage becomes immensely important in understanding the trends of use of the internet as a source of information. It is not possible to underestimate the role of social networks as a mechanism for cross collaboration of individuals but also as a primary source of information and news to the current population of global internet users.

In a 2014 TED presentation Marc Kushner of Architizer discusses the future of architectural product and process stating that the world of architecture has reached a turning point with the advent of social media. In the past 30 years, the public have remained somewhat disconnected from design, playing audience to the process, expectantly awaiting the unveiling of the final product at the discretion of the design professional. Kushner states,

> ‘it doesn’t take long to think about a building. It takes a long time to build a building, three or four years, and in the interim, and architects will design two or eight or a hundred other buildings before they know that a building they designed four years ago was a success or not. That’s because there’s never been a good feedback loop in architecture’ (Kushner, 2014:10:16).

Kushner (2014) furthermore states that in recent years that has changed, with social media now allowing for the public to play an essential role in in the process. This is achieved by allowing for constant and instantaneous feedback which now becomes available to architects years before a building is actually created. This is supplemented, for example, by the ability of current architects to produce sophisticated 3D visualisations to communicate design ideas and building form.

4.1.7.3. Ubiquitous and pervasive computing

Pervasive, or ubiquitous, computing refers to the seamless integration of computing and ICT in a means that remains unobservable, falling into the perceived natural experience of a place or activity, yet actively contributing to the effectiveness of the environmental experience. The ubiquitous computing paradigm centres on the concepts of integrating computing power in devices and environments in a manner that offers optimum support to daily activities. This scatters computing capacity across the environment, thereby removing the human-machine-PC interface, instead making use of networked sensors and devices that surround us (Gerrtisen & Horváth, 2010:765).

In 2004 McCullough spoke of a near future where focus will be on ubiquitous access to pervasive and largely invisible computer resources (2004:7). Computation would be human-centred, and we would not need to carry our own devices around with us. Instead, configurable generic devices, either handheld or embedded in the environment will bring computation to us, whenever we need it and wherever it might be. A decade later and his prediction has proven to be true. Our world is immersed in communication and information networks, with many complex processes and procedures fundamental to our daily lives occurring in complete obscurity relative to our real-world perceptions: smart watches track our movements and monitor our health, a Bluetooth connection in the car automatically plots the optimal route to work as soon as the ignition key is turned, and spending habits are analysed through algorithms and personal profiles are developed. Ubiquitous computing therefore is a new kind of computing where devices enhance everyday artefacts and situations, making available previously inaccessible situations for data capture (Kinder et al., 2008:265). Kinder et al. (2008:267) furthermore define the main characteristics of ubiquitous computing as a) invisibility, and b) a focus on mobility, smart tools and new forms of interaction.

Speaking at the 2015 World Economic Forum, ex-CEO and current executive chairman of Google, Eric Schmidt, stated that the internet is actually destined to disappear,[15] transitioning in form to become a part of everyday objects and services. ‘There will be so many IP address, so many sensors, things that you are wearing, things that you are interacting with that you won’t even sense it. It will be a part of your presence all the time.’

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[15] ‘Why Google’s Eric Schmidt says the ‘Internet will disappear’, by Christina Scolaro, 2015. http://www.cnbc.com/id/102363554 [Viewed 24 March 2015].

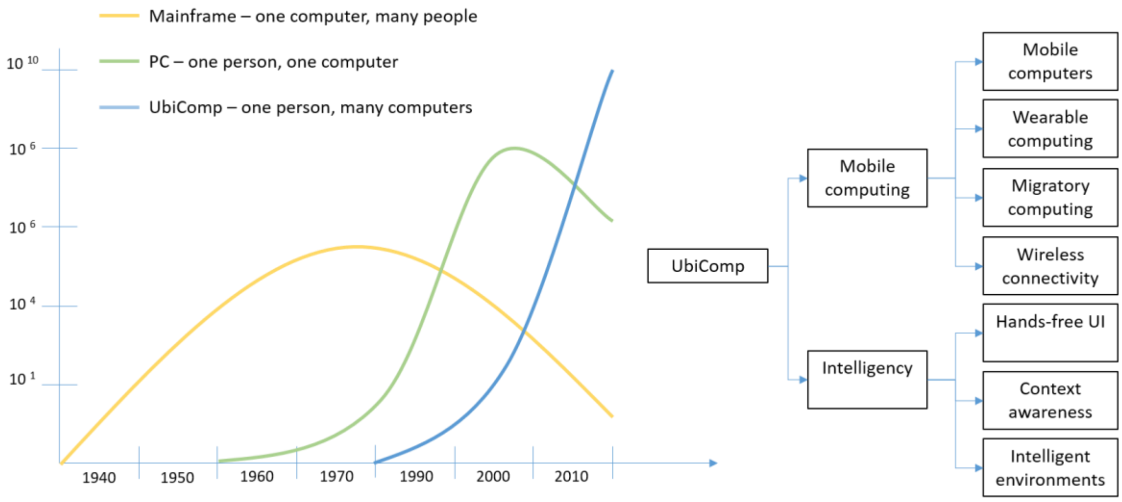

Figure 4.8: **Weiser's Major trends in computing and UbiComp Classifications**
Source: http://image.slidesharecdn.com/ubicompuploaded-140311021108-phpapp01/95/ubiquitous-computing-4-638.jpg?cb=1394504199 – [Viewed 12 May 2016].

In technological movements described as 'after cyberspace', IT contexts are no longer valued for 'immersiveness' so much as for 'periphery'. IT design has occupied itself with tools for deliberative reasoning – a process that occurs in the foreground of human attention (McCullough, 2004:49).

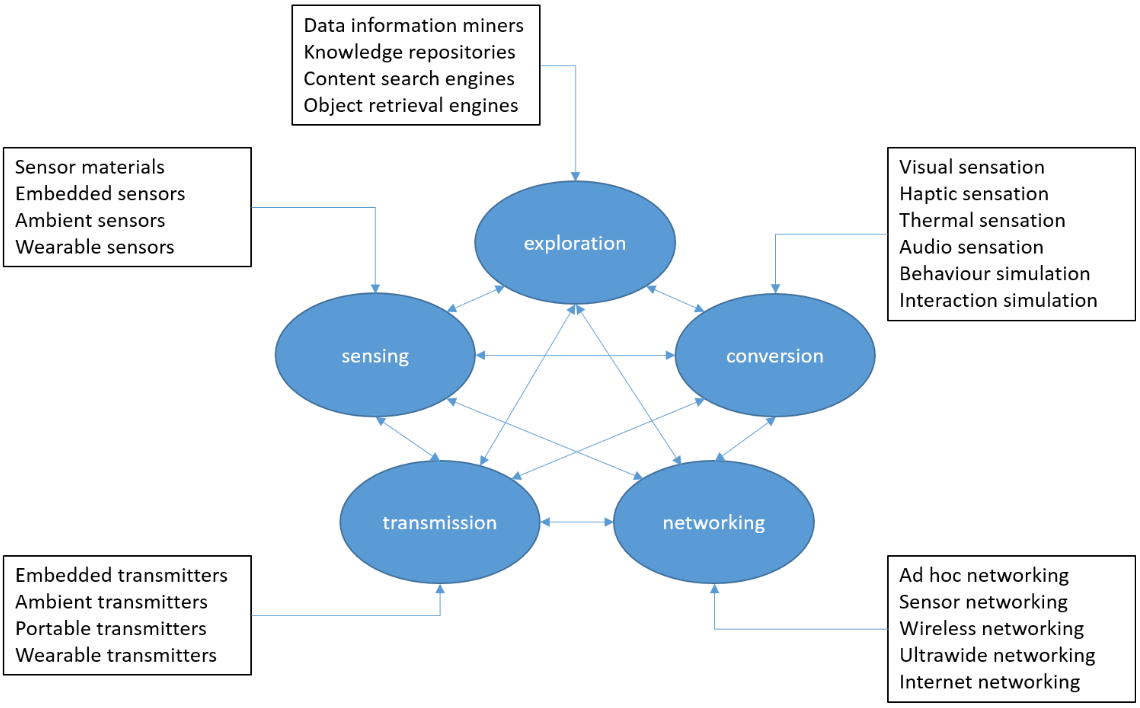

Figure 4.9: **Functional clusters of ubiquitous technologies (Gerritsen & Horváth, 2010:767)**

Most agendas of physical computing share a belief in periphery. 'Periphery is informing without overburdening.' We find it more natural to use our considerable powers of sensing the surroundings, and then to experience more capacity and resolution where our attention is focused. Graphical user interfaces have long been built on principles of shifting focus from the periphery to the centre of attention (McCullough, 2004:49). Pervasive computing takes this approach beyond the information context to include physical architecture by invisibly intertwining the shift of information from the periphery, to engaging with our central focus on tasks at hand.

Ubiquitous computing will be addressed again later in this thesis (Chapter 6 section 6.2.2), investigating the concept in greater detail with specific reference to its impact on the built-environment design process and product.

4.1.7.4. Smart cities

According to the World Health Organisation's (WHO) Global Health Observatory data,[16] in 2014 54% of the total global population lives within urban centres, an increase from 34% in 1960. The global urban population is furthermore expected to grow at 1.84% per annum between 2015 and 2020. The growing trend of urban centre migration makes it critical to observe the impact of the Information Age on quality of life on an urban centre scale as well as address the current and foreseeable trends applicable to our built environments.

In the context of this thesis, pervasive computing finds itself manifested in two forms of importance in the realm of the built environment, specifically *smart cities* and *intelligent buildings*. The researcher has chosen to expand upon these particular concepts with the aim of providing a suitable basis for expansion on the topics with specific relevance to the role of the architect in section 4.1.9 of this chapter, and the design process of the architect in Chapter 6.

The built environment, as a key contributor to human quality of life, is not exempt from the influence of the Information Age. It is therefore important to investigate how ICT is currently applied and experienced in the built environment as well as understand how it is that the last two decades have witnessed the rapid evolution of our cities from early ideologies of the 'technopolis' into the 'digital, intelligent, or smart city' (Yigitcanlar et al., 2008:63).

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[16] The GHO data repository is the World Health Organization's main health statistics repository. http://www.who.int/gho/database/en/ [Viewed 07 May 2016].

According to 'District of Future', a European Union FP7 project for the Director-General of Research and Innovation, a smart city is more than just a digital city, but instead one that is able to link social and physical capital while developing improved services and infrastructures. A smart city is thus well performing in six categories:[17]

- Smart Economy
- Smart Mobility
- Smart People
- Smart Living
- Smart Governance.

'District of Future' furthermore states that, in addressing the smart city according to these categories, a platform is created for bringing together technology, information and policy into a feasible programme of urban and service improvements. Smart Cities are therefore complex ecosystems, where preserving quality of life is a key concern. The domains of people, organisations and institutions are enabled and facilitated by internet-based infrastructure and applications operating on common platforms. The internet and information networks as 'e-services' enablers are becoming increasingly important for urban development. Cities are assuming a critical role as drivers of innovation in health, inclusion, environment and business (Schaffer et al., 2011:431). The city may therefore be labelled as 'smart' when investments in human and social capital, and traditional and modern infrastructure contribute to sustainable economic growth, high quality of life and efficient management of natural resources (Schaffer et al., 2011:432).

The massive surge in ICT has become a 'nervous system' of modern economies (Hernández-muñoz et al., 2011:448). In a White Paper on smart cities and the IoE, Clarke (2013:1) states that smart cities are currently being realised in varying manners in municipalities around the world. These cities will make use of ubiquitous communication networks, highly distributed wireless sensor technology and intelligent

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[17] 'Smart Cities', 2015. http://www.districtoffuture.eu/index.php/mod.pags/mem.detalle/id.10/relcategoria.1077/relmenu.5#.VWI3sj0aynM [Viewed 30 May 2015].

management systems in order to solve challenges and create new services. Clarke furthermore observes that smart-city technologies integrate and analyse data on an immense scale to anticipate, mitigate and prevent problems in function and operation at a city scale, while providing services, notifications and information to citizens in a proactive manner. In doing so, these smart cities will connect citizens to local government, providing a platform for greater direct participation, interaction, and collaboration (2013:1). When presented with the challenge of exploiting the opportunities provided by future internet technologies in the context of the smart city, Schaffer et al. (2011:433) identify three perspectives, as indicated in Table 4.1.

Table 4.1: Three perspectives shaping the landscape of future internet and city development (Schaffer et al., 2011:432)

	Future internet research	**Cities and urban development**	**User-driven innovation ecosystems**
Actors	Researchers ICT companies National actors	City policy actors Citizen platforms Business associations	Citizens, governments, enterprises, researchers and co-creators
Priorities	Future internet technical challenges e.g. touring, mobility, etc.	Urban development Essential infrastructures Business creation	User-driven open innovation Engagement of citizens
Resources	Experimental facilities Pilot environments technologies	Urban policy framework Organisational assets Development plans	Methodologies and tools, physical infrastructure
Policies	Creation of advanced and testbed facilities Federated cooperation Experimental research	City policies to stimulate innovation, business and urban development Innovative procurement	User-driven innovation projects Open, collaborative innovation

The first perspective of future internet research represents a technologically focused and longer-term contribution to urban innovation. The second comprises city and urban development policies. However, policy makers, citizens and organisations are observed to be more interested in shorter-term, concrete solutions. This requires further intervention to scale up plot and small-scale projects to a larger scale. The third perspective of open and user-driven innovation ecosystems is presented which seek to bridge the gap between short-term city development priorities and the longer-term technological and research programmes (Schaffer et al., 2011:433). In aligning with the future of the IoE as discussed previously in this chapter, smart cities provide an opportunity to create a collaborative system of interrelationships between people and technology, manifested in our built environments. Smart cities are therefore based on collaboration networks among human communities, innovation ecosystems and digital infrastructure, e-services and applications (Komninos, 2013:1).

The concept of spatial intelligence in cities refers to an ability of citizens to utilise intellectual capital, physical space and smart infrastructure to create environments which intelligently enable competitiveness, sustainability and inclusiveness (Komninos, 2013:1).

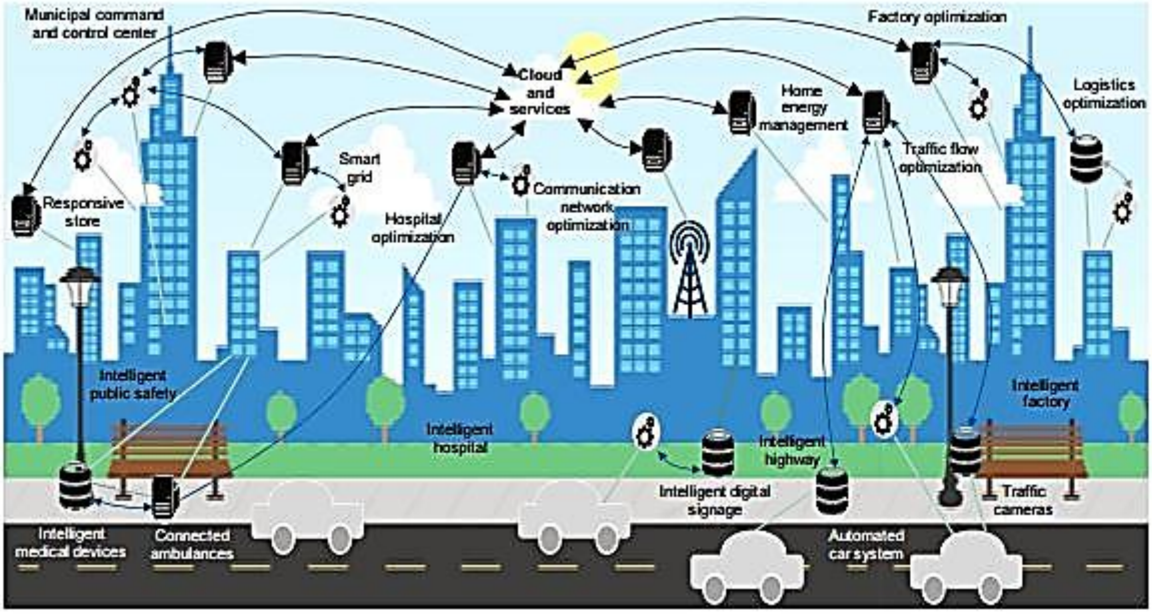


Figure 4.10: **Digital overlay of a city. Pervasive systems in place to create an interconnected digital and physical environment to enable smart-city living (Clarke, 2013:3)**

According to Clarke, the main contributors for the emergence and growth of the smart-city trend, which are born of the need for cities to investigate innovative approaches to city operations and service delivery, are the following:

- Cities are in a global competition to attract and retain talented and skilled people. This provides a basis to generate new start-ups, catalysing economic growth, employment and innovation.
- Growing urban populations put city infrastructure and resources under stress.

Smart cities, which allow for real-world urban data to be collected and analysed, will ultimately improve the ability to predict and manage urban flows and advance the collective intelligence of cities into the future. These smart cities possess this potential because they are not localised events in the cyber-sphere, but rather are integrated social, physical, institutional and digital realms in which digital components and systems improve the functioning of socio-economic activities, management of infrastructure, and enhancing the decision-making capacities of urban communities (Schaffer, 2011:434).

4.1.7.5. Intelligent buildings

Intelligent buildings is a term coined in the early 1980s, and subsequently defined by the USA Intelligent Buildings Institute as

> ‘one which provides a productive and cost-effective environment through the optimisation of its four basic elements – systems, structure, services, management – and the inter-relationship between them … There is no intelligence threshold past which a building ‘passes’ or ‘fails’. Optimal building intelligence is matching of solutions to occupant needs. The only characteristic that all intelligent buildings have in common is a structured design to accommodate change in a convenient, cost-effective manner’ (So et al., 2001:3).

As stated by Himanen (2003:55), the intelligent building concept has been defined by many global organisations such as the Intelligent Building Institute Foundation (IBI) in 1989, Associazione Italian per l‘Automazione deglie Edifici (AIAFE) in 1995, the European Intelligent Buildings Group (EIBG) in 1998 and the Smart Homes Foundation in 2001. With each definition contained in the organisations listed above, one notable landmark in the progress of the intelligent building concept was the Intelligent Building (IB) pyramid developed during the European Intelligent Building Study in 1992.

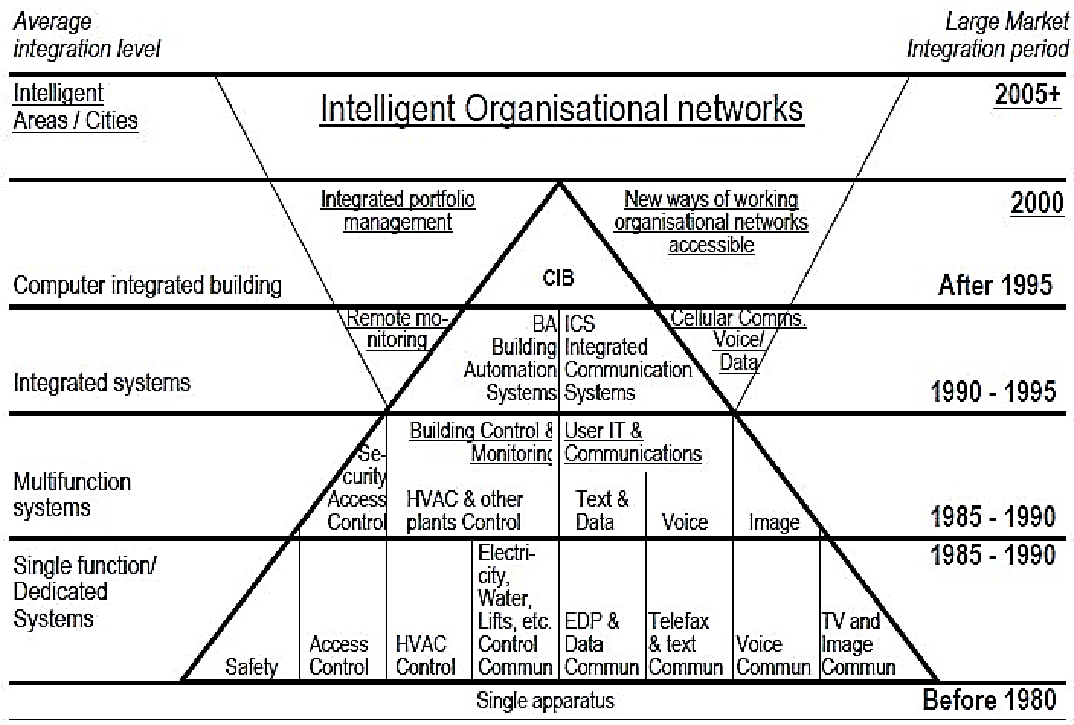
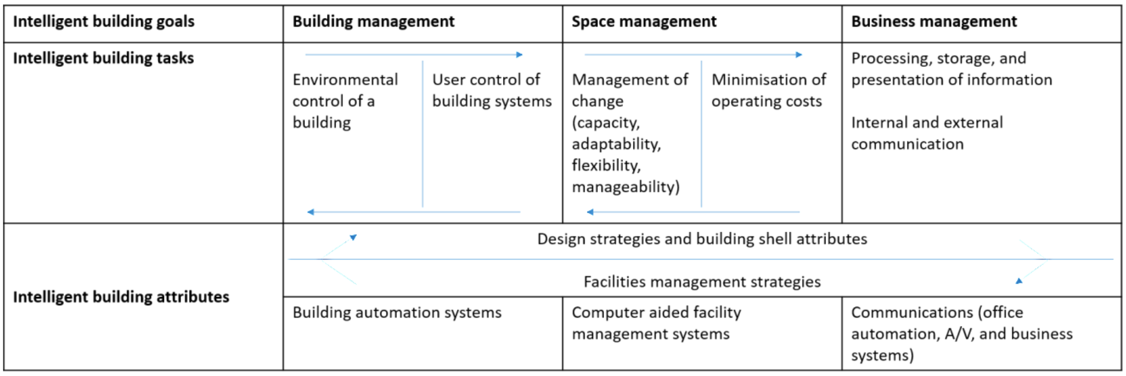


Figure 4.11: **The Intelligent Building Pyramid developed by the European Intelligent Building Study, 1992 (Himanen, 2003:56)**

This definition has been evolving since its inception, ranging from the concept of *automated buildings* between 1981 and 1985, to *responsive buildings* between 1986 and 1991, and *effective buildings* from approximately 1992. With each evolution, it was clear that a direct link to integration with IT is prevalent (Harrison, et al., 1998:1). As stated by Roman et al. (2015:60), intelligent buildings are not a new concept, having been discussed for decades already. However, the concept is now receiving renewed interest because it can now be delivered in real terms. This has been made possible by two factors: environmental awareness (social and political pressure), as well as ubiquitous and cost-effective technology. Wong et al. (2005:143) state that the concept of intelligent buildings was stimulated by the development of ICT, supplemented by a demand for increased living comfort and occupant control of their environments.

As defined by Harrison et al. (1998:3), the main goals of intelligent buildings, according to the Intelligent Buildings of Europe (IBE) project of 1992 are: a) building management, which refers to building automation and the physical environment; b) space management, which refers to the building's internal spaces, cost of operation, and flexibility of the building to accommodate changes and connectivity; and c) in the case of a commercial building, business management, which refers to the management of the organisation's core business. Within the scope of these goals, the intelligent building seeks to respond to organisational change over time, while providing a supportive and effective environment within which the building stakeholders may achieve their personal objectives, be it in living or working.



Intelligent building goals	Building management	Space management	Business management
Intelligent building tasks	Environmental control of a building User control of building systems	Management of change (capacity, adaptability, flexibility, manageability) Minimisation of operating costs	Processing, storage, and presentation of information Internal and external communication
Intelligent building attributes	Design strategies and building shell attributes Facilities management strategies		
	Building automation systems	Computer aided facility management systems	Communications (office automation, A/V, and business systems)

Figure 4.12: The IBE model of building intelligence (Harrison et al., 1998:3)

Harrison furthermore states that while the concept of intelligent building may create a preconceived notion of futuristic, high-technology buildings, this is not necessarily accurate. Intelligent buildings may rather be understood as a highly adaptable systems product that forms a seamless part of the intelligent infrastructure serving effective organisational performance (1998:7). Together with the technologically inclined defections, intelligent buildings are also recognised by researchers as having a more holistic definition. This definition includes aspects of learning ability, and building performance adjustment derived from its occupancy and its environment (Wong, 2005:144). Furthermore, So et al. (2001:2) argue that intelligent buildings are not just intelligent on their own, but also provide their occupants with greater intelligence, allowing them to operate more effectively.

Intelligent buildings therefore represent a coming together of technology and building form in a manner to supplement human activity and create self-regulating internal microclimates for optimum comfort through Building Management Systems (BMS). The use of internet and communication-based technologies and networks allow for real-time assessments and digital response. Data accumulation allows for future analysis in the pursuit of future optimisation of internal regulating control systems. The intelligent building therefore represents an enabled building that facilitates greater operating efficiency and a measure of user control that was unavailable before the digital age.

4.1.7.6. ICT in the process: Building Information Modelling

This section of the chapter is intended to provide a brief overview of the concept of BIM, which is already an industry standard for architectural process. BIM is included by the researcher as a subset of ‘smart built environments’ in order to further reinforce an important concept: that the built environment does not only ‘exist’ in the realm of the physical.

BIM refers to the process of design and documentation in architecture and engineering for the purposes of planning and construction of our buildings and cities. BIM concerns itself with establishing not only a digital 3D representation of a building prior to its construction, but also a digital database of its components, its performance characteristics, its construction timeline and phasing, and its relationship with its immediate context. The strength of the digital database (information modelling) approach to design is that, at any point in time, a digital information asset (model) is available for interrogation at specific and technical levels by one or more disciplines, thereby providing a resource of information that encourages cross collaboration of disciplines and expertise, growing the knowledge centre attached to each project, and identifying possible problems and opportunities before construction.

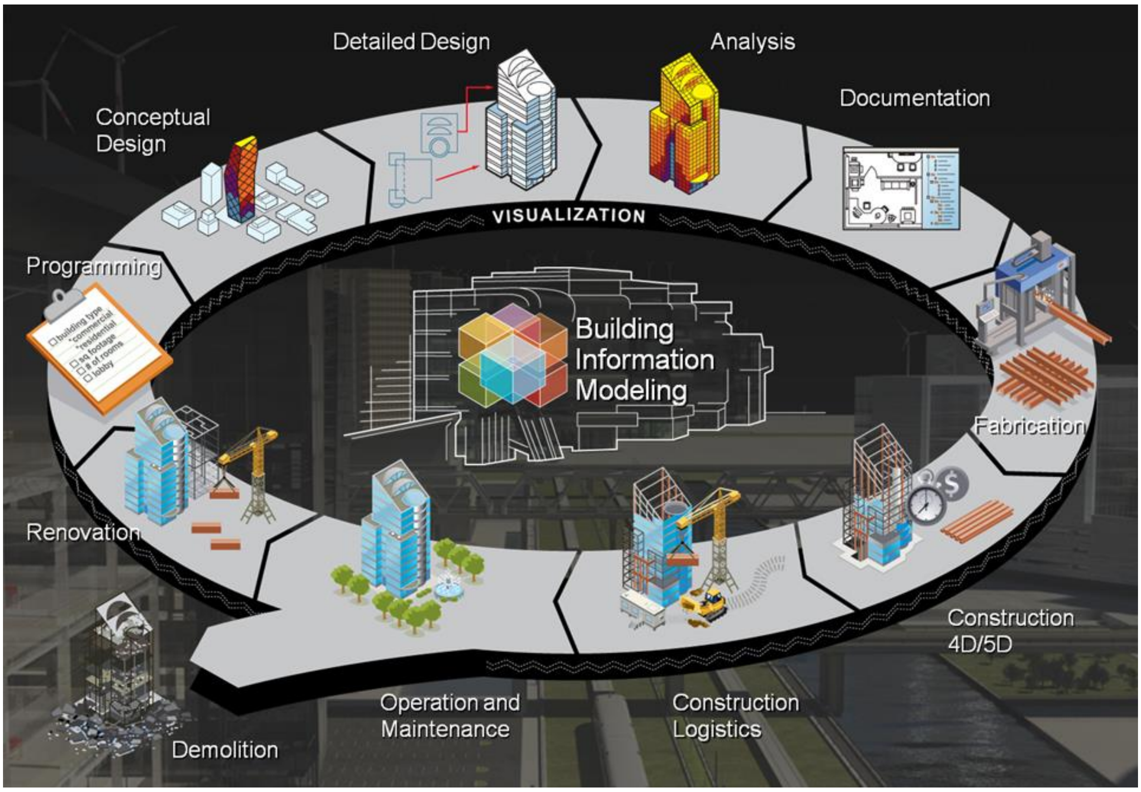


Figure 4.13: A visual representation of cyclical BIM concept
Source: http://www.builderstorm.com/wp-content/uploads/2014/08/bim_illustration.jpg

BIM also finds itself in the process of being mandated as part of the global architectural process. Proponents of this mandate have been the Dubai municipality in 2013, and most recently in the UK in 2016, where new projects of a certain complexity are required to be undertaken utilising BIM as a prerequisite for statutory approval. According to the Dubai municipality, BIM is being encouraged 'because of how much it lowers the cost of construction projects and the time taken to finish them; and increases the level of coordination between the engineers working on designing and implementing the project, and their counterparts in the management and funding and manufacturing the project'.[18]

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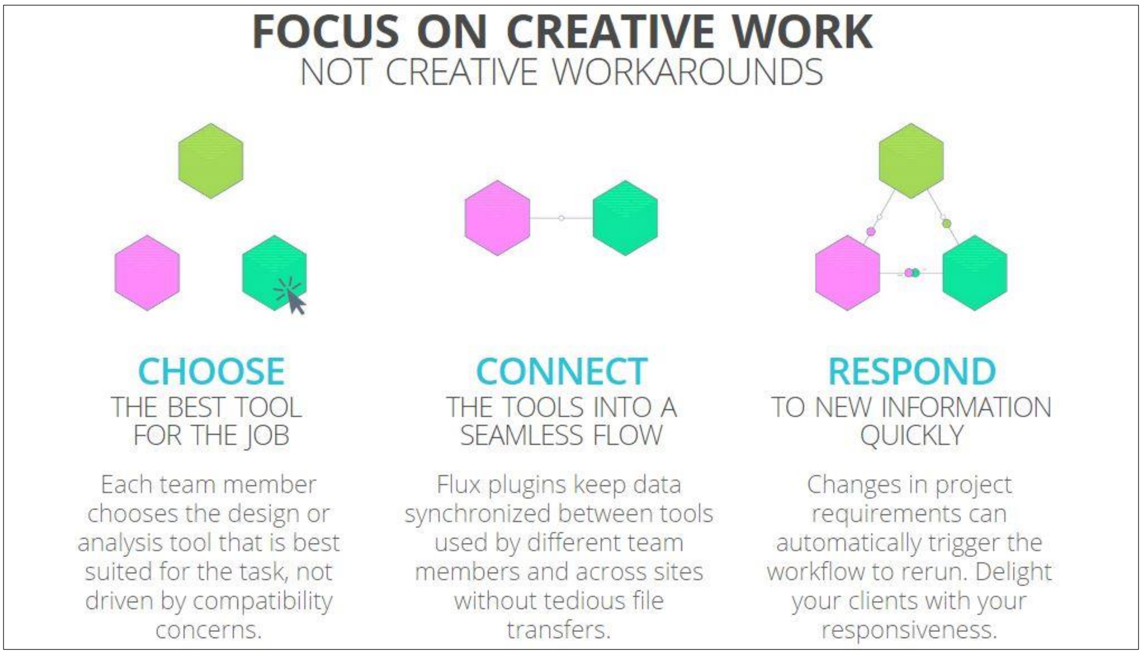
[18] 'Revealed: Dubai Municipality's updated BIM mandate', by Bhatia, N. 2015. http://www.constructionweekonline.com/article-34893-revealed-dubai-municipalitys-updated-bim-mandate/ [Viewed 13 May 2016].



FOCUS ON CREATIVE WORK
NOT CREATIVE WORKAROUNDS

CHOOSE
THE BEST TOOL FOR THE JOB

Each team member chooses the design or analysis tool that is best suited for the task, not driven by compatibility concerns.

CONNECT
THE TOOLS INTO A SEAMLESS FLOW

Flux plugins keep data synchronized between tools used by different team members and across sites without tedious file transfers.

RESPOND
TO NEW INFORMATION QUICKLY

Changes in project requirements can automatically trigger the workflow to rerun. Delight your clients with your responsiveness.

Figure 4.14: **The operational framework for Google Flux, collaborative BIM-based design tool for the architectural industry**
Source: https://flux.io/

In order to ensure the quality and scope of work produced particular to a project, BIM Levels of Detail (LOD) have been devised. BIM LOD represent a predetermined threshold of the collaborative process for project execution and development, as well as the required input during project life cycle. As stated in a 2011 BIM strategy report, this ensures clear articulation of the level of competence expected and the supporting standards and guidance notes, their relationship to each other, and how they can be applied to projects and contracts in industry (BIM Industry Working Group, 2011:16).

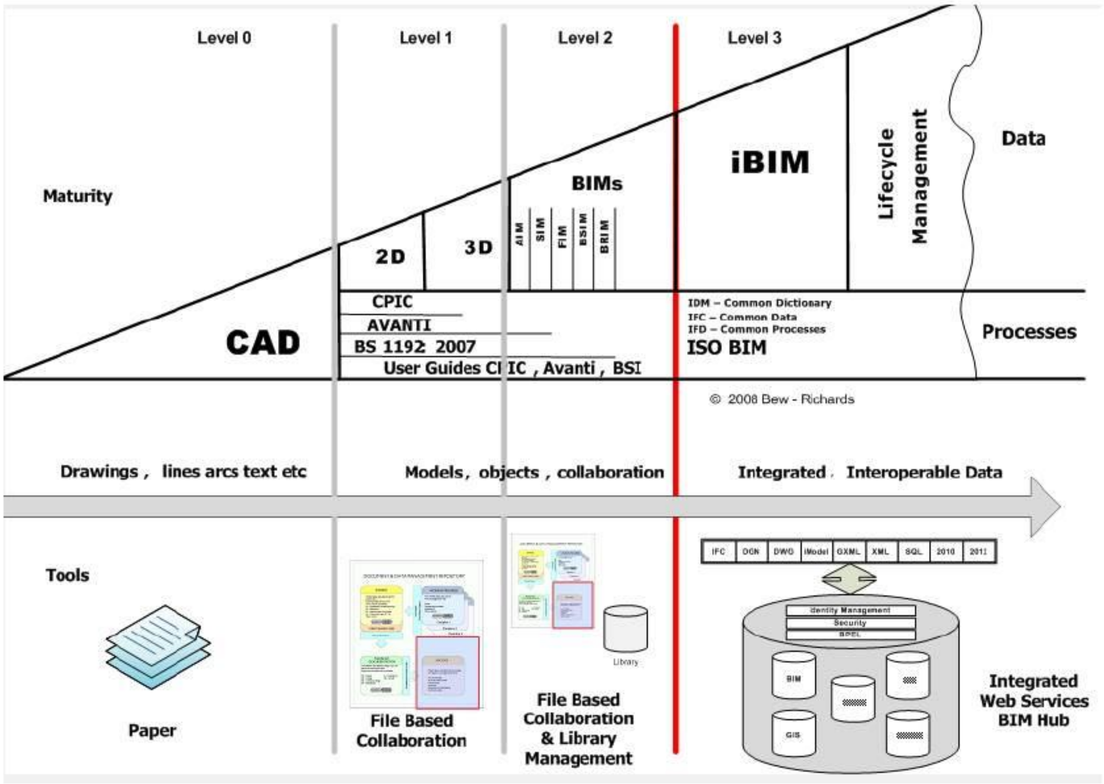


Figure 4.15: BIM Levels of Detail and maturity levels (BIM Industry Working Group, 2011:16)

While BIM presents many opportunities during planning and design, the digital model that has been created will persist in its usefulness after project completion. Since this information model remains available, it therefore transforms itself from information ‘blueprint’ of a real-world building to a digital avatar, co-existing with its physical counterpart in reality as a virtual doppelganger.

This aspect of BIM remains an immense opportunity that is yet to be explored to its full potential in current smart cities. BIM will expanded upon in greater detail in Chapter 6 section 6.1.6.4 of this thesis with particular emphasis on applicability and integration into a proposed new sustainable design methodology.

4.1.8. Why is the Information Age important to architects?

We are witnessing the early effects of ICT on the processes and products of architecture, and it is thus necessary for future research into an assessment of accomplishments so far and development of an informed view of emerging opportunities in need of further development in the field (Kalay, 2006:357). Conejos states that the design of buildings with embedded adaptive future re-use potential is a useful criterion for sustainability (2012:95), while technological innovation through IT can contribute directly to sustainability by increasing the efficiency and adaptability of products and processes (Fiksel, 2003:5336). McCullough argues that architects, and those in related disciplines of the physical environment, need to become aware of the challenges and opportunities raised by ubiquitous and pervasive computing which has woven itself into our lives almost invisibly. ‘They [architects] need to understand where technology is going, and what it has got to do with architecture ... They have been conditioned to an outlook of continuing marginalisation’ (2004:xvi). When IT becomes a part of social infrastructure, it demands design consideration from a broad range of disciplines. Social, psychological, aesthetic and functional factors all must play a role in the design (McCullough, 2004:3).

In implementing ICT integration, Fellenz and Brady refer to the need for an arbitrator to provide a holistic approach representative of the interests of the stakeholders and the various perspectives (interests) that define them. In their observation, the arbitrator should (a) have a capacity for understanding the individual perspectives and constructively relating to the specialists; (b) be able to integrate technological potential with delivery requirements; and (c) be able to achieve strong and sustainable relationships with stakeholders that add value and a basis for integration of these stakeholders into the development of future approaches and solutions (2007:41). In the opinion of the researcher, when looking to designate the role of the arbitrator in the realm of sustainable development for the built environment, the role of architect is seemingly and perfectly aligned. In keeping with the required ability of the arbitrator (2007:41), the responsibility of the architect requires that technical knowledge must be sufficient to engage with associated technologists through a holistic approach to maximise stakeholder value of ICT integration and predict the implications of ICT to ensure sustainable deployment.

When discussing it in the context of sustainable and energy-efficient design, it is important to note that Green Building has emerged as a highly sought-after direction of approach in the building industry. According to construction figures recorded by McGraw-Hill Construction as part of the Outlook 2011 Industry Forecast and Trends Conference (2011:12) in 2005, the North American market for green buildings accounted for only 2% of all non-residential construction. By 2010, this figure had increased to between 28% and 35%. This is representative of an significant upwards trend, and creates the basis for speculating that figures for 2015 will indicate adoption of non-residential Green Building construction reaching 48%. Green Building design is, however, only part of the solution.

Should architects fall short of their responsibility in recognising that a building environment designed for sustainability must attend to economic, social and environmental criteria as well as the information-based needs of humankind, they risk condemning their creations to early obsolescence. Architects, developers and other built-environment stakeholders who participate in the construction of green buildings without asking if the building is economically feasible, economically and socially necessary and adaptable over time, might find themselves erecting ‘monuments’ to energy efficiency that ultimately outlive their usefulness. This misconception of sustainable development contributes in the construction of ‘white elephant’ buildings, which, while impressive from a technological and energy-efficient standpoint, might not have the adaptability to cater to changing cultural and technological landscapes. It would be difficult to motivate the embodied energy expenditure in erecting a structure if there is no-one to inhabit it. No amount of energy efficiency in any building’s short-lived lifespan could ever account for the amount of raw material use, pollution and loss of natural resources that are required in its erection.

In a 2014 news article featured in the Guardian,[19] it was reported that a newly constructed $37 billion ‘eco-city’ built in the northern Chinese metropolis of Tianjin, marketed to one day be a ‘model for sustainable development’ now stands partially completed with no signs of ever reaching satisfactory or total occupation. This is indicative of the emerging problem that, while admirable in principle, the erection of numerous ‘eco buildings’ fails to consider the wider social and economic requirements. What can be seen is that a ‘build it and they will come’ philosophy is not adequate to ensure building occupation. A new apartment block such as those already completed in this featured city might be energy efficient and representative of a new era in design. However, if not supported by adequate economic feasibility, predictive growth analysis and provision of desired socially supportive and ancillary facilities such as schools and clinics (the feasibility of which should be adequately researched), they are at extreme risk of not attracting occupancy. If a building has no occupants to shelter, it fails in its most fundamental role.

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[19] ‘China’s “eco-cities”: empty of hospitals, shopping centres and people’, by Jonathan Kaiman, 2014. Source: http://www.theguardian.com/cities/2014/apr/14/china-tianjin-eco-city-empty-hospitals-people [Viewed 4 July 2015].

This example typifies how failing to forecast population trends and human need potentially impacts the practical life of a building. While it is not always possible to correctly predict future trends and needs, architects must still remain accountable to developing and designing built environments that are receptive to adaptive change and, if necessary, re-use. As we have seen in this thesis already, intelligent buildings and smart cities seek to alleviate the difficulty of re-configuration by superimposing a digital layer over our physical surroundings, reducing the role of the building as supporting infrastructure. While effective in principle, it cannot be denied that this initiative would be far more effective if enabled by its physical environment instead of ignoring it.

If architects continue to place themselves outside of this dialogue, the researcher proposes that the advent of technological retrofit to the basic shell of a structure to alter its purposes would continue to gain momentum to the point where the built environment becomes secondary to the IT infrastructure that activates its usefulness. While this is currently occurring, architects are necessary to this process as without adequate and sensible integration on matters of structural and services integration, future flexibility of physical space, philosophical sense of place, adaptive re-use and context, this adaptive technological retrofit would never quite reach its full potential.

The concept of ‘open building’ is a current, and globally recognised, approach to the design of buildings that seeks to address the matter of future flexibility. This concept recognises that buildings, and the neighbourhoods they occupy, are not static artefacts and during times of social and technical disruption require adjustment in some measure to remain attractive, safe and useful.[20] This concept furthermore addresses the issue of design process, asking the question of how the architecture can support stability and change towards the implementation of a ‘regenerative’ built environment. This is enabled through the use of the principle of ‘environmental levels’, which constitute the interrelated configurations of physical elements and design clusters that occur within a larger dependency hierarchy. These levels include: the urban (tissue) level; support (base building) level; infill (fit-out) level; and furniture (furnishings) level.[21] In the context of this section, the researcher observes that this principle is product focused,

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[20] ‘Open Building Concepts’. http://open-building.org/ob/concepts.html [Visited 2016-09-09].

[21] Definition of open building levels, by Kendall, D. http://open-building.org/gloss/lev.html [Visited 2016-09-09]

emphasising a resilient and regenerative approach. This approach emphasises the application of responsible approach within ‘design’ levels, but caters insufficiently to the lifecycle of the building regarding operations.

The argument is therefore not only how architects can best create robust buildings that do not require future ICT upgrade and integration, but rather how architects can design to accommodate it flexibly during the building life cycle. The challenge of this argument is evident when furthermore questioning how suitable the traditional architectural approach is towards formulation and delivery of a finite building product, and whether architecture should therefore evolve towards the creation of buildings as open systems processes instead of products.

4.1.9. Summary

In this section, an answer to the question of whether the world of today poses new challenges to the realm of human development is addressed. The researcher began by investigating the status quo of human industrial and technological development. In recognising that previous eras of human development were characteristically labelled by the technological innovation of the time – that which provided greatest significance to world-changing progress – the current era of technologically driven human evolution was identified as the Information Age, or digital revolution. This term was then investigated to provide understanding, as well as context, to its range of influence.

The Information Age represents an era of access to information and data on an unprecedented level in human history, and its main proponent is the internet: specifically, the means to transfer data and communication over vast distances instantaneously, as well as the creation of freedom of information for those connected to the information superhighway. The Information Age plays a significant role in affecting current socio-economic and cultural spheres of humanity, contributing to the current trend of globalisation, and as well as shaping the day of the everyday man and woman in the street. The impact of the digitisation of global data has also ushered in the concept of the digital economy, so that unlike the trade characteristics of old, the consumer now possesses an international appetite, and the Information Age is facilitating the worldwide exchange of goods and services as never before.

The researcher determined that the Information Age comprises interaction and networks (social and digital). More specifically, however, the principal contributing components and contributors to its emergence and growth are the digital economy, new knowledge-based societies and ICT.

ICT represents a way to accumulate, manage and direct mass data in a manner that is both appropriate and reproducible. Without the ability to derive actionable data, the internet would be a sea of unnavigable information, offering little in terms of value. Information value is therefore a function of not only the quality of the information, but the purposes for which it is intended, and the context to which it is applicable. Furthermore ICTs offer the means to communicate and share knowledge. Communication provides a limiting factor to information flow, limiting the scope of information to that which can be understood and interpreted by a single person, group or organisation. This clarity of scope is therefore integral in recognising the important role that ICT has to play in maximising the potential offered by the Information Age. This is possible through the improvement of operational efficiencies, introduction of high-level automation of tasks, and the establishment of larger communications networks providing a greater basis for knowledge exchange.

The impact of globalisation has contributed to the establishment of knowledge as a valuable and strategic asset. The knowledge society is therefore a society that is active and participating in the Information Age, pursuing greater knowledge gains in order to obtain greater societal and economic advantage. Knowledge societies are additionally focused on sustainable human development by seeking to ensure that knowledge is equitably accessible and transferable, providing gains to the generations that follow.

While these knowledge societies are digital constructs, provision of infrastructure in support of digital and information-based activity is fundamental, resulting in geographical clusters and urbanised development, such as the formation of information cities. The formation of these zones, cities and the built environments within them is therefore a by-product of societal need, and representative of knowledge-based development.

However, where active and participatory parts of society have access to information networks, ICT and benefits that these provide, those that do not find themselves on the wrong side of what has come to be known as the digital divide. This is again a question of equity and a challenge that needs to be addressed if development within the context of the Information Age is to be sustainable. This challenge is not so easily met through introduction of ICTs alone, however. Instead what is required is a holistic approach that remains sensitive to the required participatory process that is akin to societal process, as well as the integration of economic, policy and cultural resources and factors.

ICTs therefore represent more than the collection of bits, bytes, microchips and user interfaces. They are instead representative of a concept that has broad-reaching goals for human development. With this aim, the concept of ICT can be subdivided into certain attributes that are applicable to human and socio-economic development, and the built environment, such as the IoE, social networks, smart cities and intelligent buildings. The extent to which ICT has intertwined and integrated itself into everyday life was also investigated. This demonstrated that ubiquitous computing is not a feature, but a requirement of the ability for ICT to support human life for optimum experience and functionality. Ubiquitous computing is best represented in the smart-city concept, making it of key concern to architecture and the way in which the digital landscape is integrated with the physical. Each of these influential categories of ICT possess various and unique challenges, but are all bound and unified in the fact that they exist to serve humanity. Human need therefore re-asserts itself as a core goal to which knowledge-based development is oriented.

While it is important to address and acknowledge how ICT, the digital economy and knowledge-based societies are represented in our urbanised environments through smart cities, the role of ICT in the process of forming and designing these environments is not overlooked. Information and communication are an important part of the collaborative architectural process. The role of BIM is therefore of critical importance to the process, and in some locations mandated by policy. This allows the design team to build an information database, facilitating communication between stakeholders. This elevates the design approach beyond product creation to that of process creation.

4.2. Addressing hypothesis two:

Hypothesis: Sustainable development and its criteria require alignment and redefinition according to the needs of the Information Age and knowledge-based societies.

4.2.1. Addressing the evolved needs of humankind

In the previous section, it was observed that the Information Age, access to information and communication, and the pervasive integration of ICT into everyday life has influenced the establishment of new knowledge societies, which in turn demand knowledge-based development. However, revolutions in technology do not create new societies, but they do change the terms in which social, political and economic relations are played out (Mansell, 2002:407). This knowledge-based development is in response to a human-centred, knowledge-based need that has overarching consequences on the relations mentioned above. For this reason, the evolution in 'human need' requires investigation in order to establish and identify the levels to which it is deeply-rooted and persistent, or instead a fleeting desire that is symptomatic of a temporary trend.

In addressing human needs in a widely published and accepted treatise, Maslow (1943; 1954) established the hierarchy of physiological needs, safety needs, belongingness needs and esteem needs.[22] These needs form the first four components of a pyramid, and are addressed as deficit needs. Self-actualisation, the fifth component, addresses the need of being, which defines one's own place in the universe (Poston, 2009:348). When a person does not have enough of something, this is defined as a deficit need. This can be temporarily satisfied through obtaining whatever it is that is lacking (Poston, 2009:348).

The structure of the Maslow hierarchy is defined linearly as follows (Poston, 2009:349–350):

- Physiological needs: Influenced by our cravings, satisfying the basic needs to survive.
- Safety needs: The need to have stability in one's life.
- Belonging needs: A sense or a need to belong, at any stage, is influenced by several factors. Some of these influences, for example, are socio-economic influences: the education level of parents and family, the neighbourhood in which one resides etc. The level of belonging is important as this will affect the level of self-esteem.
- Esteem needs: Directly related to ego and a desire to be respected by others. The individual remains focused on the acceptance of others.
- Self-actualisation needs: The highest form of 'self-fulfilment needs', that of respect. This is achieved through accomplishment.

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[22] 'Maslow's hierarchy of needs', by McLeod, S. 2014. http://www.simplypsychology.org/maslow.html – accessed 13 May 2016.

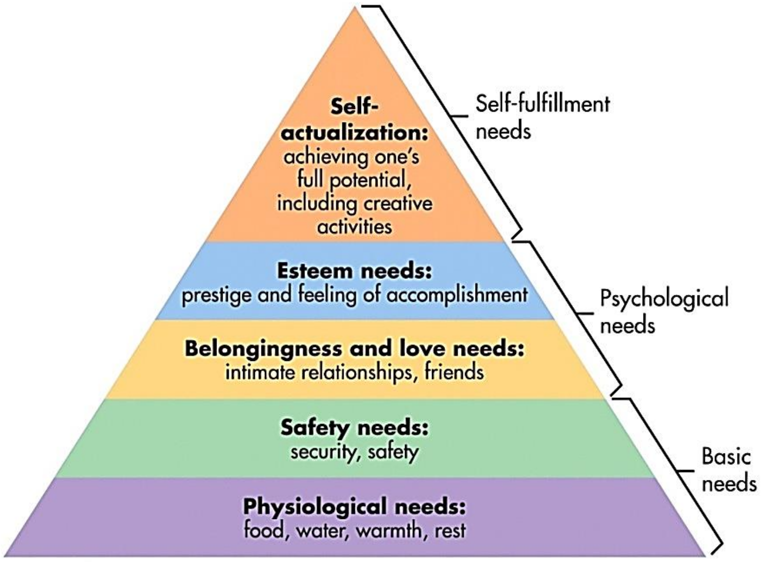

Figure 4.16: Maslow's Hierarchy of Needs
Source: http://www.21stcentech.comwp-contentuploads201110maslow.jpg [Viewed 14 April 2014)

However, Maslow's hierarchy does not always follow in sequence as it was intended, as some cultures or even stages of life may value one need over another (Poston, 2009:352). When looking at Maslow's hierarchy, it is important to remember is that anyone can regress to any point at any time within the pyramid (Poston, 2009:353).

With reference to the Information Age and the growing dependence on ICTs in society, in a study focused on the uses and gratifications in mass communication, Eighmey and McCord (1998:188), researched the human experience using the World Wide Web in order to gain functionalist perspective concerning continuing use of mass media. This has come to be known as the uses and gratifications perspective, wherein researchers focus on audience members' motivation and behaviour and assume that audience members actively use mass media to fulfil specific needs. In this exercise, it is possible to identify users as either active gratification seekers interacting with the media, or passive recipients of media content. It was subsequently determined that, while initial use of a medium may result from accidental exposure or trend-related curiosity, continuing use of a medium would seem likely to dissipate in the absence of audience rewards. Hence a dependency and development of need is created.

Audiences are attracted to information that adds value both in form and substance, but that information must reach visitors in a time period commensurate with the perceived value of the information (Eighmey, 1998:189). As an example of an Information Age mechanism, information therefore becomes a relationship with the World Wide Web.

The medium offers potential for members of the audience to become visitors and communicators in the complete sense of both terms. In this way, internet users can come calling at various times and engage in the exchange of information. In this context, the potential for human qualities and continuing relationships can lead to the advancement of our understanding of the theoretical concept known as para-social interaction (Eighmey, 1998:193).

The new social age manifested through digitisation and the internet connectivity has furthermore given rise to a social world that is intensively mediated by new media. Mansell (2002:413) states that new media literacies are crucial for sustaining democratic dialogue. This literacy concerns itself with more than the capability to read and understand digital information, however, since the extent of this mediation is often difficult to make sense of due to lack of clarity of mass information and a lack of media service-facilitated public dialogue. Mansell furthermore states that the prerequisite to making sense of the information lies in skills creation and the derived ability to disseminate information. The ability to participate democratically through proliferated use of media and access to information is therefore an observed human need of the Information Age. A lack of democratic access and capacity therefore leads to inequality, and categorisation within the established digital divide (see Chapter 4 section 4.1.6). This participatory process in the media-mediated social world is furthermore observed by the researcher to be representative of psychological and self-fulfilment needs, represented in Maslow's hierarchy as contributing to belongingness, feelings of accomplishment and fulfilling one's potential.

While psychological and self-fulfilment needs are represented through access to information, recent international policy has also shifted information-based needs to the hierarchical level of a basic human need. In 2011, a United Nations report declared the act of disallowing internet connection as a human rights violation and against international law, urging all states to ensure internet access is maintained at all times.[23] Furthermore, in 2015 the Human Rights Council of the United Nations General Assembly declared broadband access to the internet as a basic human right which

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[23] 'U.N. report declared internet access a human right', by Kravets, D. 2011. https://www.wired.com/2011/06/internet-a-human-right/ - accessed 14 May 2016.

enables individuals to exercise their right to freedom of opinion and expression,[24] while facilitating the realisation of other human rights. This sentiment among policy makers is also echoed by the public, whereby a 2010 poll[25] conducted by the BBC among 27,000 adults across 26 different countries received a 79% confirmation in perception of internet access as a fundamental right. Responding to this poll, Dr Toure of the International Telecommunication Union (ITU) stated that 'the right to communicate cannot be ignored'.[26]

The rise of new media and with it a new social world, is best represented in the form of 'social media'. While the specifics of social networks and usage have been addressed in section 4.7.1.2, the broader concept will be further addressed in the context of human need.

According to a 2014 survey (Gallup, 2014:2), it was determined that, in just one day, global social media activity accounts for:

- 4,75 billion Facebook posts
- 400 million tweets
- 1,2 billion Instagram photo 'likes'
- 4 billion YouTube videos watched.

Yet, this same survey revealed that the primary reason for the average person utilising social media sites was to interact with people they know. In the US alone, where 72% of the adult population are active in social media (Gallup, 2014:3), this need for belongingness through digital media has thus transformed the social experience.

According to Zhu and Chen (2015:336), in order to understand the human need for social media, it is necessary to investigate it according to two characteristics, namely the nature of the connection, and the level of customisation offered. The nature of the connection is concerned with discerning between profile-based and content-based

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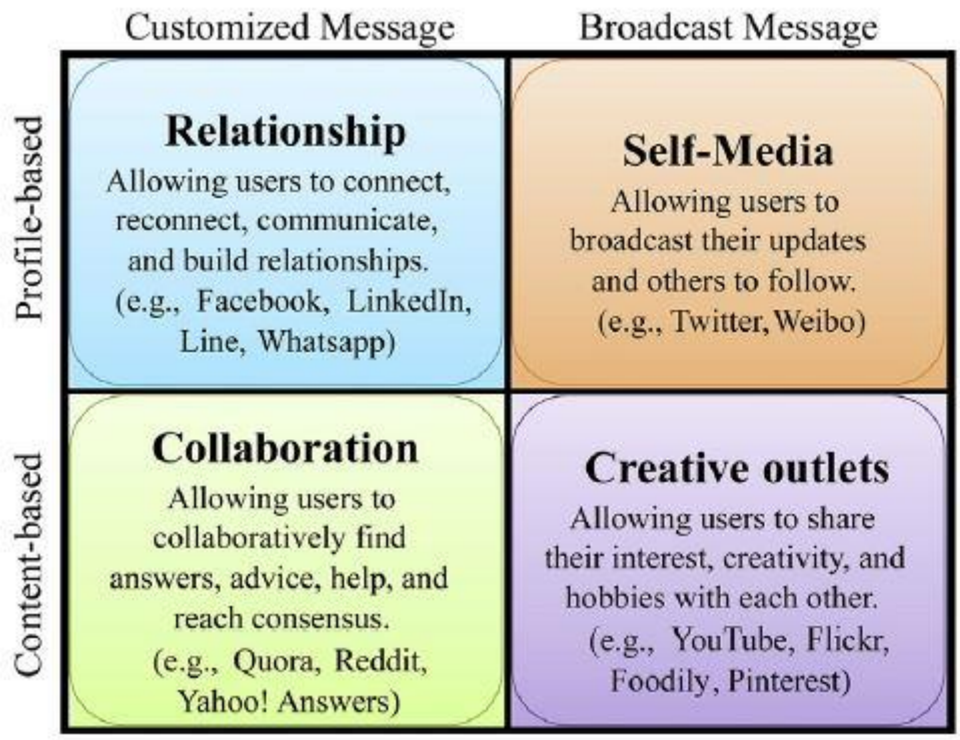
[24] 'United Nations: Broadband Access is a basic Human Right', by Salway, D. 2015. http://broadband.about.com/od/International/a/United-Nations-Broadband-Access-Is-A-Basic-Human-Right.htm - accessed 14 May 2016.

[25] ' Four in Five Regard Internet Access as a Fundamental Right' Global Poll. http://news.bbc.co.uk/2/shared/bsp/hi/pdfs/08_03_10_BBC_internet_poll.pdf - accessed 14 May 2016.

[26] ' Internet access is a 'fundamental right''. 2010. http://news.bbc.co.uk/2/hi/technology/8548190.stm – [Viewed 14 May 2016].

social media. Profile-based media focuses content on the individual, where users make connections because they are interested in the user behind the profile. Content-based social media is instead focused on the content posted, whereby users make a connection due to an interest in the content a profile provides. Levels of customisation are concerned with the degree to which a service is customised to satisfy an individual's particular preferences (Zhu and Chen, 2015:337). These two characteristics are summarised in Figure 4.17:



	Customized Message	Broadcast Message
Profile-based	**Relationship** Allowing users to connect, reconnect, communicate, and build relationships. (e.g., Facebook, LinkedIn, Line, Whatsapp)	**Self-Media** Allowing users to broadcast their updates and others to follow. (e.g., Twitter, Weibo)
Content-based	**Collaboration** Allowing users to collaboratively find answers, advice, help, and reach consensus. (e.g., Quora, Reddit, Yahoo! Answers)	**Creative outlets** Allowing users to share their interest, creativity, and hobbies with each other. (e.g., YouTube, Flickr, Foodily, Pinterest)

Figure 4.17: Social media matrix (Zhu and Chen, 2015:337)

In addressing human need, Sheldon et al. (2001:328) summarise 10 needs that are regarded as satisfying to human nature: autonomy, competence, relatedness, physical thriving, security, self-esteem, self-actualisation, pleasure stimulation, money-luxury and popularity-influence. Zhu and Chen (2015:337) observe that these needs are linked by a 'social' aspect as the common denominator, and as a result rely on social media to contribute to a general sense of relatedness.

In addition to social need, the digital age has also raised the issue of a 'need to know'. The abundance of information makes it possible, with appropriate direction and clearance, to gain knowledge in more fields than was ever previously possible. Hoffman and Branlat (2016:79) state that at any given time, any person might need to know anything and must be supported in finding it. Furthermore, human-centred computational tools need to support active information management, the active search for information, exploration of information, reflection on the meaning of information and evaluation of alternatives.

The need to be social, and the need to know are not new to the Information Age. However, these needs have moved to a greater level of complexity and abundance than has previously been experienced in human history. This need for constant connection and knowledge towards satisfaction of human needs requires recognition and representation in practices that are involved in shaping the human experience, such as the built environment.

4.2.2. Navigating the cognitive landscape

> *'The problems that exist in the world today cannot be solved by the level of thinking that created them.'*
>
> - Albert Einstein[27]

In determining our informational needs in the vastness of the digital and cognitive landscape, it is necessary to ascertain what information is appropriate and of greatest value. McCullough, in support of the argument to provide scope to personal informational requirements states that: 'Appropriateness surpasses performance as a key to technological success. Appropriateness is almost always a matter of context. We understand our better contexts as places, and we understand our better design for places as architecture' (2004:3).

One mechanism that human beings use to process and sort information is through the use of cognitive maps (Rosen et al., 2004:78). Cognitive or mental maps provide a means of storing and sorting information as drawn from our environments and serve as an accumulation or summary of experiences. These maps influence the way in which an environment 'feels' to a person, as well as determining what is noticed and what is ignored (Kaplan et al., 1982:5). Based on research from psychologists, architects and planners, Kaplan and Kaplan established a framework (Table 4.2) to describe the manner in which people use information to make sense during navigation of an

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[27] 'Albert Einstein Quotes'. http://www.alberteinsteinsite.com/quotes/einsteinquotes.html - [Viewed 2016-09-07]

‘uncertain’ world. From their research, Kaplan and Kaplan determined that these spatially-based informational needs are represented in two forms: making sense (understanding) and exploration (involvement) (Kaplan et al., 1998:13).

Preference Matrix		
	Understanding	**Exploration**
Two-Dimensional	Coherence	Complexity
Three-Dimensional	Legibility	Mystery

Table 4.2: Preference matrix of spatially-based informational needs (Kaplan et al. 1998:13)

While sorting and sifting through the information landscape requires a specific cognitive approach, this is demonstrated as being easier for some than others. In 2001 Marc Prensky coined the phrase ‘digital natives’, referring to a generation that exists today who have been enveloped in technology from a young age. This generation is therefore representative of native speakers of technology, fluent in the digital language of computers and the internet (Prensky, 2001:1). Thinyane (2010:412) states, in reference to the concept of digital natives, that this new technology-based language is symptomatic of a life of digital immersion, and that this is causing observable operational differences when compared to ‘digital immigrants’ who have been introduced to the digital realm during their lifespan. This tangible difference in the ability to speak and understand technological language results in the assertion that one cannot assume that simply introducing IT to a particular context will produce equitable and predictable results. As a result of the ubiquitous environment and sheer volume of interaction with it, users today think and process information fundamentally differently when compared to generational predecessors (Prensky, 2001:1).

Information access in the digital era of modernity is therefore not catered for in ICT adoption alone, but requires a means to navigate the information landscape that is customisable to the user, taking into consideration personal preference and capability for understanding. The researcher notes, however, that in the likelihood that the technological immersion is also potentially responsible for a biological restructuring in the way the digitally immersed generation’s brains work, and the resultant changes in thinking patterns (Prensky, 2001:1; 2009:1), that the world requires a fundamentally different approach in sustainably planning for the needs of future generations. On this basis, strategies of sustainable development catering to the needs of humankind require continuous alignment to the digital revolution.

In a 2009 paper, Prensky advances the concept of the ‘digital native and immigrant’ stating that further and prolonged immersion in technology will eventually render these concepts obsolete (2009:1). It is therefore observed that the Information Age will therefore become a basis for moving beyond comprehension, to that of digital wisdom. The wisdom of decision making and judgement in the Information Age is thus defined by the way resources are utilised, filtered and the support that is offered by digital technology. Prensky furthermore states that while technology alone will not replace good judgement and problem-solving abilities, in a complex future the digitally unenhanced person will not be able to access the tools of wisdom available to the digitally enhanced (2009:1).

4.2.2.1. Cyberspace and ‘the cave’

In Plato’s allegory of the cave, a hypothetical situation is presented whereby a number of people are chained together in a cave since childhood. In this cave, they are given only a blank wall to look at, and behind them lies a fire between which passers-by travel carrying goods, and objects. Against this wall, shadows of the passing people and the objects they carry are projected. To these people, these shadows are therefore representative of reality. In the event that one of them was freed and allowed to view the fire, the people causing the shadows, and even the outside world in the sunlight, this person would refuse to accept this as reality.

The researcher presents this short summation of this old story on the basis that without pursuit of knowledge, our realities would be constructed only from the limited perception of the world as presented to us. We would not be aware of any limitations, however, and in the greater context our existence would be inhibited. A lack of participation in the world we live in renders us as mere spectators, observing the shadows of a larger world outside of our view.

Knowledge represents the difference between sustained existence and development. Progress is a key objective of development, and should not be inhibited by limiting factors born of lack of contextual awareness, connectivity, interaction or knowledge building.

Future development must therefore be inclusive of knowledge building and participation, and environments we shape should enable and support human development. Sustainable development and the built environment therefore comprise a need to build open and democratic knowledge spaces, avoiding ignorance conducive only to cave-building.

4.2.3. Knowledge-based development

According to Ross (2000:24), the preservation and re-use of digital data and information forms both the cornerstone of future economic growth and development, and the foundation for the future of memory. The notion of learning – defined as the acquisition of knowledge which is tested, converted, stored for future use and then employed to effect change – has been given too little attention in policy circles (Campbell, 2009:195). Future development is based on learning from the lessons of the past, yet in today's digital age, there is an immense amount of information that needs to be acquired and sorted. As Roland et al. state (2012:220), the challenges in assuring this are complex. The first challenge is identified as residing in the technical realm, where a strategy is required to cope with obsolete hardware and software. Secondly, current legal frameworks are not representative of the digital age as current law makes it difficult for memory and knowledge-based institutions to capture and preserve digital data. Thirdly, social and cultural challenges are present in how to determine what in the digital realm is required to be preserved (Roland et al., 2012:221). The question is thus raised: if only a selection of available information is to be preserved, how is that determination made and by whom?

Access to, and the preservation of (digital) information will determine the stories our future selves and generations that follow will tell, the information we will access, and the information upon which future generations can build (Roland et al.: 2012:232). It is for this reason that it is imperative that our environments be suitably modified to facilitate information access within a framework that encourages its safeguard.

Carillo et al. (2012:1) state that knowledge-based development (KBD) represents a convergence of many disciplines, including economics, urbanism and geography, sociology and political science. The source of KBD is furthermore found in a compound field of cognitive psychology, technology, innovation research and management studies. One of the greatest challenges to this, specifically when addressing human activity systems, is the qualitative difference between material and knowledge-based phenomena. In a development context, knowledge flows from those who have created it to the broader spectrum of society and its beneficiaries. The use of knowledge in development is furthermore described as having two main aspects (Ferreira & Neto, 2005:4):

- How operational efficiencies can be improved through faster learning and application of knowledge; and
- How social learning and knowledge as a dimension of development can be improved to meet objectives.

In addition, where knowledge is validated this can be used as a means to test accuracy. Development is a social learning process in the sense that affected communities and social contexts are required to determine the most appropriate means to achieve their goals, the responsibility needs to be assumed by local actors and participants, and future successes need to be based in lessons from past experiences (Ferreira & Neto, 2005:4). In recognising that availability of information alone is insufficient, it is important that active stakeholders be provided with the means to form cognitive maps through which to establish parameters for determining appropriateness of information for their purposes. The application of information leads to the formation of knowledge. Acquired knowledge is furthermore defined into two main forms. Hard data (explicit knowledge) resides in documents and digital data while soft data (tacit knowledge) is stored in social and professional networks that link a wide array of stakeholders (Campbell, 2008:195).

The term ‘stakeholder’ recognises the effects of information-affected landscape on the human end user. The stakeholder may perform one of two roles based on information contribution, as well as derivation. These roles are therefore the ‘human active-user’, and the ‘active environment’. Networks of stakeholders and organisations performing functions that link knowledge with action are examples of knowledge systems. However, barriers exist that inhibit effective mobilisation of knowledge to support sustainable development, three of which are ubiquitous (Clark and Holliday, 2006:13):

- Mutual incomprehension between decision-makers – solved through collaborative production of knowledge;
- Fragmentation of the knowledge system – solved through use-inspired research and systems integration; and
- Inflexibility in a world of uncertainty – solved through the promotion of knowledge transfer and learning.

The importance of knowledge to the needs of humankind is furthermore recognised by the United Nations through its integration within the Division for Sustainable Development. The goal of this division is to promote and coordinate the implementation of the 2016 Sustainable Development Goals, while focusing work into six core functions:[28]

1. Support to UN intergovernmental processes on sustainable development;
2. Analysis and policy development;
3. Capacity management at the request of member states;
4. Inter-agency coordination;
5. Stakeholder engagement, partnerships, communication and outreach; and
6. Knowledge management.

Through its Sustainable Development Knowledge Platform[29] the UN intends to develop the mechanism to provide wide access to information and knowledge as a platform through which communication between stakeholders can occur.

From the standpoint of architecture and the built environment, in the same way in which human beings derive meaning and actionable information leading to decision making, our built environments are constantly evolving to do the same. As has been documented in this chapter, smart cities and intelligent buildings are as influenced by information availability as the human beings that populate them. It is for this reason that the preservation and availability of information, as well as the framework for its access and exploration remain a pillar of importance to the optimum functioning of our future physical environments.

4.2.4. Reinvestigating the triple bottom line: the modern case for human-centric sustainable development

In addressing the human-centric-approach in the technologically inclined Information Age, it was determined in this chapter that access to and proliferation of information and knowledge is a feature fundamental to the human developmental process. Ferreira and Neto (2005:5) state that while it is generally accepted that sustainable economic growth is related to technological innovation, new approaches to development consider that this is also a learning process, thereby creating local knowledge through

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[28] Division for Sustainable Development. https://sustainabledevelopment.un.org/about [Viewed 2016-09-15]

[29] Sustainable Development Knowledge Platform. https://sustainabledevelopment.un.org/ [Viewed 2016-09-15]

assimilation and adaptation of external knowledge. When addressing development, it is also important to address the cognitive dimension by addressing it as a social learning process contributing to people taking explicit control of personal development experiences and using those experiences to problem solve and develop their own future.

When considering development, and utilising the building industry as an example, the issue of life cycle assessment is now a prominent feature of sustainable development approaches. The continued and long-term effects of built interventions on the environment have been given substantial importance to sustainable development and resource preservation principles (Kucukvar & Tatari, 2013:958). However, adherence to ecological constraints alone does not necessitate, or even guarantee sustainable development. There is a need for greater emphasis on contextually applicable economic and social development, for which knowledge-based development is a key contributor. In addressing the means with which development initiatives are to have a pivotal role in meeting the challenges of the 21st century, greater attention needs to be paid to assumptions about (Fukuda-Parr and Lopes, 2013:viii):

- The nature of broader development as a process of societal transformation;
- The importance of indigenous capacity for transformation;
- The nature of capacity and capacity development; and
- The nature of knowledge, where it is located and how it can be transferred or shared.

Furthermore, development is required to be addressed at different levels of influence and capacity, namely (Fukuda-Parr and Lopes, 2013:9):

- **Individual:** enables individuals to embark on a continuous process of learning, building on existing knowledge and skills and extending these towards new opportunities.
- **Institutional:** builds upon existing capacities, seeking out and encouraging growth on existing initiatives.
- **Societal:** involves holistic societal capacities and transformation. Involves the creation of opportunities that expand and maintain capacities to the fullest.

This capacity of development is also understood as human resource development and is fundamental to the human-centric sustainability of interventions that seek to provide and maintain capacity and benefits at the varying levels of influence. Society, a pillar of the triple bottom line, is hereby observed as a component of greater sustainability theory, lacking scope or ability to cater to the long-term knowledge needs, both individual and institutional.

Sustainable development therefore benefits from understating its spatial and temporal scope of intervention, recognising that the individual is as fundamental to the process as is the society of which it forms a part. Local involvement stimulates knowledge creation, thereby increasing local capacities and the ability for autonomous decision making and knowledge transfer.

The triple bottom line is a steadfast feature of sustainable development; however it is observed by the researcher that the case for development has broader-reaching influences in the Information Age. Sustainable development is therefore not just achieved in the marriage of social, economic and environmental factors, but to meet the needs of current and future generations still requires a human-centric approach. This is based on the understanding that without human progress, development is an empty concept. It is evident through this investigation, therefore, that the triple bottom line is not sufficiently equipped to enable sustainable development on the various levels of development, and the concept of sustainable development to which it is applied must respond to a human-centric context in favour of capacity and knowledge-based-development.

The importance of knowledge to human development is not a new phenomenon, and it would be presumptuous to assume that knowledge is more important to current generations than it was in the past. However, the Information Age has created a far greater accessible and transferable commodity out of knowledge through digital information and communication. This has elevated knowledge as a concept of importance, and given rise to Information Age ‘knowledge societies’ that depend upon its availability and transfer to forge, stimulate, and guide further development. The three pillars of sustainable development are recognised since they have intrinsic value to human development, yet each overlaps with and integrates with the other. There can be no economic development without social cohesion to support it, for example, just as there can be no social development without a planet to accommodate it. Each pillar has value, and for this reason development aims to support and cultivate their growth and preservation. Knowledge makes a direct contribution to sustainable human development while remaining synergistically linked, and complementary to, the existing three pillars. Knowledge is a unique pillar of importance that requires specific attention, made more important through the Information Age as big data grows bigger, and information and communication technologies become more pervasive in our everyday lives. Furthermore, implementation of sustainable development as a concept is improved when attached to specific scale and scope through interpretation and assimilation of actionable intelligence (knowledge). If humankind is to benefit future generations through current interventions, knowledge-based development presents the means to focus sustainable development approaches, respond to the evolved needs of humankind, facilitate the transfer of lessons learnt, and re-integrate ideas and observations to foster adaptability of interventions towards an unpredictable future.

4.2.5. Summary and resolution of hypothesis

In this chapter, a review of the concept and consequences of human need was undertaken. This research highlighted important considerations of the Information Age that are significant for the ways in which our everyday life is conducted, as well as perceived quality of life. The digital revolution has brought with it a new form of social order, and interactive dependence. Firstly, knowledge-based societies of the Information Age represent those aspects of society with access to information, supported by ICT. It was determined through investigation (see section 4.1.5) that mass communication and media provide new and popular avenues of interaction, communal belonging and knowledge exchange. While symptomatic of ICT-enabled contexts, usage statistics in those contexts demonstrate high adoption rates, particularly in the realm of social media, whereby most users participate in order to interact with people they know for a specific purpose. In addition, it has been determined as a function of international policy that access to information and internet connectivity is now regarded as a basic human right. The information and knowledge-based needs of humankind have therefore entered into an era of legislation that equates this need with that of social democracy, and ecological preservation.

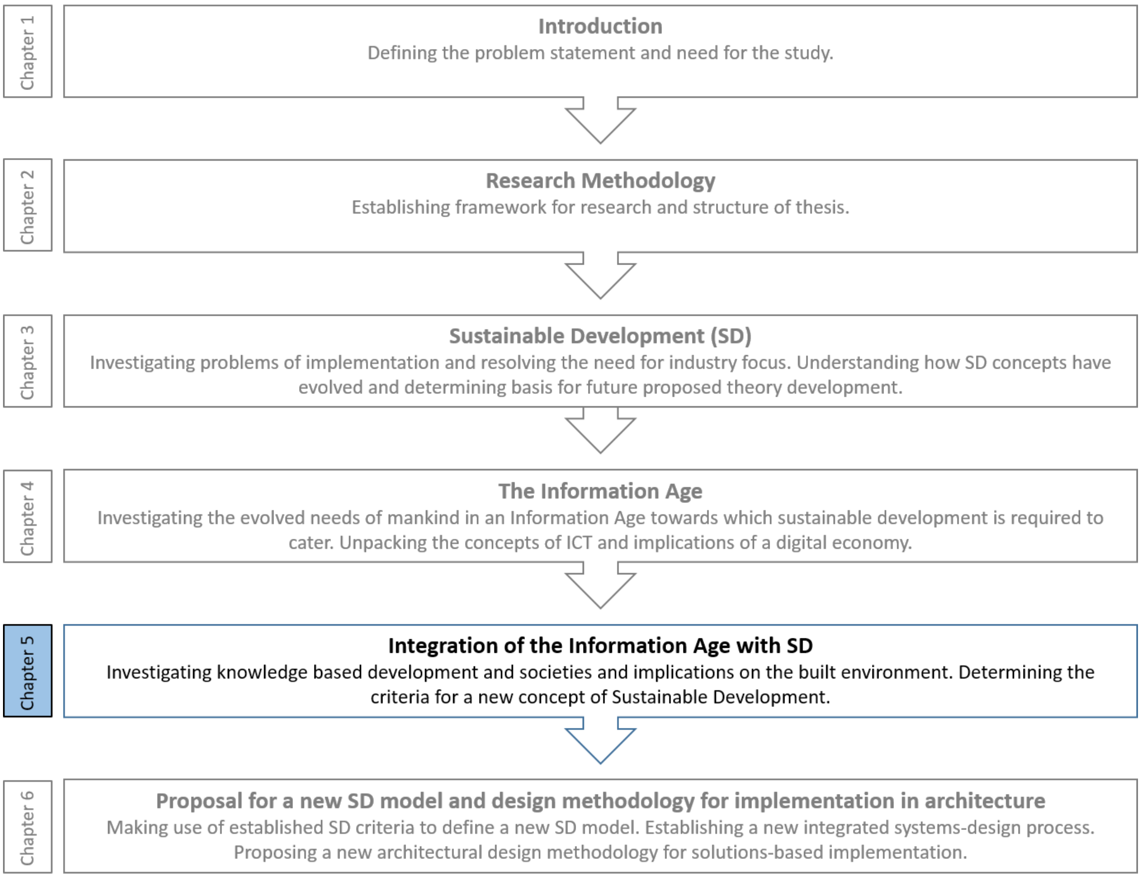
The ability to participate in the media-mediated social landscape is representative of human needs pertaining to belongingness and self-fulfilment. Challenges of access or capacity to participate is therefore representative of social inequality, and as a result is not congruent with principles of sustainable development. This inequality through lack of ICT support of human activity is defined as the digital divide. This divide, as previously discussed, is not simply bridged though introduction of technology, but has connotations in the creation and sustainment of knowledge societies. As a result, this has socio-economic influence and the need to foster knowledge creation.

In addition to the need for information and communication, human beings also possess a need to know. Where the need to gain insight or knowledge exists, society should support it. However, information, knowledge and its acquisition are only possible through directed pursuit. Interpretation of information is not automatic, and requires prior knowledge, experience or direction in order to have meaning. Technological immersion is changing the way we interpret and store information, with some faring better than others based on experience and degree of digital wisdom whereby human activity is enhanced by available ICT.

The prevalence of knowledge-based societies, representative of the Information Age, gives rise to the concept of knowledge-based development. This knowledge-based development is representative of a convergence of many disciplines, bridging the realm of the physical and the abstract. This is furthermore of great significance to sustainable development due to its human-centred approach towards an equitable future of development. Knowledge-based development is furthermore dependent on human participation, thereby attributing focus and a scale of influence to developmental strategy.

For these reasons, the concept of the triple bottom line relative to sustainable development in the Information Age requires re-evaluation to suit the evolved information and knowledge-based needs of humankind. Development is human-centric: therefore sustainable development requires a scale of approach that is inclusive of the individual and end user, society and institutions and the means by which experience and knowledge are created, managed and transferred. This recognises the value of each as participatory stakeholders and facilitates sustainable development on the basis of knowledge exchange and integration.

5. Establishing criteria for integration of concepts of ICT, knowledge-based development and sustainable development within the built environment.



Introduction
Defining the problem statement and need for the study.

Research Methodology
Establishing framework for research and structure of thesis.

Sustainable Development (SD)
Investigating problems of implementation and resolving the need for industry focus. Understanding how SD concepts have evolved and determining basis for future proposed theory development.

The Information Age
Investigating the evolved needs of mankind in an Information Age towards which sustainable development is required to cater. Unpacking the concepts of ICT and implications of a digital economy.

Integration of the Information Age with SD
Investigating knowledge based development and societies and implications on the built environment. Determining the criteria for a new concept of Sustainable Development.

Proposal for a new SD model and design methodology for implementation in architecture
Making use of established SD criteria to define a new SD model. Establishing a new integrated systems-design process. Proposing a new architectural design methodology for solutions-based implementation.

5.1. Sub-problem three:

Sub-problem: What are the aspects of ICT that align it with the goals of sustainable development in the context of the built environment?

5.1.1. Introduction

Progress of research to this point is delineated by two avenues of investigation. Firstly, it was necessary to decide whether the need for an evolved approach in pursuit of sustainable development existed. It was observed that while many evolutions of concept have emerged over the years, lack of specificity in approach and scale of implementation have hampered effective execution. Quantifiable approaches that sought to delineate specific scope, often with the exclusion of fundamental criteria of sustainable development – pursuing ecology in the absence of evaluating economic feasibility, for example. While these quantifiable approaches gain popularity due to perceived ease of implementation, it is clear that sustainable development as a holistic concept remains important, but is required to keep pace with the times. Secondly, the evolution of our society was investigated in order to determine what has changed in our world since the concept of sustainable development was delineated by the UN more than three decades ago. It was clear that we now exist in an Information Age, and as such our future depends on our ability to satisfy humankind's need for interconnectivity and communication. The 21st century world is built on a backbone of information transfer, and this brings with it massive changes in society and infrastructure. The questions thus emerge: Is it possible to merge the possibilities of ICT with the goals of sustainable development? Is this ability to shape our sustainable future in an Information Age an attainable prospect for architects as custodians of our built environments?

This chapter will begin by establishing commonalities of the overall goals of sustainable development and ICT. Furthermore ICT and sustainable development will be investigated on the basis that implementation of each is separately suited towards sustainability in architecture, and that alignment through common purpose is possible. Through an understanding of this, ICT will be more clearly defined as an integral mechanism through which sustainability in architecture may be holistically achieved.

It has been discussed in Chapter 3 that sustainable development, as a concept, is subject to re-evaluation and evolution. Humankind's transition into the Information Age represents a significant evolution in societal, economic and cultural practices, creating a new series of global challenges and opportunities. On the basis that the principal concept for sustainability is the pursuit of intergenerational equity, it thus becomes necessary to investigate the role of ICT, and the role of architecture in support of achieving this.

Where equitable growth and development are sought, greater feasibility for sustainable development is attained. The role of 'equity' in sustainable development will therefore also be investigated. Based on this understanding of (intergenerational) equity, concepts applicable to user experience in current architectural and infrastructural developments, such as the 'digital divide', will be given appropriate context for interrogation. It will be argued that systematic integration of knowledge-based technologies of a pervasive nature, through ambient infrastructure, will provide the greatest basis for equitable access to its derived opportunities, in much the same way as electricity and basic sanitation have become a staple of the built-environment user experience.

Following investigation of the proposed commonalities, a case for the importance of such an investigation in the specific realm of architecture will be established. The new challenges facing architects in the Information Age will therefore be investigated. These challenges include the recent phenomena of digital place-making and the perceived redundancy of existing structures and buildings which necessitate technological retrofit. The ongoing paradigm shift by global architects will be highlighted, prompting the importance for a proposal for an evolution of architectural approach.

To further understand the relationship of *information* and *development*, each concept will be isolated and defined, identifying deeper overlaps of importance and commonalities at their base level. With information serving as the basis for technology in the Information Age, and development serving as the basis for pursuing new architecture, these commonalities will be proposed to actively align through architecture in pursuit of equitable and sustainable future developments.

5.1.2. Establishing a framework for investigation of ICT and sustainable development

As has been discussed in the Chapter 4, ICT has pronounced itself as a relevant factor in today’s world, one that is already intertwined with every aspect of our modern lives.

To understand the importance of ICT for purposes of integration with sustainable development and architectural process, it is necessary to highlight those aspects that make ICT so important to this study. As a basis for future unpacking, these aspects can be summarised, but not limited to, the following:

- By recognising that ICT has a role to play in sustainable development, we recognise that the long-term successes of humankind are central to the concept. This requires a departure from a resistive, ecocentric approach of ‘limits to growth’ towards a future-driven approach of integrated and holistic development.
- ICT maintains an important role as enabler of information transfer.
- Information remains an important global commodity, but attains greater value and impact when made actionable. This transition to actionable information is recognised as establishment of knowledge. ICT is the mechanism through which this is made possible.

- Knowledge transfer through ICT is possible without physical, social or cultural limitation. This is a valuable opportunity for exploitation in the pursuit of equitable and sustainable growth.
- ICT is embodied in the digital and physical worlds, establishing links to both through tangible and available means. This provides the opportunity to depart from the geographical constraints of communication and lessen the impact of non-essential physical place-making.
- ICT is yet reliant on physical placement and infrastructure which is made possible, and efficiently so, through strategic architectural planning.
- Information overlay and integration is already prevalent in today's knowledge societies (see sections 4.1.5 and 4.1.7), with buildings and our physical environment serving as the backdrop to these phenomena.

ICT, which is defined as a system of computing rather than a collection of technological and digital products, refers to an ability to assimilate and interpret information from the seemingly infinite resources available throughout the globe, to communicate those aspects of it which are of importance to a specific task or operation, and facilitate strategy and coordination in order that this information be made actionable and relevant. This is a process specifically driven to operational efficiency without wasteful expenditure, while providing valuable knowledge to the receiver so as to enable future benefit. Such 'intelligent' applications have long been present in society, and many of these have found their way into the actual operational functionality of the buildings in which we live and work such as, for example, the use of Building Management Systems in intelligent buildings (see section 4.1.7.5).

A discord between advancing technology and fostering sustainable development is observed in their relative applicability. Technology embodies the advancement of a process or product in the pursuit of greater efficiency of a task or process. Where need emerges, technology is developed to meet this need. Sustainable development, as has been previously discussed in Chapter 3 of this thesis, is a concept that has been developed in broad terms with an inherent lack of specificity for focused implementation. In order to better align advancements in technology with sustainable development principles, a specific purpose or problem is sought for which certain technologies may be applicable. Thus Green Building has emerged as a focused sub-category of sustainability and brings with it specific avenues of approach towards which technology may be developed and applied. Energy efficiency is one such example. According to the United Nations Environment Programme, the built environment accounts for the consumption of approximately 40% of global energy, 25% of global water and 40% of global resources.[30]

As contributing factors towards the global warming crisis and the resultant social and political pressures for change, energy-efficient products and resource-efficient products, such as LED lighting, were developed in response and introduced to the industry as a means to curb the resource expenditure of the global building industry. This technological development is often responsive and reactive to need, and finds itself at a crossroads between bettering humankind's situation and potentially generating a profitable return on investment for its inventors. This reactive nature is prevalent since value is inherently linked to demand. However, this often makes the introduction of new technologies prohibitively expensive for early adopters, and thus results in slow availability to the mass consumer. Adoption of technology for sustainability is best pursued through the understanding and alignment of common goals. By proactively pursuing the goals of sustainable development, and thus creating demand through planning for future generations, sustainable development offers itself as a focused approach with the specific tools towards achieving this. It thus becomes important that those tasked with implementation and planning learn to integrate all available tools and align them towards common purpose. It is proposed that ICT and sustainable development are stakeholders in humankind's evolution and progress, and together can be combined to specific and common purposes in the built environment. This proposal will be investigated in this chapter to establish the feasibility of this assumption. In order to achieve this, commonalities of each will be identified with regard to:

- Stakeholder roles;
- Long-term goals;
- Principles of implementation;
- Abilities to respond to the evolving needs of humankind; and
- Abilities to respond to the evolving needs of the built environment and architectural professionals.

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[30] 'Why Buildings', http://www.unep.org/sbci/AboutSBCI/Background.asp [Viewed 9 May 2016].

Following this investigation, the observable commonalities will be summarised and highlighted in order to motivate feasible integration within the architectural design approach for sustainable development.

The first observable commonality finds itself in the pursuit of a fundamental goal as defined by the UN version of sustainable development. This fundamental goal is development with the aim of achieving intergenerational equity.

5.1.3. Intergenerational equity through knowledge

It is proposed that an evident commonality of sustainable development and ICT goals is in the establishment of the conditions for intergenerational equity. Sustainable development seeks to highlight the importance of ensuring current benefits extend towards generations of the future while ICT, in ideological terms, seeks to ensure that equitable benefit is offered to all without environmental, sociological or economic constraint. The responsibility to empower current generations to guide those that follow remains an important factor in ensuring long-term equity. Without transfer of knowledge, the successful ideas and products of today would be short-lived when deprived of the means to sustain themselves or adapt to future conditions. The conditions of achieving this goal will first be investigated in the realm of sustainable development as its association to this goal is widely recognised. Following this ICT will be explored for evidence of shared interest to this goal.

The concept of equity in sustainable development theory is already well documented and, as established by the UN, is rooted in social, economic and ecological factors. The social dimension is critical since an unjust society is unlikely to be sustainable in economic or environment terms in the long term (Jabareen, 2008:183). The pursuit of equity today is linked strongly to a right to freedom, access and operation. This necessitates that sustainable development at its core is required to empower without prejudice. Furthermore, it is found that social equity, welfare and economic opportunity are integrally related to environmental limits (Jabareen, 2008:183). A 2003 UN development report, focused on highlighting the risks of current trends of globalisation, states that the greatest benefits of globalisation have been experienced only by a fortunate few. If the currents trends continue, the global disparities between industrial and developing nations will move from inequitable to inhuman (Smith, 2003:165).

The nature of equity in sustainable development can be expressed in two forms. The first form is expressed as intergenerational equity which strives to meet the needs of current and future generations. Secondly, intra-generational equity which represents fairness in allocation of resources between competing interests. A more equitable distribution of power would contribute to environmental quality through, for example, stimulation of greater industry competitiveness. In terms of the built environment, this is achieved through the acknowledgement that it is important to build upon the concept of a building as an enabler (Jabareen, 2008:184).

While discussions have varied and numerous concepts have been developed, the basis for departure is seen in the findings of UN-sponsored papers and definitions for sustainable development, as has been previously discussed. Over the last 25 years there have been many global meetings on issues of development, with focus on four major UN-sponsored meetings and resolutions: Agenda 21, the Millennium Development Goals, the Johannesburg Summit and the WSIS. The evolution of thought within these meetings to the now established prerequisites for equitable and sustainable development is outlined below.

Agenda 21 was produced from the Rio Summit on Environment and Development in 1992, and was a statement of principles for environmental sustainability and development (UNCED). The program areas that constitute Agenda 21 are described in terms of the bases for action, objectives, activities and means of implementation. While Agenda 21 includes a section on means of implementation, it does not set forth targets or goals, instead recommending dynamic programs that could be suitably prioritised by stakeholders depending on their situations and objectives. Agenda 21 was thus promoted as an evolutionary document (Tongia, 2004:16) which would require advancement and specification.

The Millennium Declaration was adopted by the UN member states in 2000, followed by the Millennium Development Goals. These goals were projected as the road map for implementing the Millennium Declaration (Tongia, 2004:16) and included commitment to values and principles such as freedom, equality and respect for nature. These furthermore elaborated on resolutions to enhance development and eradicate poverty, protect the environment as well as the vulnerable (UN, 2000) and are considered to be the most extensive and sweeping to address most facets of human development (Tongia, 2004:15).

The Johannesburg World Summit on Sustainable Development (WSSD) in 2002 also elaborated on some of the targets of the Millennium Declaration. However, the scope of the Johannesburg Declaration was more extensive and included many areas of deprivation and action points. The summit chose to focus on five particular areas, water, energy, health, agriculture and biodiversity, known as the WEHAB framework. The summit also underlined the importance of technology for development such as cost-effective desalination of seawater recycling and renewable energy resources, diversification of energy supplies, advanced energy technologies and even phasing out of subsidies. Addressing the topic of ethics, the political global agenda, as is evident in the WSSD of 2002, addresses the 'deep fault line that divides human society between rich and poor and the ever-increasing gap between the developed and developing worlds pose a major threat to global prosperity, security and stability' (Jabareen 2008:188). Sustainable development is required to focus on poverty eradication, changing consumption and production patterns and managing the natural base for economic and social development, rather than purely on ecological matters (Jabareen, 2008:188). In addressing this, there was for the first time explicit reference to ICT for development. The importance of ICT culminated in the WSIS, phase 1 of which was held in Geneva in 2003 (Tongia, 2004:16).

A 2013 news article[31] on a study for the World Economic Forum, stated that a digital divide does exist and is seen to be most prevalent in the developing worlds. This was measured as a country's ability to make use of IT (computing, computers, and access to information) for growth and well-being. The outcome of this study indicated that where humankind was not afforded digital connectivity, these segments of society are seen to be deprived of the social and economic rewards that partner better ICT infrastructure and risk losing global competitiveness.

Quoting Bezanson and Sagasti, Mansell (1998:9) argues that 'the capacity to acquire and generate knowledge in all its forms, including the recovery and upgrading of traditional knowledge, is perhaps the most important factor in the improvement of the human condition'. He furthermore states that those without access and the appropriate capabilities risk being marginalised in the knowledge societies of the future (1998:10), and that the capacity to acquire and generate knowledge in all its forms is a critical aspect of the development process (1998:46).

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[31] 'Digital divide wide in developing world', 2013. http://www.news24.com/Technology/News/Digital-divide-wide-in-developing-world-20130410 [Viewed 10 April 2013].

A UN Global E-Government Readiness Report 2004, *Towards access for opportunity*, explains that access is required to reach opportunity. The link between access, information, knowledge and opportunity is not linear or unidirectional. Knowledge is an interpreted extension of information that captures relevance and context, and it is closely coupled with opportunities (Tongia 2008:30).

As can be observed in the most recent UN-sponsored resolutions and research, political will is moving towards equal opportunity and empowerment and integration of ICT as a facilitator is essential to developmental success.

Technology remains as the fountainhead of economic growth. However, it is evident that technological prowess alone is inadequate to guarantee success. Other factors matter: its relevance, availability, affordability (on an individual and governmental level), speed of diffusion and the social and environmental costs for harnessing it. Each of these factors is furthermore complicated through scale of implementation, be it the individual, the greater populace or branches of government responsible for laying the foundations for broader implementation. The development divide seen among and within nations is due to these factors being different between countries, rather than due to technologies specifically (Tongia, 2004:7). The responsibility therefore lies with designers and industry professionals to understand the contextual opportunities in the creation of enabling environments and systems to provide equal opportunities for sustained benefit and contribution.

> ‘We must look ahead at today’s radical changes in technology, not just as forecasters but as actors charged with designing and bringing about a sustainable and acceptable world. New knowledge gives us power for change: for good or ill, for knowledge is neutral. The problems we face go well beyond technology: problems of living in harmony with nature, and most importantly, living in harmony with each other. Information technology, so closely tied with the properties of the human mind, can give us, if we ask the right questions, the special insights we need to advance these goals’ (Herbert, Simon 1916 – 2001, Nobel Laureate in Economics, 1978)[32].

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[32] Simon, H. A. "Is it our job to forecast the future or to fashion it?” http://www.cs.cmu.edu/earthware [Viewed on 15 October 2012]

5.1.4. Global dualism

The internet is actively delivering access to information independent of geography, and free of physical distances that once perpetuated intellectual isolation. The internet has added a new dimension to inclusivity and awareness of world culture. A computer system has irrevocably changed communication forever, and its support for ever-improving software is continually ushering in new achievements in generated realism and quality of sensory experience. This information space is the first true example of a global technology of participation, creating a network model of individuals who in turn create nodes of shared meaning in virtual communities (Heim, 1998:160).

The former CEO of Google, Eric Schmidt, ahead of the release of his book delving into the future of humanity's role and capability in an age where the lines between the digital and physical realms of our world are blurring, stated in a recent news article that much of his research was devoted into the understanding that the ICT revolution is seen to be actively empowering people, rolling autocratic governments and forcing long-established companies to make dramatic changes as never seen before.[33]

Based on this premise it would be increasingly problematic should the building industry and its professionals not be open to that same paradigm – an opinion which will be expanded upon later in this chapter (section 5.1.3.4). Through technological innovation in hardware and software, for example through BIM and real-time internet-based project collaboration, it is evident that the advent of computers and computer-based telecommunication has now opened up new opportunities for architects that were previously technologically impossible: the opportunity to inhabit a different kind of space, the information space (Kalay, 2006:372).

5.1.4.1. Information space

Information space is realised in the digital realm. This realm exists in parallel with the physical, yet transcends its limitations for purposes of information transfer, both synchronous and asynchronous. Also referred to as cyberspace, this realm of

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[33] 'Ex-Google CEO shares vision', 2013. http://www.news24.com/Technology/News/Ex-Google-CEO-shares-vision-20130422 [Viewed 22 April 2013].

existence is established as an 'other' place, a dematerialised world created by technology, readied to enact the deconstructed self (Dyson, 1998:31). When exploring cyberspace, this is described as an interested party who visits digital libraries, sometimes purposefully or coincidentally, in order to obtain information to augment their knowledge or learn something new (Navrat, 2012: 174). Furthermore, in this capacity, the range of possible cognitive experiences is not limited.

Where modern science has failed to incorporate or appeal to the human psyche, cyberspace offers refuge, and this remains the primary reason for its popularity (Wertheim, 1998:53). Digital thresholds suffixed by '.com' represent more than a means of communication, they represent a freedom from the contention that we are limited by our physicality by offering a space for the 'soul' to call its own (Wertheim, 1998:47). Yet cyberspace is not just a place for the individual soul, but a collective place for communion of the many. While the body may be seated in the physical world, while linked in to the infinite depths of the internet one's self is no longer be located in physical space (Wertheim, 1998:54). The space and its information-seeking inhabitants form a forward-looking 'single' digital world of information resources offering avenues of information searching, personalisation, social networking, or contextual consideration (Navrat, 2012:175).

The digital environments offer a new kind of 'place' through which our minds experience three-dimensionally extended yet virtual forms, creating a paradox of the immaterial with what is perceived by the body to be real (Davies, 1998:145). Through the act of changing space from physical to the immaterial by leaving behind one's usual sensibilities, it is not the place that is changed, but rather one's own nature (Davies, 1998:146). In this new plane of existence, a new form of social navigation is introduced that may investigated from the various domains of both the 'real' world of human activities and 'virtual' world of information space and cyberspace (Munro et al., 2012:2). This social navigation occurs across different types of virtual worlds, considering the creation of, and behaviour within, social settings and 'places', the sociality of information creation, people as members of groups, and the nature of information itself through its location, evaluation, and use (Munro et al.: 2012,3).

5.1.4.2. The continued rise of a cultural shift

Today the context of a digital task extends beyond the world of work, play, travel and dwelling. Whether features are understood and applied depends on the context in which they are encountered. The role of computing has changed by virtue of the fact that IT has become the ambient social infrastructure and this therefore allies it with architecture. Computing is not just made of objects, it now consists of situations (McCullough, 2004:21). Formerly, architecture assembled form through the creation of variations in closure and storing an energy that could only circulate in rigid relationships of space (Beckmann, 1998:13). Architecture is now required to emerge in dual form, through emergence of an architecture that 'casts no shadows' (Beckmann, 1998:15). Munro et al*.* (2012:3) state that the general concept of interacting with computers can be seen as 'navigating' in information space. Furthermore, whereas traditional Human Computer Interaction (HCI) places the person outside of, and separate from this information space, this alternative view of HCI as navigation within the space sees users as inhabiting and moving through their information space (Munro et al., 2012:3).

This global demand is also seemingly undeterred by cross-cultural difficulties, as cultural difference is absorbed in favour of uniformity via the interests of global commercialism, resulting in an expanded and homogenised target audience (Dyson, 1998:29).

Through virtualisation of information, Heim (1998:160) interestingly observed that people ascribe the digital locale through spatial metaphors. The World Wide Web can be seen to exist in 'cyberspace', web pages are created as 'home pages', while businesses create 'websites'. The language is one of place, location and spatiality. Through these spatial metaphors, humankind is actively seeking to 'inhabit' electronic environments.

These linked realities are driven by rapid advances in computing and communication technologies. In this era, Moravec (1998:92) hypothesised that people will be seen to spend more time 'linked in' to the digital world than experiencing their immediate physical surroundings, access to technology permitting. Despite the debate of accessibility due to factors of affordability exist, the trend and demand for broad-reaching global availability of this digital realm are prevalent. This hypothesis will be expanded on in the next section by highlighting current technological applications and trends.

5.1.4.3. Living between the virtual and the physical

'Information is the prosthesis that props up the obsolete body' and 'what is important is the body as an object, not a subject – not being a particular someone but rather becoming someone else' (Stelarc cited in Massumi, 1998:335).

The virtual dimension has created a decisive cognitive rupture with accepted understanding and relevance of Newtonian concepts of space (Beckmann, 1998:4). Computing has resulted in the creation of a society whereby success in operations is no longer associated with the physical. The concept of a working environment is often attached only to the device upon which productivity in labour is achieved. In this ‘new world’, the ability to perform is not dependent on the physical environment but limited instead by hardware and software. An accountant, for example, need not be provided with an office facility to function, but instead a laptop, spreadsheet software and an internet connection would suffice. This has dramatic consequences for the profession of architecture as it is no longer a requirement to be provided with diversity of physical environments, each unique to a specific action or reason for being. The concept of space now exists in the digital and physical realms which enable the execution of a particular activity.

The global village has resulted in a capacity for organisational and company structure to allow for a staff complement comprising individual employees separated geographically and linked only by communication infrastructure and source of salary. The architect of today is thus presented with the current reality that humankind’s requirement for provision of optimised ‘conditions’ for purposes of work, play and living are not due to the physical environment, but often separate from it. The researcher is therefore of the opinion that architecture is in danger of being devolved to the creation of beautiful ‘envelopes’, within which greater function and operational effectiveness are being advanced by the detached, post-design introduction of smaller-scale technologies, devices and interconnectivity.

The future is currently being marketed as a world empowered through interconnectivity. With the development of immersive and augmented environments we have reached a new stage of evolution in the human condition through transition from analogue to digital modalities. These are zones of simulation, instant electronic transmission and simultaneity, removing all representations of the physical. The desire to be wired is the act of a larger fantasy of disembodiment, a desire to go beyond one’s body. The body is becoming a point of convergence, where humanity and technology combine to forge powerful new relationships (Branywn, 1998:325). By removing the sensory boundary between man and machine, the virtual dimension can be rendered real. Its future interface will not be sensory, but instead it will be emotional (Stenslie, 1998:25).

Google Glass,[34] as featured in Figure 5.1 below, represents a current merging of the digital and physical worlds. The device is an example of sensory interface which provides the user with a view of the world enhanced by a layer of overlaid data and information. This augmented reality operates by continually triangulating its location and orientation of view, interpreting digital markers associated to that place and time, and overlaying this gathered information onto the line of sight of its user through a transparent screen fixed to the frame of specialised glasses. Through input of the user by voice or touch requesting services such as navigation, information searches or recording of visuals, Google Glass responds in a manner that augments the user's visual and audible experience accordingly.

Figure 5.1: Google Glass wearable computing allows for an augmented reality experience of the world around us
Source: http://www.digitaltrends.com/mobile/entitled-acting-tech-nerd-kicks-google-glass-ban-controversy/#!6Y1zE [Viewed 1 July 2014]

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[34] Google Glass is an optical head-mounted display designed in the shape of a pair of eyeglasses. It was developed by Google in with the mission of producing a ubiquitous wearable computer. https://www.google.com/glass/start/ [Viewed 13 April 2014].

In its widely popular marketing campaign, the user of Google Glass could be seen to make use of the device and its ability to interpret information, to navigate through streets, and even the aisles of a book store (Figure 5.2). This has significance for architects. In the context of this global marketing campaign, the researcher interprets its message as indirectly presenting buildings as out-of-date and out-of-touch, prompting public enthusiasm at the prospect of being able to navigate them once more through the aid of technology in order to derive optimal use from our physical environments. Had the architect of the featured, yet anonymous, building known at the time of design that to efficiently operate within its walls would eventually require a navigation software to cater to the nuances of the user, it is possible the architectural design approach would have been far different. The architect should not be held to account, however, as the overwhelming majority of today's buildings predate the information revolution. What is clear is that we have entered an age where ICT and its devices are being credited as the enabling force to provide greater efficiency to our lives, and our physical environments are obstacles in which we now struggle to operate. Additionally, the ubiquitous use of ICT echoes with the basic premise of adaptable and intelligent building design in that buildings large and small are required to be designed, engineered and constructed to enable users to benefit from new, different and changing functions and thereby limit redundancy.

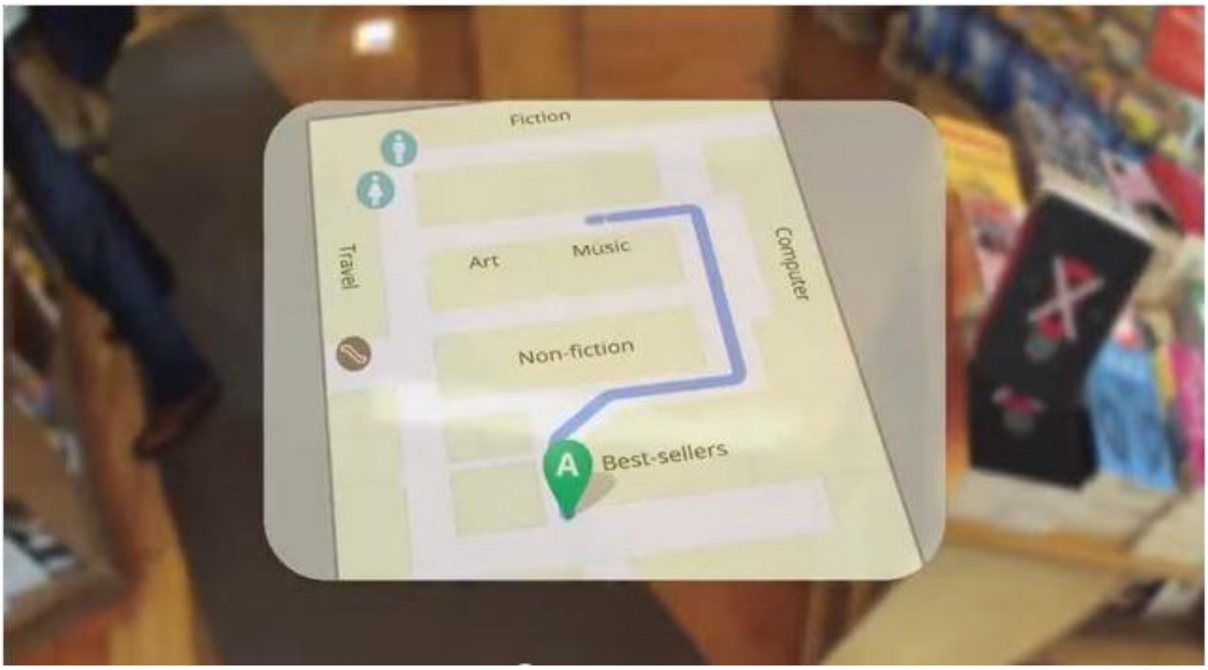

Figure 5.2: **Screenshot from Google Glass marketing film in which the user 'navigates' using augmented reality through the interior of a building (book store)**
Source: https://www.youtube.com/watch?v=ErpNpR3XYUw [Viewed 7 June 2014]

This has broader effects than the appropriateness of design as discussed above, since in some cases, buildings are no longer required at all, for example digital archives replacing libraries (Clements-Croome, 2004:viii). Architecture of old is perceived as obsolete, and the architect is being excluded from the conversation for improvement and advancement. The limits of the physical have now been eclipsed by the possibilities of the digital.

5.1.4.4. The virtual disappearance of the architect

A prevalent obstacle to inclusion of architects in the process of advancing user experience is the current paradigm of the architect. Architectural design seems to focus more on three dimensions of space rather than the temporal dimension that results in the use of that space (Ruby, 1998:182). The discipline is now invisible, with organisation of information now referred to as architecture (Beckmann, 1998:13). This is still observable today from the fact that the term ‘architect’ is now as synonymous with professions in IT as it is with design of our physical environments.

It is the opinion of the researcher that architecture currently finds itself complacently accepting that, as ‘a machine for living in’, our buildings will inevitably be subject to future retrofit of additional technologies in order to ensure continued usability. The question is therefore, why should any building be customised to fit a specific function at all during design phase? The age of technological retrofit negates the feasibility of making any building unique to a particular design brief at conception. Matter is about to vanish in favour of information.

To eliminate the time, expenditure and effort of converting a building’s use through integration of ICT, the buildings of tomorrow would hypothetically be far more future-proofed by adopting uniform and predictable forms. The act of modular retrofit and technological updating would be aided in this respect, consequently reducing the embodied energy and material wastage in such inevitable improvements. The tradition in building whereby the design of various components and services is undertaken in isolation from one another can be highly inefficient, particularly in energy use, but also in terms of cost (Smith, 2003:8).

In an early nineties interview Paul Virilio,[35] in the infancy of the Information Age, states that information can be seen to evolve constantly though history while being perennially ‘painted’ in perspective. This creates a difficult situation for architects in the sense that architecture, in its primary sense, is concerned with statics, resistance of materials, equilibrium and gravity. Architects are trained to work with the mass and energy of a building and its structure. However, in terms of information, architecture consistently remains behind the present development (Ruby, 1998:179). He furthermore states that one of the consequences of virtual space for architecture is a radical modification of its dimensions, which can be applied as an extension of the real space. The future therefore holds a meeting of the two, whereby space would be of both real and virtual nature. Architecture would be required to be split into two components. One branch would create the spaces necessary for physical survival, the other would produce virtual spaces to accommodate our sensory experiential requirements (Ruby, 1998:185).

Virilio concludes his interview poignantly through a metaphor relating to the meaning attributed to the physical by virtue of assimilation of information. To prehistoric man the mountain was an obstacle, as was its information. To modern man the mountain took on other meanings. It was attributed spiritual meaning, it was analysed for its geomorphological composition. For modern humanity the mountain contains a world of information, for prehistoric man it was merely an obstacle (Ruby 1998:185). The physical is therefore enhanced through embodied information, and through this attains extended relevance and appreciation.

As further testament to the required evolution of architects in the Information Age through an imagining of the future of the profession, Robert Venturi wrote: ‘Architecture was late in stylistically acknowledging the Industrial Revolution … let us acknowledge not too late that technology of now – of video electronics over structural engineering: let us recognise the electronic revolution in the Information Age … Viva virtual architecture, almost!’ (Mitchell, 1998:214). The researcher is therefore of the opinion that it is important for current architectural practices to heed these (still apt) warnings at the inception of the Information Age lest professionals render themselves unable to

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[35] Paul Virilio (b. 1932 in Paris) is a world-renowned philosopher, urbanist, and cultural theorist. His work focuses on urban spaces and the development of technology in relation to power and speed. He is known for his coining of the term 'dromology' to explain his theory of speed and technology. Source: http://www.egs.edu/faculty/paul-virilio/biography/ [Viewed 8 July 2014].

communicate and contribute in a shared information space accommodating human activity in the 21st century.

5.1.5. Identifying commonalities that bind the importance of ICT with concepts of sustainable development

In order to understand the relationship between ICT and development, it is necessary to define ‘development’ as a concept. Holmner states that this has been debated over many years, yet notably so in the 1977 conference ‘Towards Redefinition of Development’, in which development was defined as ‘making the Earth a fit place to live in’ (2008:42).

The relationship between information and development was recognised in a 2003 publication by the Development Bank of South Africa, titled the ‘Role of Information in Development’, in which the impact of access to and provision of information on development was quantified (Holmner, 2008:41).

ICT is now an irrevocable part of development and currently there are many initiatives, groups and programs working on ICT for sustainable development. For example, the ITU has formed a development group charged with ICT development and increased penetration, and the UN ICT Taskforce focuses on many aspects of ICT for sustainable development. In addition to these, the Development Gateway Foundation, supported by the World Bank, acts as a clearing house and repository for information on ICT and development. In 2001 the G8 also instituted the Digital Opportunities Task Force (DOT Force) to strengthen efforts on ICT development. The public challenge that Kofi Annan, the former UN Secretary General, made to Silicon Valley and ICT leaders in 2002 to make ICT relevant for global human development can be gauged by the level of the International Conference on ICT for Sustainable Development’s global visibility (Tongia, 2004:33). The WSIS, organised by the UN in conjunction with the ITU, importantly emphasised the growing relevance of ICT in the global domain. Phase 1 targets dealt primarily with ICT infrastructure, seeking to ensure connectivity and shared access to ICTs and internet for at least half the planet (Tongia, 2004:22).

Based on the Telecommunication Development Report (2003) developed by the International Telecommunication Union (ITU), an estimated one-third of the world‘s population has never made a phone call, and only one-tenth have used the internet. In spite of this deprivation over 80% of the world’s population actually has access to telephony; even developing countries have been shown to have about two-thirds coverage on average. The question then becomes not one of availability, but affordability, and perceived need for access (Tongia, 2004:25). The need for appropriate adoption, adaptation, and transfer, and the selection of ICT applications as a result of informed choices and the development of user capabilities should not be underestimated (Mansell, 1998:97). ICTs have many revolutionary implications, but in order to achieve their potential benefits it is necessary to focus on user-oriented and cost-effective applications rather than on technology-driven applications (Mansell, 1998:95).

Central to sustainability problems is the prediction, direction and control of current, evolving and future technology and knowledge development. This will quickly become mandatory, given the rate of information growth (Yang, 2005:xvi). An integrated approach would allow for proactive innovations to optimise energy of the built environment rather than just improve it reactively. For example, ICTs offer the opportunity to improve the way energy profiling tools and techniques are used to measure and inform the energy performance of buildings throughout their life cycle (Crosbie, 2011:205). If a nearly ubiquitous infrastructure were built and available, numerous development projects would be enhanced or enabled. Ending the digital divide should be a policy imperative by making ICT universally available, accessible and affordable (Tongia, 2004:85).

With recognised and increasing significance to the construction industry over recent decades, ICT possesses key characteristics that are capable of scoping, benchmarking, modelling, simulating, communicating and integrating processes and routines for sustainable development (Yang, 2005:xvi). Dedicated research will subsequently be required to identify future roles and priorities for ICT in sustainable development (Yang, 2005:xvi). Success of ICT for sustainable development requires integration, scalability and sustainability and is required to be integrated into development as well as engineering and societal systems. It is a means, not an end. (Tongia, 2004:13).

In architecture, the current trend is towards a more distributed and globally connected, yet integrated, process of architectural design. Technological revolutions have been historically closely linked to social evolutions. Typically, inventions of social, political and economic importance were incremental refinements of earlier technologies and social structures. However, some have had a ‘revolutionary’ force, resulting in major economic, political and social changes. ICT is regarded as such a revolutionary force.

ICT has made the production, manipulation, and interpretation of information accessible and shareable (Kalay, 2006:358), thus giving rise to our current ‘knowledge societies’.

A technological revolution that impacts information processing has the potential to affect the core processes and products of architecture, and have a ‘revolutionary’ effect on the profession and the discipline of architecture. ICT can do so by transforming the hierarchical design process into a network of design, manufacturing, marketing and management organisations, where the responsibility for design operations is distributed across multiple professions, organisations, and geographic locations (Kalay, 2006:358). It can do so by transforming access to information from a sequential process into a dynamic one, where decisions are made in an asynchronous yet coordinated manner. It can accentuate and promote the principles underlying architecture, while stimulating an integrative and systems approach, thereby promoting mass customisation and lowering costs without sacrificing quality. Furthermore, by embedding interconnected computational devices in both the building components themselves and the means of assembling them, the process of construction and its products can become more ‘intelligent’, able to respond to the changing needs of the occupants without redesign (Kalay, 2006:359), and improving product resilience and appropriateness.

5.1.6. Summary

In a world where social and political pressure is aligned to the development of the building industry towards pursuit of energy efficiency and adherence to ecological constraints of our planet, industry role players and stakeholders have been growing steadily more responsive. This response is greatly assisted through the development of new technologies in support of best practice in building product delivery. In addition to these waves of pressure relating to the need for applied sustainable solutions, the Information Age has furthermore created a similar pressure for meeting the information and communication needs of humankind. Research was thus conducted to understand if the demand for adequate reaction to sustainable and ICT-based development shared commonalities, as well as afforded opportunities for alignment. While technological adoption is a feature of human development, the applicability of information and communication was highlighted due to its prevalence as the defining technology of the Information Age. In order to understand the appropriate means with which to include technological solutions to sustainable development problems, the common goals to which both are applied were thus identified.

Sustainable development concerns itself with meeting the needs of current and future generations, and for this reason intergenerational equity was identified as a common factor of importance to sustainability and ICT theory. This takes cognisance of the fact that human need and development lies at the heart of both concepts. Therefore the drivers of long-term equity, welfare and economic prosperity were determined as the basis on which current interventions could empower and enable the end user. In both sustainable development and ICT this trait is shared, thereby highlighting that both could equally serve as a means to facilitate the other if correctly and jointly applied.

‘The Information Age is kindest to those who adapt’ (Smith, 2003:166). ICT is also one of the most important means of narrowing the gap between the rich and the poor. While prosperity and equity remain an important feature of the vision for sustainable development, an important contributor to achieving this is the means to generate and acquire knowledge. The impact of ICT and the creation of a global digital economy has therefore subsequently led to the emergence of the global phenomenon known as knowledge societies. These knowledge societies are a constant feature of the broader socio-economic and cultural context, and as such remain aligned with human development. Sustainable development is therefore similarly aligned with the preservation of this knowledge requirement if human progress is to be sufficiently facilitated.

Human life is interactive life, for which architecture serves as a backdrop. Today, IT has expanded the realm of communication to allow people to interact remotely, asynchronously and indirectly. Digital systems are carried, worn and embedded into physical situations in a manner that has fundamentally altered how people interact (McCullough, 2004:xiv). Computers have equally evolved to form ambient, social and local provisions in everyday life, and in doing so have established those realities and themselves as an indelible part of architecture (McCullough, 2004:xiv).

ICT is an irrevocable feature of modern life, pervasively intertwining itself with day-to-day tasks. In the context of the Information Age, the concept of reality has also adopted a different connotation. The digital realm has created a reality made up of bits and bytes, and as a result exists parallel to the naturalistic environment that we ‘see’ and ‘touch’. However, each reality is required to be understood and addressed, as aligning human development with the Information Age means to exist between these two worlds. Information space, dematerialised and virtual, serves as a facilitator of digital tasks. These tasks are now commonplace to working and living the Information Age, and as a result must be considered when addressing human development. However, for all the opportunities that information space creates, it also raises the question of the ability of the physical world to help or hamper global progress, and the role that our built environments might still carry to this aim. Global information and communication technologies are demonstrating proficiency in augmenting and even replacing our physical environments in pursuit of greater human efficiencies. The role of the building environment risks becoming redundant to digital practices, as by implication the role of the architectural designer risks becoming obsolete to the fluid and flexible virtual environments now on offer if design practices are not adequately responsive to the knowledge processes affecting sustainable development. An integrative systems approach is required to not only efficiently apply technology to product, but also address the long-term informational need that has been created by current knowledge societies. The following section will therefore address the feasibility of achieving this.

5.2. Addressing hypothesis three:

Hypothesis: Alignment of the goals of sustainable development and ICT provides a basis for advancement of sustainable development principles in architectural design process and product within the Information Age.

5.2.1. Introduction

Having investigated how sustainable development orientates its goals towards a future of equitable development, and that knowledge transfer through access to information and communication serves as the great equaliser of our age, it becomes clear that one cannot pursue *true* sustainable development in the 21st century without integrating both concepts. While the possibilities of sustainable development and ICT are possible to overlap and combine, this remains difficult to implement without direction. As has been discussed in earlier chapters, sustainable development is required to be implemented with focused resolve, and thus the researcher seeks to direct these concepts towards the realm of the built environment. The researcher recognises that sustainable built environments remain of value and importance, the goals of which require alignment to the realities and requirements of the Information Age. Sustainable built environments are therefore required to respond to needs of planetary ecology, social responsibility, economic feasibility and knowledge creation and transfer. The role of our built environment must therefore not be restricted to that of ‘audience’ to the evolution of our species, but more so as an ‘actor’ in our continued development.

Information and knowledge have no value unless they result in decision making and action (Holmner, 2008:44). Recognising the importance of sustainability theory and future equity of experience in architecture of the future requires a basis for implementation so as to give the availability of information in this digital age value. In addressing the proposed hypothesis it is therefore understood that pursuit of optimised architectural product cannot exist without treating the process.

In this chapter, previous investigations pertaining to ICT, principles of sustainable development, and the concept of knowledge societies through separate interrogation will therefore be addressed in aspects of common importance. By establishing the ‘overlap’ alignment of each may be sought so as to narrow the immense field of each down to a scale of feasible implementation.

Having identified commonalities between ICT and sustainable development, alignment of process pursuant to these commonalities will be investigated. Providing focus of approach through initial investigation of applicability for sustainable development principles in the Information Age will furthermore provide a basis for establishing applicable constraints for architectural process.

5.2.2. Sustainable development criteria for the Information Age

As an example of current initiatives in ICT integration in sustainable development implementation strategy, the European Commission’s Digital Agenda forms one of seven identified pillars for European Union growth by 2020. This Digital Agenda’s main objective is to develop a single market in order to generate smart, sustainable and inclusive growth (EC, 2015), and comprises seven pillars. While developed by the European Commission and developed for implementation within the European context, these pillars have global significance for the manner with which ICT is being integrated as an enabler of policy and strategy for sustainable development. While this is politically important for the European Union to promote internally, the researcher argues that, in the context of the global village and today’s interconnected information societies, this Agenda has significance for this thesis and as such is investigated below. The seven pillars of the Digital Agenda are therefore summarised as follows (EC, 2015):

- The digital single market: in recognising that we are physically regulated by travel constraints and a need for visa permissions, yet the internet does not stop at the border. Establishing a means to share ideas and services without constraint of trade or geo-blocking is thus important.

- Enhancing interoperability and standards: establishing a level playing field for devices and software by enhancing the interoperability of devices, applications, data repositories, services and networks in a review of standard-setting policy.
- Strengthening online trust and security: establishing measures to prevent cyber-crime and attacks while investigating the effectiveness of digital law enforcement.
- Promoting fast internet access for all: establishing competitively fast and ultra-fast internet access for all through next-generation networks (NGNs).
- Investing in research and innovation: promotion of world-class ICT research and innovation to boost growth via public-private partnerships.
- Promoting digital literacy, skills and inclusion: facilitate collaboration among business and education providers, public and private stakeholders to attract people into ICT education and overcome unequal access.
- ICT-enabled benefits: to exploit potential offered by ICTs in climate change, ageing population management, digitisation of content and intelligent transport systems.

The Digital Agenda recognises that the constraints towards implementation are contained in matters of policy, society and physical infrastructure for the delivery and implementation of material objects, such as transport and communication infrastructures.

According to the researcher, this agenda demonstrates that availability of information is but one component of sustainability pursuits. Availability is required to be aided in applicability of information. As highlighted previously in this thesis, where information is made actionable, the transition to knowledge is made. Holmner states (2008:60) that knowledge societies are a progression of information societies and as such both are conjoined concepts. Neither can exist without the other. Information is regarded as having economic value to promote development, and the use of modern ICTs leads to an availability of information that has the potential to affect political process and empowerment, reliant on a process of data exchange that is not biased by geography or context (2008:61). The information life cycle thus makes it possible for data to transform into information. This life cycle can become a knowledge life cycle depending on the requirements of the user (2008:45).

In Holmner's evaluation of criteria to establish compliance with the definition of a generic knowledge and information society, the following criteria are investigated (2008:71):

- Economic criterion
- Spatial and technological criterion
- Political criterion
- Social criterion
- Cultural criterion
- Physical infrastructure criterion
- Knowledge criterion.

These criteria are interpreted by the researcher to overlap with or extend upon the criteria of sustainable development, a correlation which will thus be investigated. In the context of this thesis, it must be remembered that specific application in the shaping the built environment is being investigated, for applicability in global contexts. For this reason the criteria for information societies will be investigated by the researcher to understand the implications for architecture and sustainable development.

5.2.2.1. Economic criterion

In addition to serving as a criterion for compliance with knowledge societies, economics is recognised to be a designated and important criterion in the three pillar approach to sustainable development as defined by the UN. In the context of this investigation, economics it will firstly be understood and defined as a concept, following which its applicability to the Information Age will be investigated.

As stated on the online resource Investopedia,[36] economics, often referred to as the 'dismal science', refers to the social science that is concerned with the study of how individuals, governments, companies and countries make choices on the allocation of finite resources in order to satisfy their needs. Economics is generally broken down into two categories, namely: macro- and microeconomics.

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[36] 'What is 'Economics?', http://www.investopedia.com/terms/e/economics.asp [Viewed 25 January 2015].

Microeconomics refers to the behaviour of individual consumers, while macroeconomics is concerned with the behaviour of the broader aggregate economy.

Currently global economics is generally practised according to two popular approaches named the classical and Keynesian approaches. Classical economists follow the belief that markets are correctly functioning, will react quickly to changes in equilibrium, and that government policy and input should be minimised to best allow it to perform as it should. Keynesian economists are of a contrary nature. These economists instead believe that markets are slow to react to changes in equilibrium, and that active governmental intervention is required to re-establish or maintain equilibrium. Economics exists as a mechanism for understanding behaviour on a micro and macro scale as a result of our existence within a value-based society. Value is generally attributed to a commodity or product as a ratio of supply and demand. The greater the demand, the greater is the value. This value is then applied in compound effect when the commodity is judged on its availability.

Intellectual capital is the most valuable asset of the information and knowledge society and should not be ignored in favour of technological capacity (Holmner, 2008:78). With specific reference to the current economics of global capitalism, it would not be possible for these markets to function effectively without the inclusion of computers and telecommunication systems (Holmner, 2008:73). Additionally, affordability of implementation poses significant difficulty towards delivering usable content.

Information and knowledge societies both operate within the paradigm of the economics of information (Holmner, 2008:60). Access to information is the conduit through which intellectual capital is transferred, and technology remains the mechanism through which identification of pertinent information may be sorted and obtained. For this reason it may be observed that knowledge societies of today (the Information Age) have elevated the status of information to having intrinsic importance in the realm of economics. Access to information and intellectual capital is as much central to the concept of economics as trade of currency or other commodities.

With regard to global economic approaches, the classical approach would assume that the economic system is capable of rectifying itself in times of a disruption to equilibrium, with minimal regulatory or political input. Intellectual capital would therefore be assumed to involve itself as the demand emerges, with the availability of support technology being provided and developed on a commercial level for integration with society on macro and micro levels. The Keynesian approach would assume the contrary. In this approach it would be assumed that any tilt of the scale in service or disservice to a particular segment of society would require active input to rectify. This input would be expected from the private sector, but also equally from central government.

Both approaches are commonly used, with many proponents for each. It has been observed in this thesis, through phenomena such as the ‘digital divide’, that penetration of information capital and the infrastructure to support it in our knowledge societies is slow to develop. This indicates a greater social inclination towards the Keynesian approach. It is therefore the opinion of the researcher that long-term equitable success will be dependent on both a commercial and a regulatory stance for implementation and availability to the precious economic resource known as intellectual capital.

5.2.2.2. Spatial and technological criterion

Space is defined as either physical or virtual, setting definable limits within which concepts or matter exist. In the context of a physical built environment, spatial elements are described as including rooms, atriums, hallways, and are understood to be definable and distinct entities. An organisation of a number of rooms as a composition – a space system (Leupen et al., 1997:31) – would seek to do so within a broader definition of space, thereby increasing or decreasing the scope of space depending on the scope of one’s actions or desires. The same can be said of the virtual – the information space. While physical space is definable and tangible, so too is information space, once defined parameters of composition and scope are attached. This is important as, if one were to use the virtual space of the internet as an example, this *space* is seemingly limitless. To derive actionable information – knowledge – effectively, applicable parameters of space must be defined. This can be self-imposed by the explorer, but would require pre-established goals and knowledge of the environment in order to better navigate. Parameters can also be imposed by an external third party. In the case of both the physical and virtual, predefined spatial parameters provide optimised environments within which learning and focused exploration are possible. This is additionally subject to the level of freedom the ‘imposer of spatial parameters’ wishes to make available to actors within these environments. Understanding the role of an environment – physical or digital – as enabler or inhibitor, as teacher or shepherd, or as an open or closed system, is a definitive prerequisite of any spatial designer. Furthermore, the decision to create static or fluid, self-regulating and adaptable boundaries is equally important. It should not be forgotten that evolution of technology has been historically and fundamentally enhanced by exploration and humankind's curiosity about the unknown. To attempt to manage this innate trait of our species is a decision that requires careful consideration.

Technology is an umbrella term which is used to describe applications or products which have emerged through scientific knowledge and discovery. Technology is a concept for the ages, encompassing those aspects of a civilisation at any given time which were thought to be revolutionary or even evolutionary. From the forging of steel, to the horseless carriage, to innovations in silicon computer chips and microprocessors, technology is a blanket concept that seeks to embody humankind's greatest scientific achievements. In today's Information Age, technology inspires imagery of touch-screen cell phones and tablets, of augmented reality glasses and driverless cars. Technology in this age is even further categorised into avenues of approach such as ICT as is discussed in this thesis. This represents the technology of knowledge transfer, and its existence as a concept is testament to the information revolution of our times.

Technology is more than theoretical, it is a physical embodiment of a concept. It remains of practical and applicable use to humankind and is developed for specific purposes. Technology represents something that is possible to hold in one's hand, to see, to touch and to experience. Technology is a mechanism through which possibilities are realised, but technology cannot exist without the presence of two major role players. The role players are *context*, and *the user*. The user of technologies is widespread, and most often in direct control of the technological application in question. The user, however, is not free to experience all technology since certain limiting factors continue to exist such as the prohibitive costs of certain technologies, or dependence on a certain supportive infrastructure (as is discussed in a later criterion). For example, if one were sufficiently fortunate to own the latest smartphone, its value as a useful device would depend on cellular reception, availability of Wi-Fi or even a charging point. Ultimately the user plays an important role for the simple reason that a technological artefact's value would decline even further if there was no-one in a position to actually use it. Context is important as another defining characteristic of what gives a technological element value. The core value of technology is found in its application. The digital or physical context within which humankind operates today is largely affected through technology, and affect is measured in quantifiable change to one's environment or circumstance. Context not only establishes the status quo, but also serves as the basis for departure upon which the need for future exploration is based. Technology is thus as much an enabler as it is a delimiter, setting boundaries for innovation and knowledge transfer or inspiring growth through unlimited information resources and communication possibilities.

Development is defined by Boon as ‘making the Earth a fit place to live in’ (Holmner, 2008:42). Development and the spatial criterion are therefore bound by the establishment of equitable and habitable spaces through physical or digital place-making. As has been discussed, the realm of existence now transcends the physical with much of human existence now invested in the virtual. Emphasis on suitability of contextual sustainable development must not be underestimated. As with the economic criterion, it remains at the discretion of the custodians of this spatial and technological user-based ‘environment’ to define the parameters of the user experience. What this does, however, is lend scope to an otherwise limitless world of possibilities.

Through application of spatial and technological criteria to development in the Information Age, vagueness of approach is eliminated and replaced instead with actionable milestones and a freedom to discover new knowledge through selected processes based on user circumstances and contextual opportunities.

5.2.2.3. Political criterion

Holmner (2008:165) states that an information and knowledge society can be successful if the society has the necessary infrastructures and levels of democracy to ensure the information-based rights of citizen. The opportunity to act spontaneously in a diversity of fields outside of government control and the control of other central potential domination is the definition of ‘freedom’ according to the Freedom House, an independent non-governmental organisation. According to Freedom House, freedom is measured in a number of sectors, namely religious freedom, freedom of association, freedom of expression, media freedom and internet freedom. This is based on the penetration of civil and democratic governance.

According to the Freedom House 2015 annual report on political rights and civil liberties (Aghekyan et al., 2015:4), in the past nine years, the number of countries with declines in freedom have outnumbered those with gains. Of the notable developments that set the stage for the documented results of decline in freedom in 2014, the decline of internet freedom was established as a key contributor (Aghekyan et al., 2015:7).

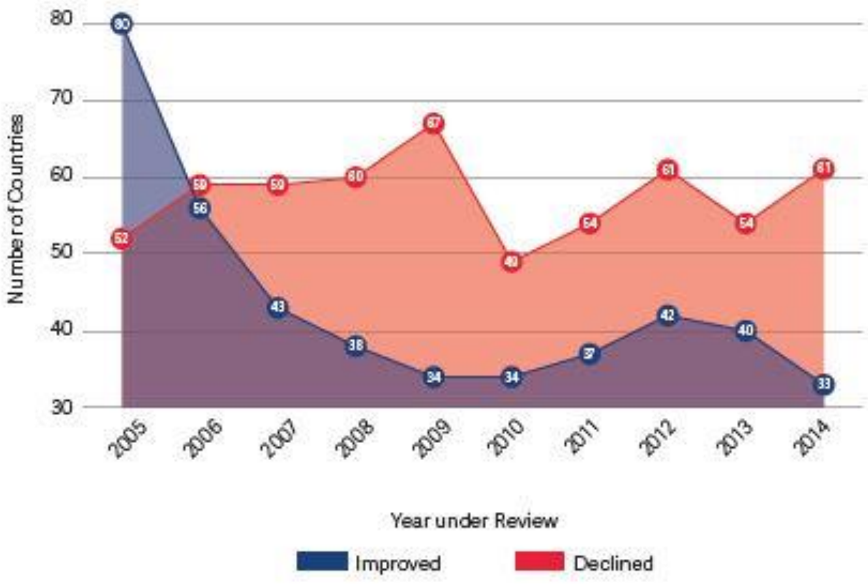

Figure 5.3: **Countries with declines in freedom have outnumbered those with gains in the past nine years (Aghekyan et al.: 2015:4)**

In Chapter 3 of this thesis, it was discussed that global sustainability trends are informed by social influence, which in turn creates pressure on government policy. Private enterprise is establishing new criteria upon which to develop, which is leveraging public and social support. This support carries with it influence, and global politics is constantly posturing to ride the waves of social pressure. Social support for freedom of information and digital internet access is overwhelmingly present in connected societies and as such the internet, as an example, has remained largely unregulated (some would say miraculously). International policymakers and governments are aware of the value that society places on information freedom, and has been actively representing its role as a supporter of this notion.[37] According to the UN, for example, the right to information underlies all other human rights. In the context of this thesis, the researcher agrees with this notion. Information predicates a more equitable existence, and through access to information, knowledge generation is possible.

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[37] 'Finland makes broadband a "legal right"', 2010. http://www.bbc.com/news/10461048 [Viewed 7 September 2014.

In pursuit of penetration of democratic values in society, the political agenda in the Information Age is required to establish freedom to pursue and access knowledge. In the context of sustainable development, this freedom should be provided in a manner that would support current as well as future generations. Development would thus be required to leverage current policy, or be established in such a way as to provoke sufficient public pressure to influence policy. While public pressure has been previously highlighted as a means to rally political support, this avenue of approach is not guaranteed to succeed and can take years to establish any cause worth supporting depending on the level of public profile.

One way in which the political climate is evolving in the Information Age is with regard to the regulation of information. Recent global occurrences of large-scale hacking and data theft have prompted governments into trying to assume some method of control over data distribution, access and digital realm anonymity. This has prompted concern from the private sector, citing ‘big-brother’ concerns. As reported in a 2015 news article,[38] the Cyber-security Summit of February 2015 saw the US President address attendees over the necessary integrated approach of technology companies, law enforcement and government to tackle concerns over privacy and encryption, yet three of the top four software companies in the world refused the invitation to attend. This was symbolic of a deep and current mistrust of over-regulation which might come at the expense of information freedom and right to privacy. It is therefore critical to recognise that while political support is understood to be an important contributor for creating and sustaining information freedom, this might create counter-productive conditions if pursued with the aim of controlling and monitoring a populace rather than enabling them.

In creating a case for sustainable built environments representative of a democratic Information Age, it would be necessary to evaluate the incumbent policy that would create a feasible basis for the design proposal, but also support its continued existence and the role it plays for its users.

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[38] ‘Three of Tech’s Top CEOs to Skip Obama Cybersecurity Summit’, by Chris Strohm, 2015. http://www.bloomberg.com/news/articles/2015-02-11/three-of-tech-s-biggest-ceos-to-skip-obama-cybersecurity-summit [Viewed 16 February 2015].

5.2.2.4. Social criterion

As with the economic criterion, the social criterion is represented in the UN-defined categories of sustainable development. If the social criterion is to be described by quality of life, this can be assessed, even quantified, by a number of factors. The WHO Quality of Life Group bases their assessment on, and defines the concept of quality of life as, an individual's perception of their position in life in the context of the culture and value systems which influence them, and interpret this in relation to their goals, expectations, standards and concerns (WHOQOL Group, 1995:1403). By assessing quality of life through these factors, it was assumed that results could be objectively obtained independent of various cultural settings. This assessment was also undertaken to evaluate the extent to which quality of life was determined individually, socially, and culturally (WHOQOL Group, 1995:1404). In order to correctly assess quality of life as a concept, it needed to be understood. The first assumption in its definition is the recognition that it remains a subjective concept. This concept can, however, be perceived in two levels: objective conditions (material resources), and subjective conditions (satisfaction with resources) (WHOQOL Group, 1995:1405). The second assumption is that quality of life is its multidimensional character. In recognition of this, quality of life is seen to include an individual's perceptions of the following dimensions: physical, psychological (cognitive and affective state), and social (interpersonal relationships). The third assumption is that quality of life includes positive and negative dimensions, and both should be interrogated in any assessment. In recognition of these three principal assumptions, quality of life is organised into six categories: (WHOQOL Group, 1995:1405):

- Physical domain
- Psychological domain
- Level of independence
- Social relationships
- Environment
- Personal beliefs.

Through this methodology of assessment the WHOQOL Group strives not only to redefine the concept of quality of life, but also to develop an international measure (Williams, 2000:13). Subsequent to its initial release, the assessment tool has since been recognised by the WHOQOL as requiring some modest re-evaluation. Early attempts at assessment that sought to investigate physical health while including psychological, social and spiritual domains of life, were inclined to focus on functional status at a singular scale rather than on the broader concept (WHOQOL, 1998:1569). Therefore in the past decades the WHOQOL Group has periodically reconsidered the concept of quality of life, but the process of measurement is still developing. This measure will yet require continued re-evaluation if it seeks to maintain validity and appropriateness. In this aim, and in the context of the thesis, this characteristic is shared with the measure of sustainable development as concept.

Information should be regarded as an enhancer of the quality of life within an information and knowledge society (Holmner, 2008:79). Information is attainable via many different sources, but for the purposes of this chapter the researcher will be investigating those mechanisms suited to interrogation as a product of the Information Age, namely ICT. Castells notes that, in the context of the information revolution, technology does not determine society: it embodies it. However, society also does not determine technological innovation: it uses it (2010:5). Castells further states that the dilemma of technological determinism is most likely a false problem, since technology is society, and society cannot be understood or represented without its technological tools (2010:5). The adoption of technologies is directly influenced by the social paradigm of the time. For example, at a time when IT was in its infancy in America in the 1960s and 1970s, when the US Defense Advanced Research Projects Agency (DARPA) was investigating a decentralised communications network that could survive attack on any singular station by being made up of thousands of linked autonomous PCs, the libertarian spirit of the time appropriated this new technology and evolved this communications network into what we know as the internet today. Had this network been developed within a different period, political context or social paradigm, it is likely that its technological adoption would have fared differently. If innovation is a derivative of perceived need, societal needs in pursuit of enhancing life are a principal driver for technological development. In this case, when freedom of expression and thought was sought, the technology was embraced as a mechanism for free access to information and communication.

Since information is understood to be an enhancer of quality of life, in the context of sustainable development, its role must be investigated as satisfying, as a minimum requirement, the six categories deemed to affect quality of life as listed above.

5.2.2.5. Cultural criterion

In the context of the Information Age, Europe's Information Society Thematic Portal, Culture and Society section, states that digital libraries increase the accessibility of cultural resources, and open new ways to experience cultural heritage. In support of this ICT can play an important role in providing access to such culturally diverse content, preserving a nation's cultural heritage through initiatives such as digital libraries (Holmner 2008:258). In establishing a platform for investigating the cultural criterion, Holmner identifies the following indicators (2008:255):

- Language diversity
- Production of indigenous content
- Universal access to electronic information and cyberspace.

In support of sustainable development's goal to ensure that benefits to today's generation are felt by tomorrow's generation, the cultural criterion poses some challenges. According to its website, in a category dedicated to building inclusive knowledge societies, UNESCO states that freedom of expression is a human right that will take on increasing importance driven by the free flow of information and ideas, and by the ability to convert this into knowledge (UNESCO, 2015). The pursuit of development is therefore dependent on freedom of expression and universal access to information, and ICTs are the principal means through which information and knowledge are accessed (UNESCO, 2015). UNESCO furthermore highlights the importance of culture on the agenda, by stating that it serves as a force for promoting social cohesion and youth engagement, acting as a basis for social resilience. In this category assigned to addressing the 'power of culture for development' (UNESCO, 2015), it is stated that no development can be sustainable without culture on the agenda.

When compared with Webster's statement that technology, specifically ICTs, are presented as the main motors for change, bringing about radial social transitions (2001:2), it is interesting to note that these same technologies are highlighted above as the main motors behind cultural preservation and remembrance in a time of rapid globalisation. This globalisation is a key aspect to understand since it identifies a process of increasing interpenetration and interdependence of activities on a global scale which occur in real time. This globalisation is concurrently linked to 'a decline in national sovereignty' (Webster, 2001:3), in which no country can exist in isolation, yet is required to participate in a global manner, be it on the stock markets, or in politics. This has implications for culture in the simple manner with which a sharing of practices and ideas across borders creates an evolved *modus operandi* for effective and efficient living and working. As stated by Webster (2001:4) however, these trends can also be seen to stimulate a decline in community, replaced with associative relationships, existing in a state of post-modern relativism in which values and conduct are regarded as highly differentiated, incommensurable lifestyle choices.

Based on the above, it is proposed by the researcher that culture is therefore a determinant of the current trends of a particular generation, in a particular context, at any given point in time. This does not imply that understanding of any particular culture should be forsaken for the varying trends of an evolving society, but it should be recognised that recognition of cultural value and influence is beneficial, and that preservation of cultural history should be maintained. The researcher extends this by recognising that cultural practices may often become impractical or contradictory to societal norms as time passes, and as a result may thus become discarded or forgotten. The Information Age provides a platform upon which digital memory may be stored for long-term, equitable and global access. This bridges culture and heritage, both of which exist concurrently as concepts.

5.2.2.6. Physical infrastructure

Infrastructure can be defined in many ways, and is dependent on its context and applicability. Holmner refers to Britz et al. (2006) in stating that the information and knowledge society of today is still underpinned by a reliable, and highly sophisticated physical infrastructure (2008:282). The infrastructure of society is broadly defined as including aspects such as roads, airports, railways, motor vehicles and warehouses (2008:284). Without reliable infrastructure, the continued feasibility of the information and knowledge society would be seriously compromised. The ability of any country or region to produce, store, transport and export goods has a direct impact on the economy of that country, impacting directly the level of local and international economic interest as well as GDP. Holmner states, however, that the physical infrastructure criterion does not have a direct impact on the interaction and exchange of data, information and knowledge on both a local and global scale, but does affect other criteria, such as the economic criterion, which in turn have a bearing on the interaction and exchange process (2008:285).

While the presence and numbers of infrastructural elements such as motor vehicles, roads and airports, have a bearing on the infrastructural level of a country, not every country is the same. For an evaluation of the feasibility of sustainable development within the Information Age, the researcher proposes that there are levels to infrastructure that are possible to investigate on the basis of scale of implementation. For this reason, it is important to evaluate the presence of physical infrastructure as a facilitator of information transfer.

As has been previously indicated in the economic criterion, knowledge and information have value as a form of commodity, and hence the production, storage, sale and transfer are as vital to the digital age economy as physical goods and raw material. Furthermore, ICT infrastructure facilitates the movement of capital and the coordination of global production and transportation, allowing for new methods of international investment and expansion of services (Ngwenyama, 2010:237).

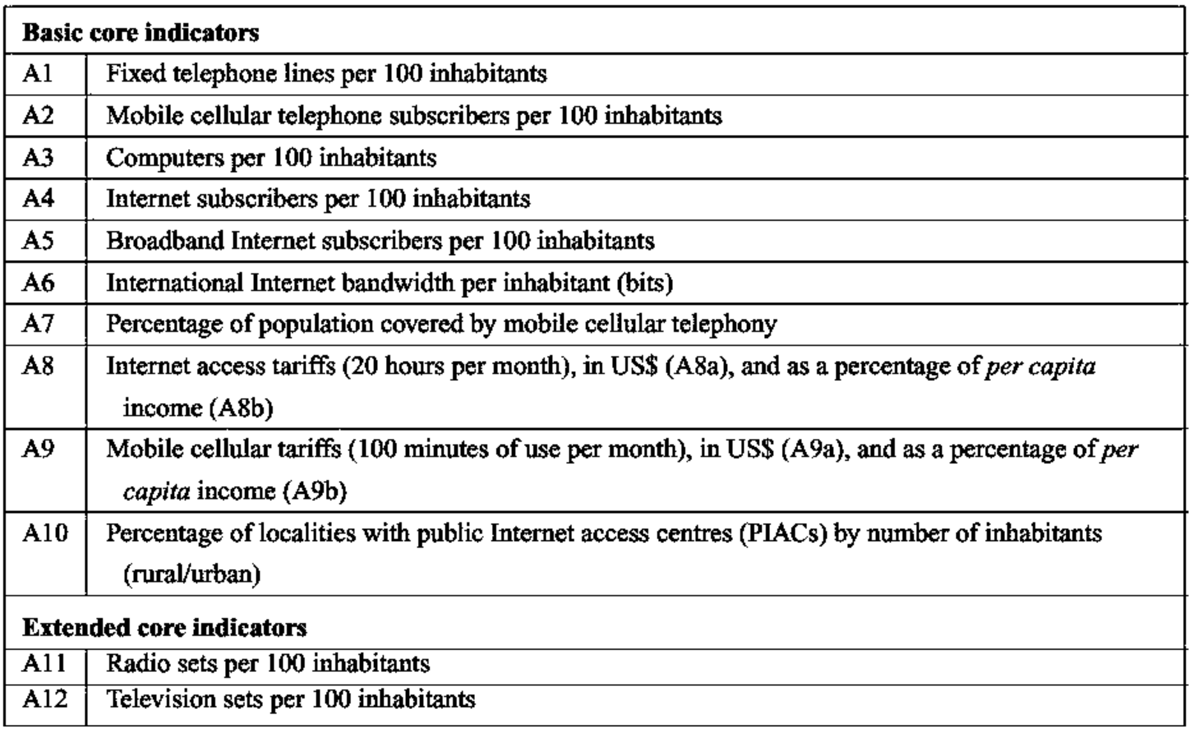
In a study investigating ICT infrastructure in Africa, Mayer et al. (2009:vi), use the term *coverage* instead of *access*, It is stated that the mandate for access reflects a political decision to establish targets for public ICT facilities, service and affordability. Universal coverage, however, is a more infrastructure-oriented concept that is easier to objectively quantify. The goal for global infrastructural development is towards universal coverage, which serves as a prerequisite for universal access. Universal coverage is deemed to be achieved in a country or locale where 98% of the population live within range of supportive infrastructure such as a mobile network signal, or where this same percentage of population has a connection (land-based) to broadband facilities.

ICT access is dependent on physical infrastructure coverage, since information requires a ‘conduit’ in order to allow it pass from sender, or storage, to receiver. ICT infrastructure on a country or city scale is therefore currently summarised, but not limited to, two broad categories.

The first category of ICT infrastructure relates to *voice services* through telecommunications. These voice services refer to the ability to communicate over distance through voice alone, and are accessible via fixed-line as well as mobile network coverage. The second category of infrastructure relates to *broadband data services*. Broadband data services refer to the ability to obtain, download and transfer data via peripherally connected devices. This importantly allows for access to information, as well as both synchronous (Skype, video conferencing, instant messaging) and asynchronous means of communication (email). It is important to note that while widespread ICT accessibility has been previously discussed as providing many social and economic benefits, there is a required monetary investment in order to establish the conditions for infrastructural coverage. Once coverage is achieved, achieving universal access to ICT services transitions into a matter of achieving social and political consensus on what level of services constitute a basic right, what skills are required by the population to derive optimum benefit from those services, and whether political will exists to invest the required public funds (Mayer, 2009:vi).

In order to quantify the penetration and availability of infrastructural coverage, core indicators have been established by the Partnership on Measuring ICT for Development, collected by the ITU as published in the World Telecommunication/ICT Indicators database (WTI) (Roberts, 2008:21).

Table 5.1: Core indicators on ICT infrastructure and access (Roberts, 2008:22)



Basic core indicators	
A1	Fixed telephone lines per 100 inhabitants
A2	Mobile cellular telephone subscribers per 100 inhabitants
A3	Computers per 100 inhabitants
A4	Internet subscribers per 100 inhabitants
A5	Broadband Internet subscribers per 100 inhabitants
A6	International Internet bandwidth per inhabitant (bits)
A7	Percentage of population covered by mobile cellular telephony
A8	Internet access tariffs (20 hours per month), in US$ (A8a), and as a percentage of *per capita* income (A8b)
A9	Mobile cellular tariffs (100 minutes of use per month), in US$ (A9a), and as a percentage of *per capita* income (A9b)
A10	Percentage of localities with public Internet access centres (PIACs) by number of inhabitants (rural/urban)
Extended core indicators	
A11	Radio sets per 100 inhabitants
A12	Television sets per 100 inhabitants

These indicators provide a quantifiable means to establish levels of community access based on infrastructural availability. With the growing uptake in global mobile broadband, the fifth WTI meeting in 2007 to discuss the requirement to re-evaluate the indicator resulted in agreement that the indicators did not require updating (Roberts, 2008:22). It is, however, agreed that for any investigation into community ICT accessibility should be regularly updated and re-investigated in order to correctly maintain accurate quantification with rapidly changing, and newly available technologies.

In pursuit of sustainable development in architecture, responsible analysis of infrastructural constraints is a prerequisite to determining an appropriate design response. It is the opinion of the researcher that, while designing for available infrastructural coverage is important, the indicators above should not be actively used as parameters within which design should begin, but rather as an active map to establishing what infrastructural shortfalls exist, and which therefore should be included in the project implementation strategy so as to achieve the ultimate goal of universal access. In order for ICT to justifiably serve the country, the community, or the local population of any architectural intervention, creating the parameters for equitable access to information are as important to sustainable development as all other criteria listed above. In this way, the built environment is actively required to evaluate the conditions of the greater locality, quantifying what shortfall in telecommunications might exist, for example, and establishing what form of infrastructural provision would best cater to this need. In an example of a fixed-line telecommunications shortfall, investigation into feasibility of installing this absent infrastructure, with likelihood of political support for public fund investment, could be weighed against leveraging the availability of mobile network connectivity. The statistical uptake of individuals in the area making use of mobile services could then be interrogated against the feasibility of available tariff rates to determine the current and future appropriateness for this particular infrastructural adoption. By establishing a means to evaluate trends of infrastructural adoption and requirements for growth, the researcher proposes that built environments would therefore be in a position to optimally comply with existing infrastructure, but adequately prepare for future need, hence catering to sustainable development principles.

It is also important to note that global ICT infrastructures contribute two to three percent of the global carbon footprint (Riaz, 2009:1) and, that subsequently, strategies for green ICT infrastructure should undertake a systematic approach. It should not be assumed that energy savings of individual ICT equipment or processes would result in overall reduction of global energy or carbon dioxide emissions (Riaz, 2009:2).

5.2.2.7. Knowledge criterion

In setting the stage for the knowledge criterion, Holmner refers to the Okinawa charter on the Global Information Society, which states that the resilience of a global information society depends on democratic values that foster human development such as the free flow of information and knowledge (2008:304). Knowledge has always been central to economic growth and the rise of social well-being, and the ability to invent and innovate, which is to create new knowledge and ideas that are embodied in products and processes have always served to fuel development (David, 2002:9).

According to von Krogh et al. (2000:4), the concept of knowledge is difficult to define because it can take on many faces depending on context. Two concepts of understanding of the term are offered here:

1. Knowledge as justified true belief. When knowledge is created out of a situation, it is done by justification of, and committing to personal belief or observation of the world. In this way knowledge is a reality construct rather than something that is universally or abstractly true.
2. Tacit and explicit knowledge. In this form knowledge is possible to document in paper form, or it can be linked to the senses or skills of the body and its movement. This tacit knowledge makes sense intuitively, although it is often hard to describe. Tacit knowledge is furthermore recognised to be shifting in nature, and strongly context specific.

Lorch states that it is important to distinguish between the notions of ‘information’ and ‘knowledge’ in the development of new ideas and skills, with particular reference to building performance. Knowledge is not easily transferable, and is formally attached to an individual or group, whereas, by comparison, information is independent of context (2008:2). Knowledge represents a more in-depth understanding of the subject and embodies the capabilities of assessment. These provide the basis for judgement, interpretation and understanding. In comparison, information represents simple storage of data which can be distributed or stored. Without contextual significance, and existing on its own, information does not provide any significant understanding and serves to limit the users acting upon it (Gann, 2008:37). ‘Knowledge is a key determinant of human well-being, with its contributions integrally linked to a societies system of capital assets and institutions’ (Clark and Holliday, 2006:2).

In establishing the criteria for investigation of appropriate development within knowledge societies, three indicators are identified (Holmner, 2008:305):

- The ability to interpret, translate, synthesise and make use of existing global knowledge as a prerequisite for the interaction and exchange process through computer and information literacy skills;
- Availability of ICT infrastructure; and
- Creation of local content as a basis for information exchange.

These indicators draw attention to the fact that a knowledge society requires some form of information feedback or exchange, and as a result the capacity of individuals as well as the environment to contribute to this exchange process should therefore be understood in the planning for sustainable development. Information technologies can affect knowledge creation in a number of ways, most notably in the sheer capacity that is afforded to individuals with sufficient levels of literacy and information accessibility (David, 2002:11). When compared to previous generations when intellectual centres were localised and available to the few, such as libraries or educational institutions, enabled accessibility through ICT opens the door to infinite opportunities for information exchange.

McCullough and Matson (2012:64) state that knowledge within a systems methodology is not the result of master design, but can be manipulated in ways that improve overall performance. The application of knowledge in this capacity mobilises science and technology, is more agile in the in the face of challenges, and more effective in contributing to sustainable development when combined with understanding from multiple sources. This contributes to the creation of learning-driven organisations that engage a broad stakeholder community in setting the agenda and process of accountability, and are more conducive to evolving to different challenges as they emerge.

In the context of the built environment, the appropriateness of any particular architectural intervention should be audited against the capacity of individuals to derive maximum potential for information exchange, based on the particular intended function of the building at any given point in time. With the aim of producing sustainable development representative of the knowledge criterion, an understanding of capacity of building users is necessary. Capacity relates to levels of literacy and infrastructure, and by interrogating each it can be determined if the ability of an architectural intervention to provide equitable access to information could be feasibly achieved. By understanding the constraints available to any particular context (in literacy and infrastructure), a strategic plan can therefore be developed to cater for the associated deficiencies. The challenge to sustainable development as has been raised previously in Chapter 3, is that to this point implementation of its principles has been reactive and largely dedicated towards achieving success at a fixed point in time. Knowledge that does exists is rarely effectively integrated into systems that support decision-making (Clark, 2006:2). By creating conditions for knowledge exchange, the goal of deriving intergenerational benefit is largely achieved by ensuring propagation and preservation of knowledge for the benefit of present and future global societies.

Information technologies, in the context of the Information Age, enhance creative interaction between product designers, suppliers and the end user. In an age of simulation, it also becomes possible to obtain information feedback on products or solutions yet to be materialised, opening up new possibilities for information exchange (David, 2002:12).

5.2.3. ICT and architecture

To modernity, technology was for world-making; to overcome limits and transcend what was presented to us by circumstantial placement in the physical world (McCullough, 2004:23). In pursuit of this the researcher proposes technological and architecture development share commonalities.

With the continued development of smart cities, intelligent buildings, and advanced digital ‘realities’, as discussed in Chapter 4, sections 4.1.7, 4.1.8 and 4.1.9, we are witnessing the early effects of IT on the processes and products of architecture. It is therefore necessary for future research into an assessment of accomplishments and an informed view of emerging opportunities in need of further development (Kalay, 2006:357). Conejos states that the design of future buildings with embedded adaptive re-use potential is a useful criterion for sustainability (Conejos, 2012:95), while technological innovation through IT can contribute directly to sustainability by increasing the efficiency and adaptability of products and processes (Fiksel, 2003:5336). McCullough argues that architects, and those in related disciplines of the physical environment, thus need to become aware of the challenges and opportunities raised by ubiquitous and pervasive computing which has woven itself into our lives almost invisibly. ‘They [architects] need to understand where technology is going, and what it has got to do with architecture … They have been conditioned to an outlook of continuing marginalisation’ (2004:xvi). When IT becomes a part of social infrastructure, it demands design consideration from a broad range of disciplines. Social, psychological, aesthetic and functional factors all must play a role in the design (McCullough, 2004:3).

Persistent structures and buildings remain essential to the way in which people understand and use the world (McCullough, 2004:xv). This serves as an important basis for the current IT paradigm shifts beyond those of cyberspace, as a basis for a new form of interactive design. Practising digital designers now make a case for design (McCullough, 2004:xv), a case which must be understood and valued by the designer of the physical. Appropriateness in interactive design must remain at the forefront of necessity – more features do not imply better technology. Architects are necessary to advance the science of the computer-human interface into a culture of situated interaction design (McCullough, 2004:22).

> ‘The “horseless carriage” paradigm views technology as a means to alter the perception of a practice about itself, as it is transformed by a new technology. In using the term a “horseless carriage” at the turn of the 20th century, the task of transportation has been described through the lens of a previous technology, not realising that the practice of travel had already dramatically changed. Understanding this paradigm requires asking a different question than the first one: rather than how can the new tools assist designers, one should ask how do the affordances they provide change to the practice of design itself?’ (Kalay, 2006:359).

According to Abel (2004:vii), architecture-technology relationships are commonly over-simplified, and while many designers may aim to be on the *cutting edge*, the processes that are used are comparatively diverse in how they conceptualise and maximise the use of technology. The popular architectural paradigm has, for this reason, been slow to catch up with the morphological freedom offered by digital technologies and recent trends. However, the 2015 JB Knowledge Construction Technology report[39] indicates that 40% of industry professionals make use of multiple forms of software to conduct their tasks, demonstrating a slow yet progressive increase in technological adoption in the overall construction industry.

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[39] ‘Three steps to utilise technology in construction’, Bigelow, B. 2015. http://www.enr.com/articles/9034-three-steps-to-utilize-technology-in-construction?v=preview [Viewed 08 May 2016].

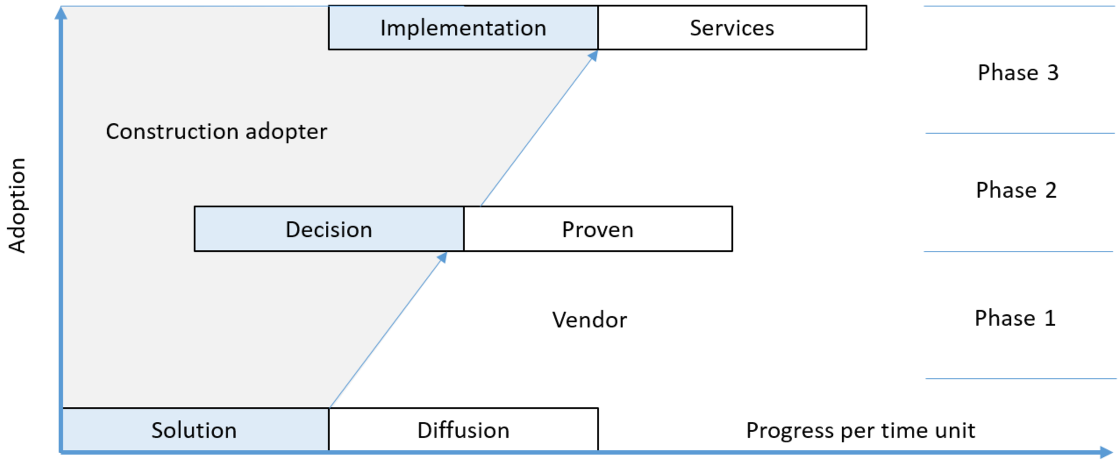

Figure 5.4: Construction Technology Adoption Model (CTAM) (Sepasgozar & Bernold, 2012:659)

In Figure 5.4, phase 1 of adoption concerns itself with the identification of solutions and information gathering. Sepasgozar and Bernold (2012:663) state that the decision to adopt new technologies is often the result of a variety of factors and functions based on perceived ease of use and usefulness, technology attributes, cost, availability, intention to use, organisation characteristics and attitude, as well as software vendor support and service. These factors contribute to inertia of adoption, often slowing technological uptake. Phase 2 concerns itself with the decision to implement and phase 3 with the actual implementation of the identified technology. In a study by Manley and McFallen (2003:6), it was pointed out that the most common driver for innovative technology adoption in companies was improved 'efficiency and productivity', followed closely by client pressure. By comparison, the factor of 'knowledge or information' is rated far lower, and 'quality' rated the lowest. This is indicative of the sentiment among architectural practices that technological adoption is more attractive as a business tool and driver of profit than it is a tool for pursuit of innovative practice. However, when the adoption of technology is focused in greater detail towards that of BIM – thereby demonstrating industry knowledge of advanced technological practices – the reasons for adoption change in favour of factors such as competitive pressure, policy pressure, and client pressure (Eddie et al*.*, 2013:347). A report on market adoption and growth in the construction industry by McGraw-Hill Construction furthermore indicated that while BIM adoption in 2009 was below 45%, the trends indicated a 10% increase of uptake per annum (Young et al*.*, 2008:2). This is evidence of the need to remain competitive in a changing market whereby industry requirements may ultimately exceed the design professional's ability to meet them without adequate technical, and personal development.

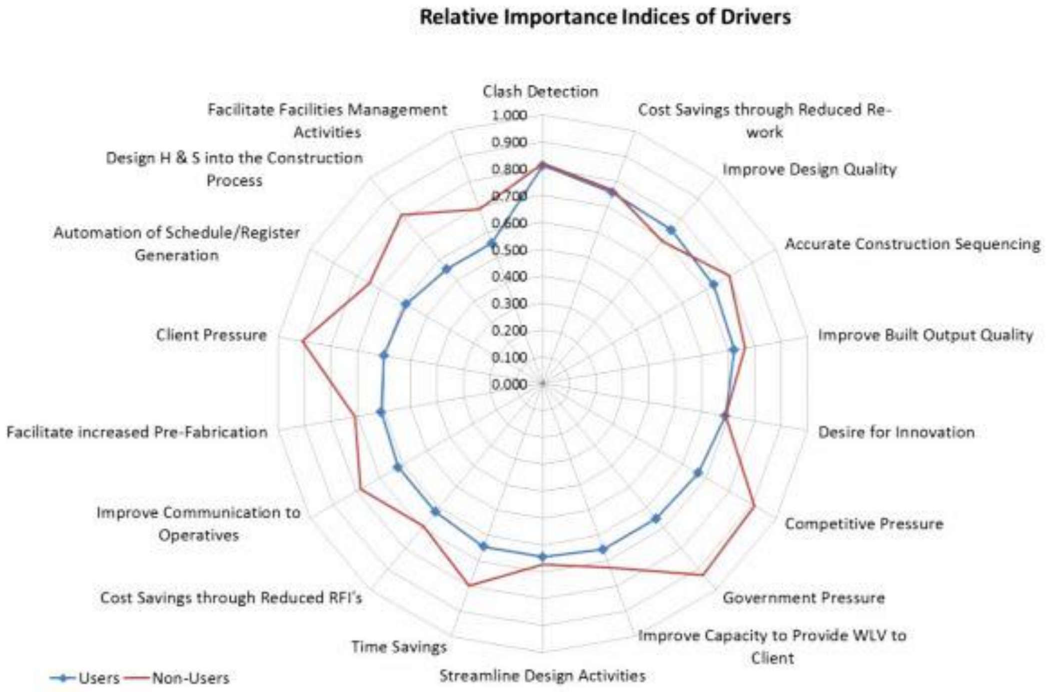

Figure 5.5: **Relative Importance Indices values for Users and Non-Users of BIM**
Source: Eddie et al., ITcon vol. 18, 2013, pp. 348

While technological adoption in process remains an important hurdle to overcome, technological adoption in the product is just as integral. McCullough states in his book *Digital ground*, that the 'saturation of the world with sensors and microchips should be a major story and an active concern for all designers (2004:xiii)'. To ignore computing would be to our detriment. To neglect further prospects in ambient, abundant IT will not negate their irrevocable importance in the world. It is thus wiser to accept them as a design challenge, to emphasise their more wholesome prospects, and to connect them with what we value about the built world (2004:xiii). In the future, computation will be human-centred. We will not need to carry our own devices around with us. Instead, configurable generic devices, either handheld or embedded in the environment will bring computation to us, whenever we need it and wherever it might be (McCullough, 2004:7). Digital networks are no longer separate from architecture. Pervasive computing has to be inscribed into the social and environmental complexity of the existing physical environment (McCullough, 2004:xiii).

> 'Today the context of a digital task has extended beyond the world of work, play, travel and dwelling. Whether features are understood and applied depends on context in which they are encountered. The role of computing has changed. IT has become ambient social infrastructure. This allies it with architecture. No longer just made of objects, computing now consists of situations' (McCullough, 2004:21).

Though digital experiences and increased globalisation are commonly pronounced through smaller high-value artefacts such as personal electronic devices and peripherals, it is affecting the way buildings are made. The Industrial Revolution provided architects the means to practise nationally and internationally, with materials and components supplementing this globalised approach through specialised manufacture and distribution by land, sea or air. Through the information revolution, design and construction professional teams can be created unrestricted by geographical location. To operate effectively in this manner, architects require knowledge and expertise in global construction practices and fabrication possibilities, market conditions, contextual characteristics, and available technologies for multidisciplinary collaboration (Mitchell, 1998:205). Information can be delivered through ICT, and explicit knowledge can also be delivered through ICT (Holmner, 2008:44).

5.2.3.1. Characteristics of ICT adoption in developed and developing contexts

While this thesis is written based on global intervention and applicability, the researcher notes that there are disparities between what is comparatively possible in developed and developing contexts. Du Plessis (1999:379) states that the international construction community's understanding of sustainable development is compromised by a communication gap between these contexts. It is furthermore argued that the inclusion of the developing world within the debate is essential if sustainable development is to be achieved. Sustainable development should not be restricted in its success by its geographical location or national boundaries, yet differences in contexts do exist. These differences must be understood if they are to be responded to appropriately in the interest of sustainable development.

In a news article in the *Wall Street Journal* by Julian Evans[40] (2010), it was stated that emerging and frontier markets are becoming too big to ignore, with three of the top five companies in the world by market capitalisation, and 10 of the top 20 funds of the past decade based in developing countries. However, this same article draws attention to

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[40] 'Pioneering on the Frontier – the possibilities and perils of emerging markets', by Julian Evans, 2010. http://www.wsj.com/articles/SB10001424052748703466704575489363001850690 [Viewed 7 March 2015].

the fact that even though opportunities exist, the perception of higher risk is attached. This risk is described in matters of lower levels of human rights, political instability, weak market infrastructure and high levels of bureaucracy. Considering that global economic growth has been notably contracted in recent years with particular emphasis on developed contexts, opportunities for real economic growth can be seen to be presenting themselves in developing contexts. It can thus be observed that not only is the debate on sustainable development ethically based in equitable expansion both in developed and developing contexts, but a real opportunity for global economic development also exists in doing so.

As has been discussed previously in Chapter 4 section 4.1.4 concerning the digital divide, there exists a disparity in society between those who have access to information, and those that do not. What is important to note, is that the digital divide exists in both developed and developing contexts. The diffusion of ICT has witnessed a marked increase in recent years, yet the rate of adoption across contexts diverges notably. This divergence is observable regardless of income levels of countries (Erumban 2006:302). Adoption rates are observed to be highly dependent on the attitudes of individuals within a particular context and may be influenced by that context's social and cultural characteristics (Erumban, 2006:308).

In 2015, a study by the ITU (2015) states that 40% of the world's population are using the internet, while two-thirds of these users can be traced to the developing world. In these developing countries, the number of internet users doubled to 1.9 billion users from 2005 to 2014.

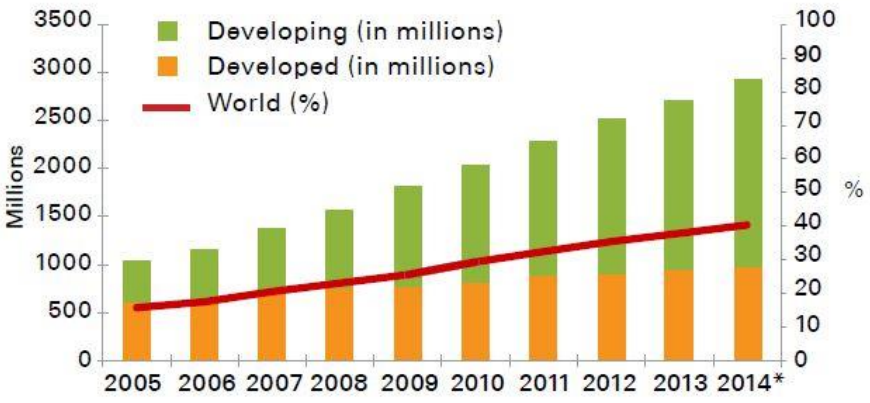

Figure 5.6.: **An estimate of individuals using the internet, total and percentage, 2005-2014**
Source: ITU database (2015:5)

In addition to internet access, it has been observed that the number of mobile-broadband subscriptions reached 2.3 billion across the globe, with 55% of these subscriptions prevalent in developing countries. Mobile-broadband penetration was estimated to have reached 32% by the end of 2014. This was double the rate of penetration three years earlier (ITU, 2015:1).

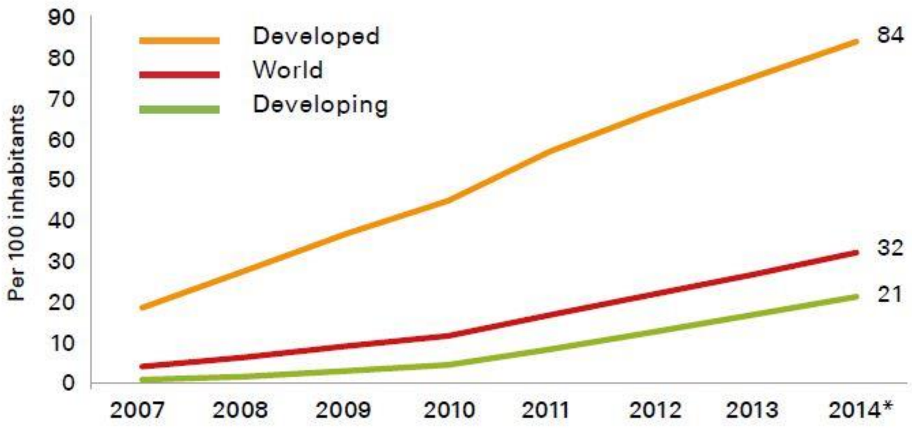

Figure 5.7: Estimated mobile-broadband penetration in the past 10 years
Source: ITU Database (2015:1)

Mobile broadband is observed to be the fastest-growing market segment with double-digit growth rates, growing fastest in developing countries, with 2015/2016 rates expected to be twice as high as in developed countries (ITU, 2015:1).

Interestingly, while mobile-broadband rates are on the rise in developing worlds, fixed-broadband growth is seen to be slowing (ITU, 2015:4). Global growth is estimated to be 4.4% in 2014 due to a slowdown in fixed-broadband penetration in developing countries from 18% in 2011 to 6% in 2014. In 2013 the number of fixed-broadband subscriptions in developing countries overtook those in developed countries (ITU, 2015:4).

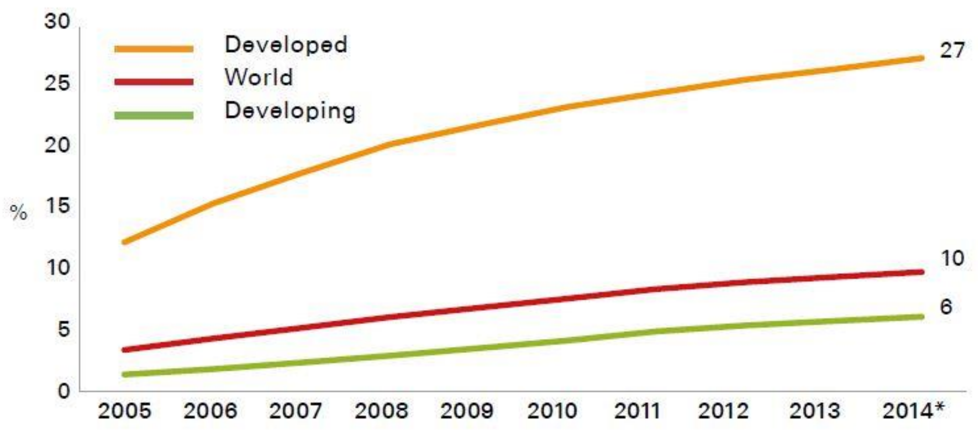

Figure 5.8: **An estimate of fixed-broadband penetration in the past 10 years**
Source: ITU database (2015:4)

These figures indicate that while ICT adoption is lower in developing countries, the trend for uptake is rising. This marks an interesting point in history whereby it can be seen that the Information Age is penetrating the global community. The conditions that define ICT adoption in a particular context cannot therefore be assumed to be a function of residing within a developed or developing context, but instead are observed by some to be a function of political and social conditions, as is explored below.

Figure 5.9 shows that even in countries of similar economic conditions, there is considerable divergence in adoption. The divergence in adoption rates can be seen to assume importance as most developed countries share similar structural and institutional characteristics, such as qualified workforce and modern infrastructure (2006:307).

As highlighted previously in this chapter (5.2.2.), a number of criteria are available for interrogation that determine the state of compliance with being an effective knowledge society. While various levels of compliance may be understood within a single developed country, it is also important to note that there are various prevailing factors within developing contexts that create restrictions on ICT pervasion and compliance with knowledge society criteria.

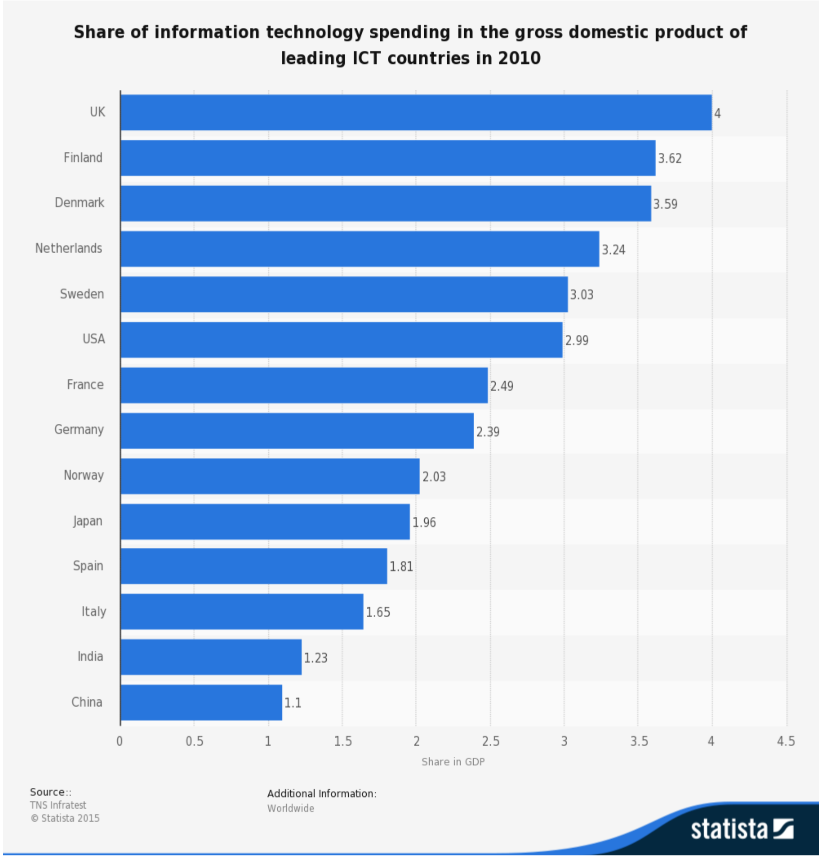

Figure 5.9: **Share of IT spending in the GDP of leading CT countries in 2010**
Source: http://www.statista.com/statistics/270566/share-of-it-expenditures-in-the-gdp-of-leading-ict-countries/ [Viewed 13 April 2012]

It can be observed, for example, that provision of technological infrastructure for ICT is currently sparse or not present in developing contexts (Holmner, 2008:74). This creates an unavoidable challenge to implementation of sustainable development in the Information Age, and as such the base constraints of a particular developing context should be understood and interrogated.

Statistically, developing contexts on average yield lower literacy levels than their developed counterparts. As has been discussed previously, literacy is an indicator for the social criterion, hence serving as an obstacle to free access to information and knowledge. This is not something that a single built-environment professional, or sustainable development planner can account for in any particular architectural intervention. This responsibility initially resides with context-specific policy, governance and educational legacy.

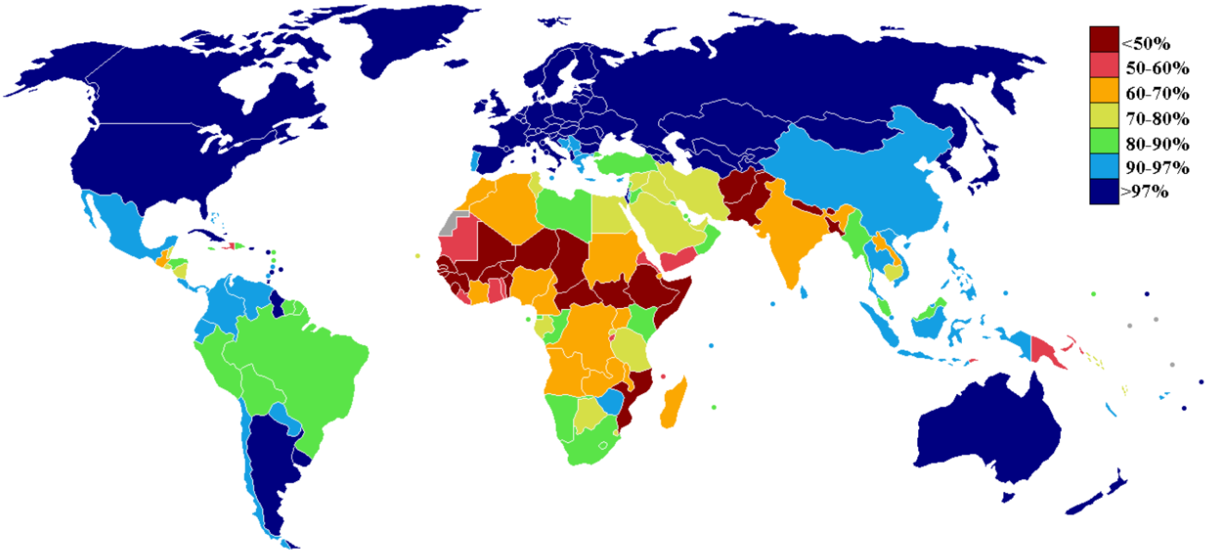

Figure 5.10: World literacy rates
Source: http://en.wikipedia.org/wiki/File:Literacy_rate_world.PNG [Viewed 13 April 2012]

In recognising that ICT adoption rates, even among countries of similar economic status, can be observed to be characterised by the attitudes and cultural environment a country (Erumban, 2006:308), the political attitude towards access to information is currently changing due to the wave of social pressure prevalent in the information revolution, as has been previously discussed in Chapter 3 of this thesis.

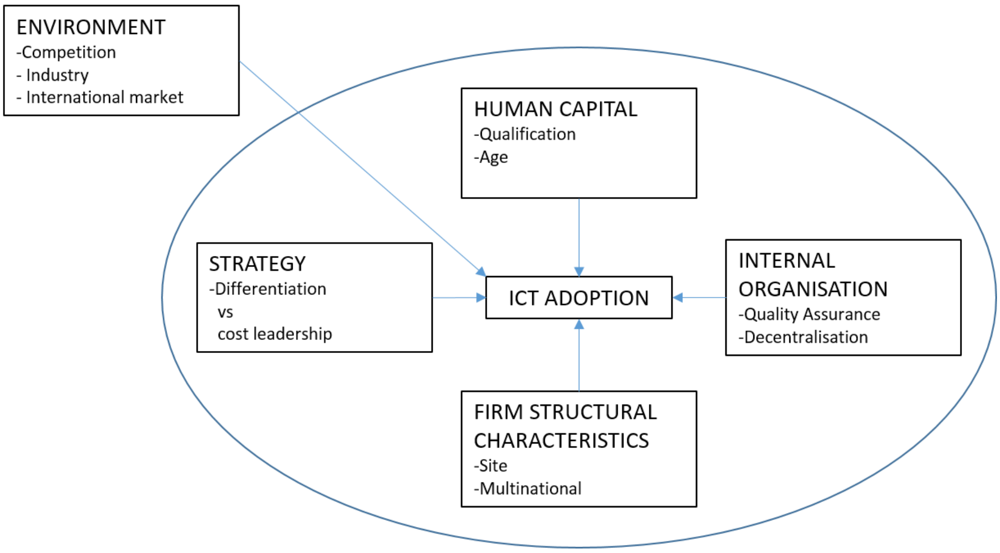

Figure 5.11: Theoretical model in determining factors for ICT adoption (Bayon-Moriones et al., 2007:354)

It has also been empirically considered by some that that competitive pressure can be seen as a determinant in higher ICT adoption, as indicated in the theoretical model above, while others similarly contest this hypothesis (Boyo-Moriones et al., 2007:354).

When comparing this conclusion with that of Erumban, citing cultural influence as a principal determinant, the researcher proposes that while competition can be seen to provide necessary impetus to individuals to adopt ICTs with the aim of increasing efficiency and knowledge in a particular field, albeit for personal or economic gain, this is still subject to cultural context, and sector of industry affected. Competition cannot be discounted, however, since levels of competition provide an indication of demand for a skill, service, product or social requirement. Competition is therefore better suited as an economic indicator rather than a key criterion for knowledge society compliance.

While the uptake of ICT technology in developing contexts when compared to developed contexts is generally slower due to concentration of technological roll-outs in contexts of higher potential usage volumes (and hence higher initial profit), this actually presents an opportunity for ground-up implementation towards holistically planned networks and infrastructure with planning for greater flexibility for more conceivable future technologies. Having already implemented vast networks of IT infrastructure – broadband internet and voice communication – in developing contexts, much of this infrastructure is currently in the process of being replaced or upgraded. Developing countries have the benefit of by-passing the technology learning curve already experienced in developed countries, and as a result minimise redundant infrastructure by catering to technologies too early only for these to fall out of favour.

An example of infrastructural redundancy to some degree can be observed in transmission of data via the internet for individuals which required the provision of a fixed-line and modem connection to a dedicated personal computer. Today, the greatest observable rate of penetration of global internet connections occurs through mobile technologies, as is referred to in Figure 5.8 (page 169). This is particularly prevalent in developing countries since the logistics required in laying or routing cables to all areas of their respective countries, especially rural areas, are both difficult to implement as well as costly. As a result internet connection through mobile devices and wireless connections, such as 3G, 4G and LTE, are proving far more accessible options for information connectivity by removing the need for laying of physical cables to urban and rural areas. Unfortunately, the costs associated with such wireless connections are proving high and out of reach of the average low-income populations, providing an economic boundary to an available opportunity to actively engage in current knowledge societies. This integration without a prerequisite for physical connection or plug in point has implications on the design strategy of the future, particularly in developing contexts, in order to minimise future upgrade or additional retrofit to maintain a building's role as a sustainable enabler. It thus becomes possible for the built-environment professional to establish that connectivity within certain contexts is achieved, for example, by a majority though mobile devices and wireless technologies, and therefore cater to the prevailing conditions appropriately using the benefit of global hindsight.

In determining the capacity for adoption and technological accumulation in developed and developing countries, two stocks of resources are identified (Bell, 1997:84), namely:

- Skills, knowledge and institutions that determine a country's capacity to generate and manage change in the technology it uses; and
- Capital goods, knowledge and labour skills required for production.

These resources may be observed to overlap with the previously identified criteria, specifically those of knowledge (section 5.2.2.7.), physical infrastructure (section 5.2.2.6.) and technology (section 5.2.2.2.). While these overlap, the researcher interprets these to be production-focused and better suited to evaluating industrial capacity instead of capacity for sustainable development. It is for this reason the researcher will continue to refer to the previously described key criterion as a suitable basis for interrogation of compliance in both developed and developing contexts.

While it has been discussed that differences do exist between developing and developed contexts, as well as internally within each context, it is understood that in the overall international community ICTs are widely tasked with the role of becoming a powerful tool of development and poverty eradication, through pursuit of achieving the Millennium Development Goals. Many development organisations, such as the World Bank, regard ICT as a tool for development with many current programs having an ICT component (Holmner, 2008:74). It is therefore the position of the researcher that each context requires thorough investigation, that designation within a developed or developing context cannot be assumed to carry with it predetermined success rates of ICT adoption. It is also proposed that the equally measured importance of ICT integration within both developed and developing contexts for planning future sustainable development cannot be overstated.

5.2.3.2. Integration of concepts within the built environment

The Global Knowledge Partnership Foundation[41] is an example of a worldwide network devoted to implementation of sustainable and unbiased development through the power of information technologies. In recognising the significance of ICT in sustainable development, integration is the middle ground between design and technology (Bachman, 2003:viii).

The process of integration refers, in the context of this chapter, to the means of bringing together complex concepts in recognition of a shared and common purpose. In this chapter, it has been observed that the goals of sustainable development and ICT overlap in particular ways when evaluated against the requirements of today's knowledge societies. It has also been observed that these goals are possible to assimilate into planning of the built environment.

As director of the Centre for Development of Informatics at the University of Manchester, and a founding academic developing the field of 'ICT4D' (Information and Communication Technologies for Development), Richard Heeks's Design-Reality Model has been used since the late 1990s to illustrate the successes and failures of ICT4D projects, and through this model illustrates the importance of placing focus on information as opposed to technology in pursuit of bridging the digital divide (Holmner, 2008:44). Here, emphasis on technology is less important than knowledge transfer. To understand how to enable the greater population to achieve equity in knowledge, one should not pursue the introduction of technological artefacts, but embrace a culture of connectivity so as to facilitate the emergence of connected cities and infrastructure so that access to information becomes pervasive and ubiquitous. It is only when we are immersed without conscious effort to attain benefit that we are freed to explore our potential. A person who is required to concentrate on their next step moves less freely than another who walks unconsciously.

The responsibility to provide enabling environments in our knowledge societies requires our physical environments to become ambient (ubiquitous) infrastructure, to support knowledge transfer.

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[41] The Global Knowledge Partnership Foundation has the role as knowledge broker, networking, communication and dissemination, logistics partner for all organisations, companies and, governments involved in development. http://gkpfoundation.org/ [Visited 2016-09-07]

Architecture is arguably already among the most inclusive of all disciplines. Concepts of psychology, art and engineering are coordinated and combined in the production of building design. Integration therefore concerns itself with the aspect of architecture in which design opportunities are enabled through technology while assimilation of design criteria converge these possibilities towards a final solution (Bachman, 2003:vii). For this reason, the researcher argues that architecture perfectly presents itself as a sector conducive to effective integration of concepts of sustainable development, including ICT, in the Information Age into product and process.

As mentioned above, integration is suitably attainable when attributed to a particular solution. In the architecture, the *solution* is embodied in three scales of implementation:

- Context and environment
- The building
- The user.

In order to ensure thorough integration of concepts, each of these scales of implementation are required to be interrogated according to the established criteria of sustainable development in the Information Age, as listed in the previous chapter. These criteria are again listed as follows:

- Economic criterion
- Spatial and technological criterion
- Political criterion
- Social criterion
- Cultural criterion
- Physical infrastructure criterion
- Knowledge criterion.

In addition to this, the criterion of ecology must be incorporated. While this remains a basis for the principal three pillars of sustainable development as referred to in Chapter 3, the built environment is widely acknowledged to bear responsibility in the preservation of natural resources and minimisation of their expenditure. In his 2003 paper on Biodiversity in the Information Age, Wilson states that the greatest contributor to ecological damage and species extinction is through habitat destruction, even though the past decades have brought with them greater awareness of the ecological plight of the planet than ever before. However, the increasing attention to the biodiversity crisis highlights the inadequacy of biodiversity research itself (2003:45).

Wilson furthermore states that new biodiversity studies are creating online databases that make it possible for research and discovery to be accelerated 10-fold over processes of the pre-digital era. DNA sequencing and genomics have further created the opportunity for sequencing automation and computer-aided advancements in the process. In this manner, discoveries that are generated remotely can be applied directly to meet the needs of the geographic region for which the research is of greatest importance, being of equal importance to agriculture, medicine and economic growth (2003:46).

Finally, in order to establish a truly sustainable and integrated approach, the UN definition of sustainable development reminds us that not only are the pillars (criteria) required to be responsibly responded to, but in doing so the solution should be of equal benefit to future generations In recognising this, the concept of time is required to be integrated into the strategy of implementation. This broadens the scope of implementation not only to include process and product, but that of operation as well.

For an architectural solution to maintain its successful implementation, it will be required to contribute to the important concept of knowledge exchange. As discussed in Chapter 4, ICT integration within buildings (such as BMSs) and architectural process (such as BIMs), which provide the basis for a building to exist both physically and virtually, providing continuous feedback and information to a specified data retrieval point, allowing for interrogation and interpretation of information to be applied in actionable response. This provides a basis for periodic objective (and subjective) re-evaluation to the key criterion in order to establish what changes, if any, might be required to implement to its structure, performance, function or even existence in order that it might best serve each influenced scale of implementation. This will be explored in greater detail in Chapter 6.

By understanding the complexity of this issue, the framework is established for investigation of a methodology of approach based on defined principles, offering solutions that are conceived on a basis of feasibility, responsibility, sustainability and continuous self-evaluation. With this aim, the requirements of sustainable development, the goals of ICT, the demands of our knowledge societies, and the form of our architectural solutions may be best responded to. The researcher therefore proposes that a methodology for built-environment planning is possible to determine, and will therefore investigate this in the next chapter.

5.2.4. Summary and resolution of hypothesis

In resolution of this hypothesis, it was firstly understood that common ground exists between the concept of sustainable development and that of ICT. Having already established the principles of sustainable development, the information revolution has brought with it new requirements for establishing sustainable growth and development. This was corroborated in theory through reference to international processes and movements emphasising the importance of ICT as a role player in sustainable and equitable global growth, such as the Digital Agenda pioneered by the European Union. Through explorations into applicability and integration of ICT within development initiatives, it is evident that information availability and freedom of access are important components within sustainable development pursuits of today. Access to information, with particular emphasis on broadband internet, has already been recognised in numerous national policies as a basic human right in both developing and developed countries. ICT is observed as a means to establish a single market, whereby the digital realm transcends restrictions of the physical. This factor, when combined with the means to promote education and literacy, as well as data collection and information storage, provides a basis for establishment of a knowledge network. Knowledge is created when information is made actionable. In an environment where access to information is fostered as a basic right, the means of knowledge exchange brings with it the foundations for equitable development on a global scale.

It is observed that our world can be defined as a system of inter-linked knowledge societies. In an age where access to information is not equitable in different regions, it is clear that varying degrees of compliance with the concept of a knowledge society exist. Disparities between countries and contexts regarding equitable access and creation of knowledge are most notably categorised by the term ‘digital divide’. This term simplistically describes a visible trend in certain contexts between the ‘haves’ and the ‘have-nots’. In order to best devise a contextually appropriate strategy it is necessary to determine the factors that either inhibit or enable equitable knowledge exchange.

As a basis for investigation of compliance with the requirements of a knowledge society, numerous core criteria were established and investigated with particular emphasis on their applicability in sustainable development. It was determined that the criteria of knowledge societies shared a common purpose when aligned with those of sustainable development. These criteria were thus expanded upon in order to draw specific reference to this common purpose.

The economic criterion established that information has intrinsic value, and as such is therefore a commodity in its own right. To this purpose, the economy of information follows the Keynesian approach in the sense that it is not self-rectifying, but instead requires continual input. This is the basis for the importance of preservation of knowledge exchange.

The spatial and technological criterion established that space is a relative concept based on required output or process. Technology is a concept used to describe process and products that have emerged through innovation and application of knowledge. ICT represents the technology of knowledge transfer and as such is a primary indicator of this criterion. Through contextually specific investigations, the parameters of spatial and technological response can be quantified through measurement of change to environment and applicability of knowledge. In the political criterion it was established that the knowledge society thrives in a political climate of democracy whereby the information rights of citizens are observed.

The knowledge society citizen in this respect is not defined by borders, but instead resides in a global community. Freedom of access to information cannot exist in a context devoid of civil liberty, but in doing so requires statutory compliance to the societal requirements of today in readying the policy to enable this.

The social criterion establishes that quality of life is directly influenced by an individual’s position within their own determined culture and value system as well as the capacity to pursue personal goals. Information is regarded as an enhancer of quality of life in a knowledge society, and that technology does not define society, but instead embodies it.

The cultural criterion was investigated to describe the importance of cultural recognition and understanding in the global village, as well as cultural heritage. In an age of displacement and international cross-culturalism, information storage and access provide a platform of digital memory which may be accessed equitably and permanently. In recognition of the concept that culture is a determinant of time and context-specific trends, understanding of culture, its influences and heritage is an important resource.

The criterion of physical infrastructure observed that ICT infrastructure is divided into two categories: access and coverage. These concern themselves with the exchange of information via voice and data. In order to best cater to the information needs of a knowledge society, understanding physical infrastructure characteristics of a particular context are imperative in establishing the correct planning strategy.

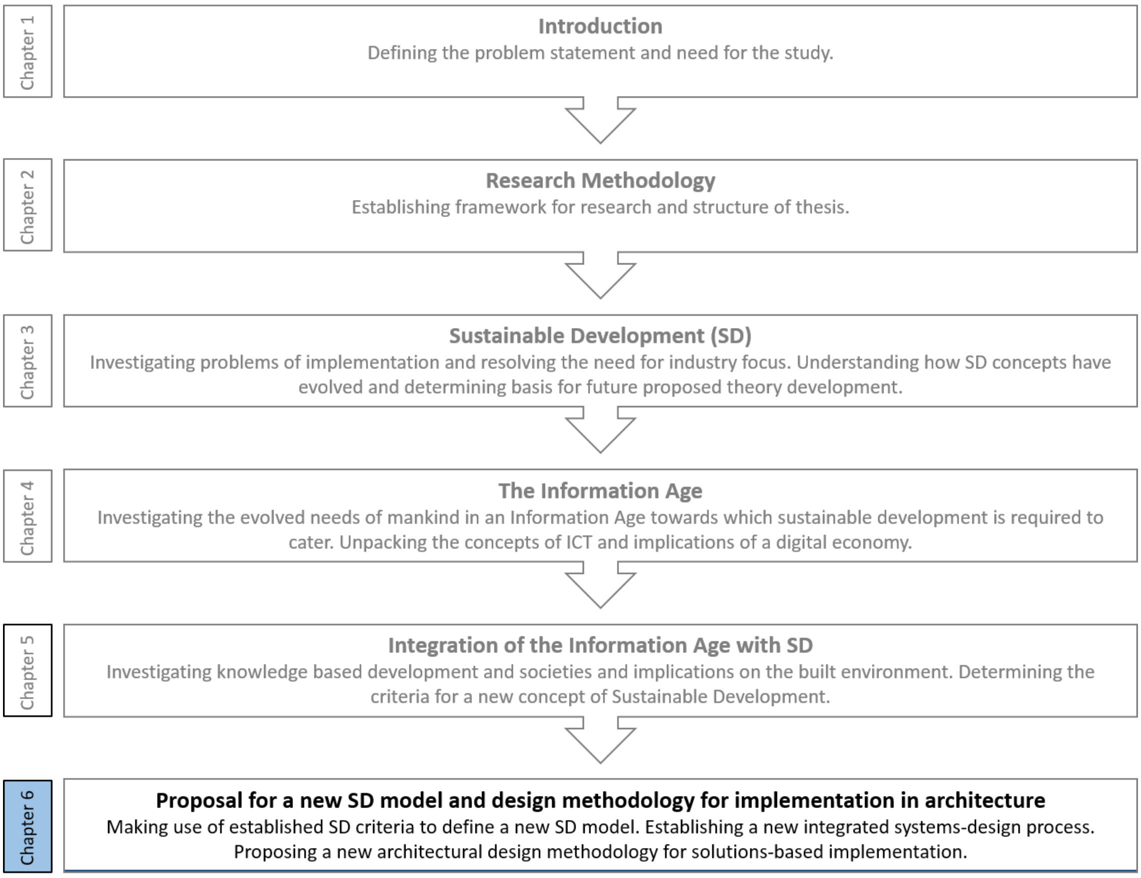
The knowledge criterion determines that the appropriateness of a proposed solution should be measured by its effectiveness in providing individuals with the means to engage in information exchange. Information exchange is based on contextual characteristics pertaining to levels of literacy, availability of infrastructure and the ability to create local content.

The environmental criterion concerns itself with the common goals of sustainable development through ensuring pursuit of ecologically responsible implementation so as not to inhibit or reduce the capacity of the Earth to support it.

ICT is the conduit through which knowledge exchange in the Information Age is best enabled. In order for our built environments to provide the means to integrate this capability, it must be recognised that ICT is not additive but inclusive. ICT is required to become pervasive and ubiquitous. Integration of ICT into architectural infrastructure and operation in pursuit of enabling knowledge exchange is required to be of equal importance as economic feasibility, or environmental responsibility. In a world where access to ICTs is not so simply determined by a context residing within developed or developing worlds, we instead see that access to information is flexibly achieved, utilising the infrastructural means available to individuals. Access to information is now globally received by residents in the Information Age not as a question of ‘if’, but rather of ‘how’.

In the next chapter, the basis for interrogation of knowledge society compliance will be incorporated into a strategy for implementation with specific focus on the built environment. By establishing quantifiable criteria with specific focus of scale, an architectural methodology will be proposed in pursuit of satisfying the requirements of sustainable development in the Information Age.

6. Proposal for a new sustainable development model and architectural design methodology



Introduction
Defining the problem statement and need for the study.

Research Methodology
Establishing framework for research and structure of thesis.

Sustainable Development (SD)
Investigating problems of implementation and resolving the need for industry focus. Understanding how SD concepts have evolved and determining basis for future proposed theory development.

The Information Age
Investigating the evolved needs of mankind in an Information Age towards which sustainable development is required to cater. Unpacking the concepts of ICT and implications of a digital economy.

Integration of the Information Age with SD
Investigating knowledge based development and societies and implications on the built environment. Determining the criteria for a new concept of Sustainable Development.

Proposal for a new SD model and design methodology for implementation in architecture
Making use of established SD criteria to define a new SD model. Establishing a new integrated systems-design process. Proposing a new architectural design methodology for solutions-based implementation.

6.1. Sub-problem four:

Sub-problem: How can architectural approach in design and implementation towards sustainable development in the built environment be improved to meet the needs of the Information Age and knowledge-based development?

6.1.1. Introduction

In previous chapters, the researcher has investigated: the status quo of sustainability principles and reasons for challenges of implementation (Chapter 3); the coming of the Information Age and implications for humanity (Chapter 4); the relationship that exists between concepts of sustainability and IT (Chapter 5); the impact of IT and the Information Age on the built environment (Chapter 5); and the key criteria for understanding sustainable built environments in the Information Age (Chapter 5). It is thus the intention of the researcher to prepare the case to devise an appropriate theoretical basis for architectural design to exist in synergy with the Information Age. The symbiotic relationship will result in a scenario of the built environment as stakeholder, and enabler in a proposed concept of sustainability for the Information Age. The emphasis at this stage is to devise the means for architects to proactively enable sustainable practices through a focused approach.

In understanding how best to shape the design process, it becomes necessary to unpack the contributing factors contributing to decision making, information assimilation and interpretation, and knowledge building. The goals of sustainable development and the built environment will be identified for congruency. The following criteria will therefore be investigated:

- Systems and integrated processes for decision making;
- Access to information and knowledge creation;
- Shaping architectural design process to incorporate sustainable development goals; and
- Quantifying success.

In the context of this thesis, research has been undertaken to this point to provide a base for findings and assumptions to be directed towards focus on the built environment, while remaining particularly accessible in strategy for the architects that shape it. Broader concepts have been explored in order to understand the principle goals for which they have been developed in order to prioritise these goals for architectural implementation.

Prior to embarking upon focused strategy for implementation of the sustainable development model as addressed in section 6.1.1., the researcher will determine the design process to which sustainable development implementation strategy is required to be linked. A basis for overlapping implementation strategy and architectural methodology will then be established.

Through this investigation, the basis for sustainable design process will be established by identifying constraints and opportunities essential to appropriate and sustainable development. Furthermore, the researcher will investigate current understandings of architectural design process and methodology, establishing the need for a redefinition thereof. The goal is to apply the principles of process and constraints building towards the proposed model for sustainable development in the pursuit of laying the foundation for a cohesive and integrated architectural design methodology.

6.1.2. A revised model for sustainable development

> *'The biggest challenge we face is shifting human consciousness, not saving the planet. The planet doesn't need saving, we do.'*
>
> \- Xiuhtezcatl Roske-Martinez[42]

Previously in this thesis, the researcher asserted that humankind exists today within an Information Age (Chapter 4), and that this digital revolution has irrevocably changed the world in a way that the early proponents of sustainable development could not have foreseen. This was investigated on the premise that the case for sustainable development relies, at its core, on the ability of a system or product to serve the needs of current and future generations (Chapter 3).

In order to meet the needs of future generations, the concept of intergenerational equity was introduced into the research. This concept was unpacked in order to understand the criteria for, as a minimum requirement, the provision for equal opportunity and benefit over time (Chapter 5 section 5.1.3). It was determined that a major contributor to equity between generations was a formalised process of communication and the ability to ensure that information was suitably transferred and interpreted. Transferring of information to the point of action was described as the formulation of knowledge, and as such forms an integral part in enabling future stakeholders by equipping them for further decision making based on lessons of the past.

Sustainable development has already been well documented for its inclusion of the sociological, economic and environmental pillars associated with triple bottom line theory (Chapter 3). In recognising that the accepted sustainable development theory of this thesis reflects the needs of the principle three pillars, yet at its core is required to meet the sustained needs of future generations, it is therefore determined by the researcher that the application and development of knowledge is equally fundamental to the success of sustainable development. Without humankind, development cannot exist and as such the researcher interprets that knowledge, as a concept, makes satisfying the needs of humankind a fundamental criteria for successful development.

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[42] 'The Huffington Post - Colorado Teenager Rallies Youth Around The World To Protect The Planet' - http://www.huffingtonpost.com/2015/04/22/kid-warrior-earth-guardian_n_7111530.html [Viewed 17 January 2016].

As investigated in Chapter 4 section 4.2, knowledge is not a new concept of importance for human beings and development. However, in substantiating the argument for its importance in evolved processes of humankind, the researcher furthermore anecdotally compares the importance and evolution of knowledge to that of nutritional sustenance.

Since the dawn of our species, the planet has been abundant in sources of nutrition, requiring only that human beings locate and process these in order to begin a new day based on the successes of the previous. Recognising that it is literally possible to starve to death on raw foods,[43] a marked spike in human evolution occurred with the discovery of fire. Fire allowed human beings to prepare and process their food in ways that were previously impossible, deriving levels of nutrition surpassing anything that came before. Activating the potential within raw nutritional sources gave rise to evolution of human practices. Cooking brought with it a reduction in the cost of digestion, making more metabolic energy available for other activities. The access to 'quick calories' contributed to not only more time spent in innovative hunting, but also to a new social dynamic.[44] The researcher observes a strong commonality in human evolution. By substituting nutrition for knowledge, and fire for the prevailing features of the Information Age (including ICT, the internet, smart cities – see Chapter 4), we are now presented with a reality whereby knowledge is capable of being processed and interpreted far beyond any previous time in human history. The ability to derive greater benefit from this available 'resource' gives rise to an evolution in approach and paradigm. In so far as we would not forsake our ability to sustain our nutritional needs, sustainable development is therefore required to meet to our newly evolved knowledge needs.

Sustainable development is therefore primed for the integration of an additional core criterion of influence in order to define the broad target to which future strategies for implementation of sustainable development in the built environment should be considered. Whereas the already established three pillars permeate and influence the others – there can be no economic development without an ecological and social

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[43] 'Why Fire makes us human' by Jerry Adler, 2013. Smithsonian Magazine. http://www.smithsonianmag.com/science-nature/why-fire-makes-us-human-72989884/?no-ist [Viewed 18 March 2016].

[44] 'Evolution by Fire' by Jonathan Shaw, 2009. Harvard Magazine. http://harvardmagazine.com/2009/11/cooking-and-human-evolution [Viewed 18 March 2016].

system to support it – this additional pillar of knowledge will permeate and influence the others, yet satisfy the needs of humankind that have now become prevalent since the inception of sustainable development as a concept.

A requirement for a newly developed iteration of a model for sustainable development is thus proposed.

6.1.2.1. First iteration

Previously in this study, three varying models for sustainable development were identified (Chapter 3 section 3.1.6), namely Khan's model (Figure 3.2), Giddings's three rings model (Figure 3.3) and Giddings's nested model (Figure 3.4). These were presented in the context of this thesis as the most widely understood and accepted models in the understanding of sustainable development based on the triple bottom line concept. Of these models, the researcher is of the opinion that the three rings model is not only the most recognisable and utilised, but the also the most appropriate version to accommodate further elaboration. When compared to Khan's model and Giddings's nested model, the three rings model stands out for the reason that it seeks not only balance between the pillars of influence, but intimates that in combining the influencing social, economic and ecological factors a newly observable phenomenon is created, possibly even quantifiable. This model of is the only one to identify sustainable development as an observable, created entity with the possibility of investigating it on an individual basis, removed from the pillars that informed its creation. By comparison, Khan's model and the nested model imply importance to the interrelationships between the three pillars, paying tribute to the fact that we, as practitioners, need to remain mindful of each at all times by following a process in favour of a definable objective or product. In the scope of sustainable development in the built environment, progress towards an objective facilitates the possibility for a more focused approach and for the establishment of criteria within a methodological framework for execution. For this reason, the researcher is of the opinion that the three rings model provides a greater basis for further iteration within the scope of defining a new model for sustainable development. In the scope of creating a model for a focused approach to the built environment, the researcher defines a new model for sustainable development below:

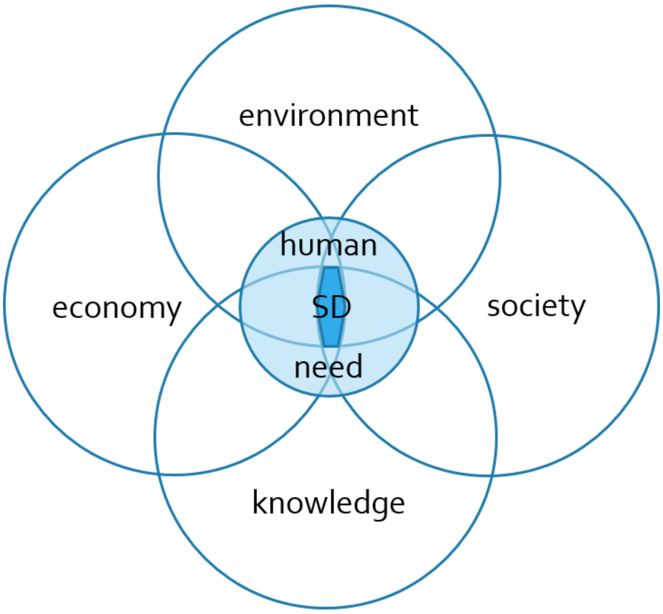

Figure 6.1: **Proposed four-pillar model for Sustainable Development (SD)**

Figure 6.1, serving as a first iteration of Giddings's three rings model for sustainable development (Figure 3.3), summarises the researcher's argument for a model within the Information Age and determines the basis for a greater detailed implementation strategy later in this chapter. The model is summarised as a representation of the following assertion.

Sustainable development, as an aspirational concept principally pursuant of the intergenerational needs of humankind, requires consideration of ecological, sociological, economic and knowledge factors. Human need is thus defined as those factors which contribute to quality of life, cognisant of the successful consideration of the defined four pillars of influence. Each pillar is considered not only for impact, but also in determining best practice for the preservation of each in pursuit of the end goal. This end goal is classifiable as sustainable development, where the impact of each pillar and its contribution to human need has been assessed.

These factors are derived by their capacity for establishing equitable transfer of social, ecological, economic and knowledge capital towards future generations. Yet while each is afforded equal consideration, this does not imply that each are of equal importance. The particular characteristics of each architectural challenge will require specific interpretation and the pillars weighted as most applicable.

Furthermore, designing for sustainability based upon this model requires an awareness that it is not intended for use at only the inception of any project, for evaluation of success at completion, nor for any singular fixed moment in time. This model, comprising revised criteria, is instead a definition of the intended holistic goal which each project should constantly measure itself against. Investigation of these sustainable development criteria is therefore required to accommodate constant evaluation and re-evaluation over the lifespan of a project or intervention. This first iteration model is therefore not appropriate as a tool meant to quantify success of any sustainability intervention, but a basis for a framework for preparation of best-practice design, monitoring, and evaluation of performance according to changing contextual factors.

In establishing this, and recognising that quantifying the approach remains a challenge, the researcher is of the opinion that the model, while uniquely tuned for the needs humankind in the Information Age, still remains a vague definition of a goal that requires further elaboration. Further development of this model is therefore required to provide greater focus may be given for implementation within the context of the built environment.

6.1.2.2. Second iteration

In order to attribute greater focus and applicability to the first iteration of the sustainable development model, as shown above, the researcher refers to previously identified criteria for sustainable development in the Information Age (Chapter 5 section 5.2.2). The researcher furthermore recognises that the core pillars of sustainable development are required to form a part of sustainable development theory, and that the second iteration of the model should advance as a concept from the first. For this reason, the researcher is of the opinion that 'environment' must form a part of the criteria as summarised:

- Economic criterion
- Spatial and technological criterion
- Political criterion
- Social criterion
- Cultural criterion
- Physical infrastructure criterion
- Knowledge criterion
- Environmental criterion.

In assessing the sustainable development criteria above, it becomes possible to discern between the core criteria, as based on the first iteration (Figure 6.1, and the ancillary criteria. In dividing these criteria, the following groups are formed:

Core criteria:

- Environmental criterion
- Economic criterion
- Social criterion
- Knowledge criterion.

Ancillary criteria:

- Political criterion
- Spatial and technological criterion
- Cultural criterion
- Physical infrastructure criterion.

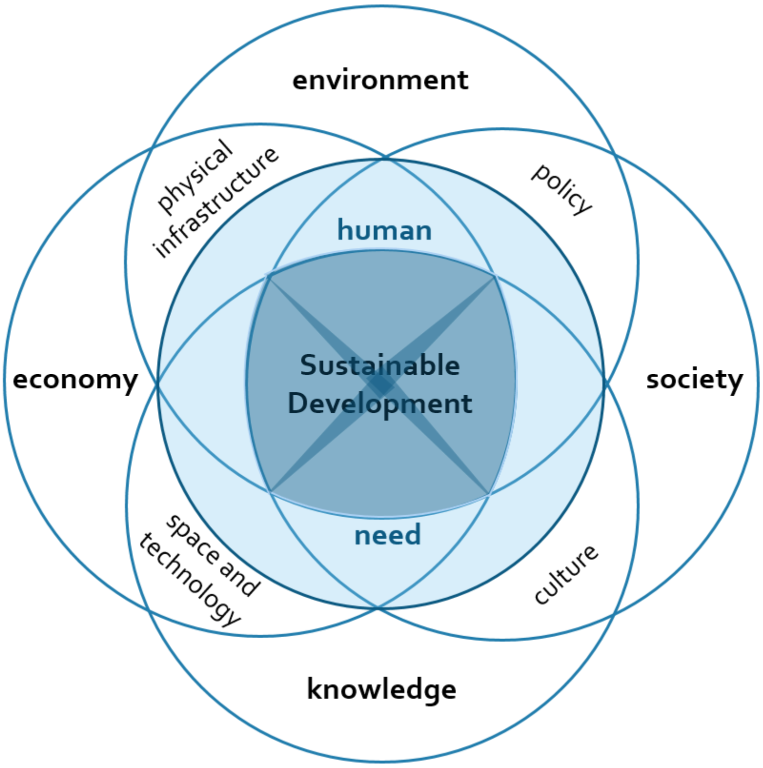

Figure 6.2: **Second iteration of sustainable development model for the built environment Proposed nested model evaluating core and ancillary criteria towards a unified objective within the realm of human need**

These core and ancillary criteria therefore offer a specific scope of investigation, recognising that sustainable development theory requires detailed analysis of any proposed intervention during planning, but also the means to re-evaluate itself during its lifespan.

The first iteration of the model sought to demonstrate that while evolved in concept, the four-pillar approach adopted the same vagueness of approach as the early sustainability models from which it drew reference. For this purpose, even though human need was introduced as a basis to provide some greater focus, a more generic scope provided a limited objective and thus a target of smaller significance.

This second iteration of the proposed model serves to demonstrate that additive criteria for investigation need not affect the magnitude of scope of the problem. Instead it makes it possible to focus the investigation onto each criterion, reducing the 'superior' portion of each core criterion and attributing meaning to each deeper overlap. For example, this makes it possible to focus attention not solely on broader concepts in society, but those aspects which, when combined with the environment applicable to the problem, affect policy. Thus, while the number of criteria is increased in the second iteration, this does not mean an increase of scope. Instead, greater focus is more achievable within the same relative scope of a problem. In doing so, human need is broadened as an internalised concept, ensuring a more feasible investigation which, in the opinion of the researcher, provides greater flexibility of approach and further opportunity for option analysis. All of this combined creates a larger target for sustainable development, recognising that sustainable development is not a finite result but rather a fluid result comprising many factors that are likely to change over time. Achieving a broader and more unified execution of sustainable development theory allows for greater flexibility in approach and implementation.

The second iteration model, illustrated in Figure 6.2, serves as the basis for developing implementation theory in this thesis. The researcher asserts that this model contains within it the necessary criteria to inform focused and appropriate sustainable development strategies. However, as has been researched already in this thesis, a disconnect exists between what industry role players need to do, and how to do it. This results in perpetuating the place of well-intentioned policy and strategy to the realm of academia and research, and distancing it from implementation. What is required at this stage is an investigation into making this model accessible in practical terms to built environment professionals, and industry stakeholders. Addressing the appropriateness of sustainable development approach within the scope of the creation of built environments therefore requires focus on architectural design methodology and process.

6.1.3. Design methodology and process

The researcher recognises that a fundamental difference exists between the terms ‘process’ and ‘methodology’. The term ‘process’ refers to a series of actions in the pursuit of achieving a particular result. In comparison, a ‘methodology’ refers to a set of methods or rules particular to a discipline, important in a science or art.[45] While both terms prescribe clarity of action, and due to the scientific nature of this thesis and the discipline which it serves, the development of a methodology remains an important objective of this research.

Design, as an activity, has been a part of civilised society for thousands of years, providing the basis for invention and creativity manifesting itself in the tangible and physical. Over the years, various schools of thought have developed, evolved and reacted against the other – for example, modernism vs. post-modernism – in order to formulate design interventions that served a particular need of the time, represented a paradigm of society, benefited from advancements in technology or subscribed to a particular trend. The researcher is of the opinion that this investigation should therefore not document a history of design processes and paradigms, plot the changing schools of thought, nor favour any approach over the other. What is required instead is an understanding of the fundamentals of the design process in order to best integrate these into implementation strategy for sustainable development. In establishing this common ground, the basis for ease of adoption is created.

In the paper ‘Discovering the design problem’, Lloyd et al. (1994:125) draw attention to the need to determine what makes design problems and design thinking qualitatively different from other forms of problem solving and thinking. It is stated that recent theoretical and empirical models of design have originated from three general areas, namely engineering, architecture and computer programming. Engineering models are based on analysis of problems based on synthesis of solutions with design described

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[45] Definitions as per Merriam-Webster dictionary: ‘Process.’ *Merriam-Webster.com*. Merriam-Webster, n.d. Web. 21 Jan. 2016. & ‘Methodology.’ *Merriam-Webster.com*. Merriam-Webster, n.d. Web. 21 Jan. 2016

as a series of phases. Each phase would need to be completed before the next can begin. Architectural models posit that solution concepts precede problem analysis. The designer therefore generates a solution in order to begin to think about the problem. Architectural models are otherwise referred to by Roozenburg and Cross as *conjecture-analysis* models (1991:260). Computer programming models see designers interrogating the structure of design problems (Lloyd, 1994:126) in what Roozenburg and Cross also describe as *analysis-synthesis* models of design (1991:261). Lloyd et al. furthermore state that research is inconclusive as to whether there are qualitative differences in approach between disciplines. Instead what is observable is that models derived from a particular discipline capture the primary nature of applicable design problems, yet do not adequately describe designer behaviour. This highlights that some combination of approaches may be prevalent in each discipline. This also provides a basis to deduce that the design process analysis is qualitative, taking into account designer behaviour as an unpredictable factor of influence. Having observed multiple approaches in practice, and therefore based on experience, the researcher is of the opinion that the design process is designer-oriented.

Salingaros (1999:78) offers a different opinion on design process in architecture, stating that these processes are symptomatic of a loss of mathematical quality, with education focusing on developing ‘creativity’ and impetus to create. Architectural education, however, does not teach how to establish if they are solutions. Salingaros furthermore states that contemporary architectural theory validates designs through investigation of conformation to stylistic dictates. In doing so the deductive process is blocked, therefore ignoring the consequences of design decisions and propagating mistakes of the past. It is argued in his paper, that a re-introduction of mathematical theory into architectural process is required with a return to a historical mandate where the two disciplines were indistinguishable, in order that design success may be better quantified.

Sariyildiz and Ozsariyildiz (1998:3) state that in architectural design, there are hardly any uniform rules applicable to the design process, but there are some fundamental questions that each designer will have to face when developing a concept. Perugia (2015:3) refers to these questions as steps in design activity consisting of recognition, analysis and expression of possible connections between identified problems and solutions, while taking into account the external dynamics of organisational, economic, or political factors. According to Mahmoodi (2001), design ‘types’ can be, but are not limited to:

- Pragmatic – involving research in the form of experimentation and observations to understand and measure the behaviour of users and environment in support (2001:116);
- Typologic (Iconic) – implementing of pre-established solutions (2001:116).
- Analogic – using images and inspiration from nature, art, or existing buildings to inspire ideas in the mind of the designer (2001:117); and
- Syntactic (Canonic) – working by a rule-based system, often geometric (2001:117).

In support of these 'types' of design, methodologies have been created in support of linear, systematic, and interactive design processes.

Wardah and Khalil (2016:32) state that many studies have been conducted on design processes and methodologies, critically analysing, evaluating, and proposing alternative methods for creative problem solving. Many designers, however, when probed for reasons to explain their actions, are unable to provide explanations, rendering the design process still somewhat abstract or 'mystical' as a phenomenon. Wardah an Khalil furthermore state that the act of architectural design is a complex process in recognition of the fact that each architect is subject to using their own conceptual framework that can assist in setting boundaries and defining reasonable objectives (2016:32).

Having determined that the design process is highly qualitative and subject to the preferences of approach based on design process and 'type', it is observable that defining a design methodology ultimately allows for different processes to participate in any stage of design activity (Wardah & Khalil, 2016: 42). It is quite clear that there is no 'correct' process, and that this is subject to the 'thinking process' deemed most suitable to the designer. The challenge is therefore upon the researcher to expand upon a process that is sufficiently representative of common practice, that may be developed to meet the goals of the proposed model for sustainable development in Figure 6.2. The researcher will therefore draw upon personal applied experience as a practising architectural professional in the design process as a basis for departure. It is intended that this process may be addressed as an open-framework to accommodate the individual designer by offering goal-orientated direction, while incorporating reliable and replicable principles of approach.

According to Leupen et al., which served as the official syllabus for the researcher's architectural training, architectural design is concerned with a given program and a location. The program can be fixed beforehand or evolve and change as the design progresses (1997:13). The first step towards a design product requires development of a design concept, the creation of which requires a process. This process, or creative operation, requires that designers formulate a formal elaboration of this concept, and test it against the requirements. This will either yield positive results or demand further testing and iteration.

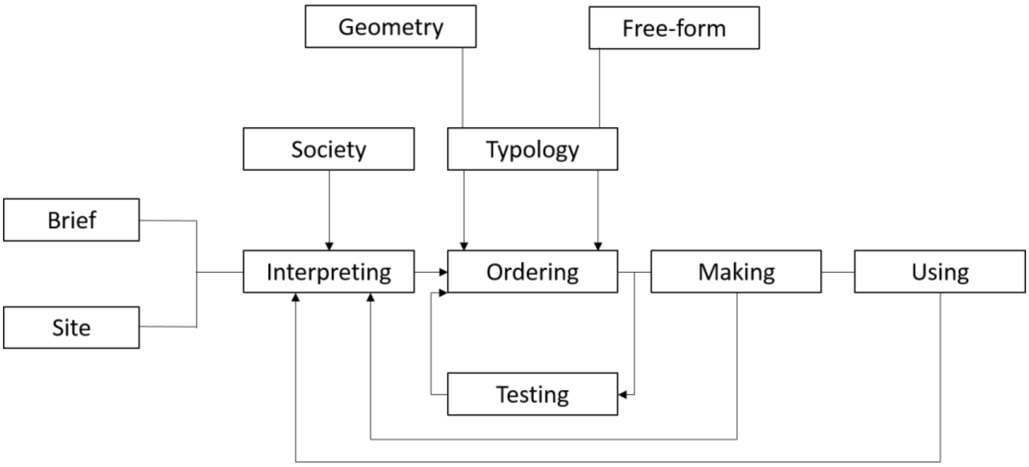

Figure 6.3: Schematic diagram of the design process (Leupen et al., 1997:17)

This repetitive process is partly cyclical and partly directional (Leupen et al., 1997:14). The design process is furthermore described as comprising the following factors:

- Form
- Typology
- Composition
- Context.

What these factors indicate is that the design process concerns itself not just with creation of product (typology, composition and form), but with broader influence (context). Influence, in this regard, refers to the design process as being affected by, as well as affecting its context. The design process is therefore not reactionary. It is fundamental that design processes take into account that, as with architecture, creating a physical intervention has consequences on its locality, its users and the environment with which it interacts. It is not a question of deciding ‘what fits best’ according to current contextual conditions, but how best the context may continue to benefit from something new and necessary.

6.1.3.1. Existing concepts in integrated design and planning

Concepts pertaining to integration in design and development, due to its importance in the industry, are already in existence. These include, for example, Integrated Project Delivery (IPD), and Integrated Design and Delivery Solutions (IDDS).

IPD aims to improve project results through a collaborative approach of aligning the goals of the contributing professional team, and cultivating early involvement and agreement of all parties (Kent & Becerik-Gerber, 2010:815). The American Institute of Architects defines it as a project delivery approach that integrates people, systems, business structures and practices into a process. The aim of this process is to optimise results, increase value to the owner, reduce waste, and increase efficiency through all phases of a project (Eckblad et al., 2007:1). While many definitions exist, IPD consistently and primarily concerns itself with considering the relationships between stakeholders, and the timing of their involvement and engagement (Asmar et al., 2013:1). IPD was developed, and is adopted based on the following needs (Nofera et al., 2011:5):

- Market demand for efficient and reliable processes that produce predictable outcomes;
- Industry desire for a solution to poor coordination between disciplines on projects that can improve efficiencies and quality of service;
- Technology drivers to enhance capabilities, such as the availability of BIM;
- Sustainability pressure; and
- Collaborative style to impact the working culture of the industry.

Furthermore, in order to generate the conditions for effective IPD collaboration, the following components and tools are Identified by Nofera et al. as important:

- Integrated form of agreement;
- Process planning;
- Charrettes;
- Building Information Modelling (BIM);
- Target Value Design accommodating project costing during the design;
- Pull Scheduling; and
- Self-based design.

While IPD has also been recognised as an effective facilitator for the use of BIM in collaborative construction projects, industry adoption has experienced challenges due to concerns about the implications on new legal frameworks and a perceived need for industry role players to increase requisite skills and competencies pertaining to collaboration and information management (Kent & Becerik-Gerber, 2010:816). IPD exists as a collaborative framework to assist the design process, ensuring early project input and information sharing, and contributing to a holistic approach. IPD therefore establishes a sufficient base upon which systems thinking may occur, but does not define the actual design methodology, nor does it define the sustainability goals of a project. IPD would therefore be benefitted by the introduction of these aspects.

According to the International Council for research and Innovation in Building and Construction (CIB) (Owen et al., 2009:3), the development of IDDS is representative of a need in the construction sector to adopt new processes and technologies, while supporting continuous improvement. It is defined as the use of ‘collaborative work process and enhanced skills, with integrated data, information, and knowledge management to minimise structural and process inefficiencies and to enhance the value delivered during design, build, and operation, and across projects’ (Owen et al., 2009:3). The vision of IDDS is to span the construction life cycle of a project, from concept design through to operations, and improve local and area sustainability goals while providing greater flexibility of design options and stakeholder collaboration. This is achieved through integration of processes such as Integrated Project Delivery (IPD) together with BIM and other process-catalytic automation technologies (Owen, 2012:3). It is furthermore stated that the rising importance of knowledge capture and reuse further creates a case for integrated design (Owen et al., 2009:3). IDDS consists of four main work elements, supplemented by a description of their respective intentions:

- Collaborative processes – the creation of end-to-end vertically integrated processes, linked with an effective knowledge management system, will require structural and process changes (Owen et al., 2009:8).
- Enhanced skills – where a prevailing condition for focused skills in the team exist, increased performance requirements and project complexity will require additional specialists and increase the need for skills integration and knowledge sharing (Owen et al., 2009:9).
- Integrated information and automation systems – supported through a cohesive BIM environment and qualified individuals in each professional team, wider

integration of information and data standards, and process interoperability between disciplines is required (Owen et al., 2009:10).

- Knowledge management – codifying, using, and continually updating critical knowledge and business processes based on internal and stakeholder feedback over the full life cycle of a project (Owen et al., 2009:11).

These elements interact, directly and indirectly with the industry foundations comprised of technology, processes, and people.

The 2009 CIB White Paper on IDDS furthermore states that a gap exists in the industry for comprehensive planning and management tools to allow for full evaluation of alternatives for integrated processes (Owen, 2009:13). This paper therefore sets out a conceptual framework and theoretical vision for IDDS that would be benefitted from additional research into the means for industry implementation through actionable methodology of approach. Progress in this field will furthermore benefit from ongoing education and training of construction professionals supported by knowledge-centric processes (Owen, 2012:3).

In further defining the research targets for IDDS, four are identified (Owen, 2012:6):

1. Development of improved sustainability models and measures;
2. Definition of the built environment information fabric (BEIF);
3. Improvement of current practices; and
4. Cultural change and knowledge management and dissemination.

These targets are defined to prepare the industry for changes that are yet to come. In this way the conceptual framework offered by IDDS might be best placed to allow for customisation and future research to aid in its implementation. These targets are also observed by the researcher as representing prevalent gaps in the concept of IDDS, for which this thesis provides some resolution. Through constructive research, case building, and the inherent process of deductive logic, these gaps are furthermore substantiated in the context of this study. With reference to the targets above, this thesis provides:

1. An improved sustainability model (chapter 6.1.2);
2. Delineation of the impact of the Information Age 21st century concept of sustainability and the built environment with a human centric focus (chapters 4 and 5);

3. The proposal for an integrated systems design methodology for improvement of current practices (chapter 6.1.3. to 6.1.7); and
4. The integration of knowledge into the sustainable development model as well as knowledge management and dissemination into the systems-design process (chapter 6).

While IDDS emphasises concept over implementation methodology, it also refers to BIM as a catalyst to the progression of architectural process (Prins & Owen, 2011:227). The researcher concurs with this assertion. Therefore, while BIM is still in a process of development and is yet to offer the capacity to completely handle information-based problem solving and knowledge management of a project (Prins & Owen, 2011:228), it is due to its existing catalytic role in process advancement that BIM will be referred to as a contributing factor within the methodology section of this thesis.

The researcher therefore observes that while IPD concerns the establishment of early cohesive collaborative partnerships and supporting contractual agreement to the benefit of project delivery, and IDDS is recognised by the researcher to be successful as a conceptual framework, a suitable process methodology requires further consideration of the design problem through consideration the product, the components that comprise it, and the relationships between them. In this way, the design is advanced to resolving the design problem not simply as a product, but as a systems process.

6.1.3.2. Systems and integrated processes for decision making

> *'We cannot solve our problems with the same level of thinking we used when we created them.'*
>
> - Albert Einstein, 1985[46]

A system is a set of any two interrelated elements of any kind (Ackoff, 1974:13). As stated by Blanchard et al., systems are as pervasive as the universe in which they exist (2006:1). Du Toit (2011:36) expands upon this by stating that systems are prevalent everywhere, in nature, in public services, in business and other fields. The following definitions of systems are offered (Du Toit, 2011:36):

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[46] https://en.wikiquote.org/wiki/Albert_Einstein

- An assemblage or combination of elements or parts forming a complex or unitary whole; and
- An assemblage of objects united by some form of regular interaction or interdependence.

According to Blanchard (2006), a system comprises three elements:

- Components consisting of input, process and output;
- Attributes of those components; and
- Relationships between components and attributes.

Dettmer describes a system as ‘a collection of interrelated, independent components or processes that act in concert to turn inputs into some kind of outputs in pursuit of some goal’ (1997:3). These systems influence, and are influenced by external factors. Dettmer (1997:4) furthermore states that a system can only be considered in the context of the system within which it exists. This definition is explained in Figure 6.4.

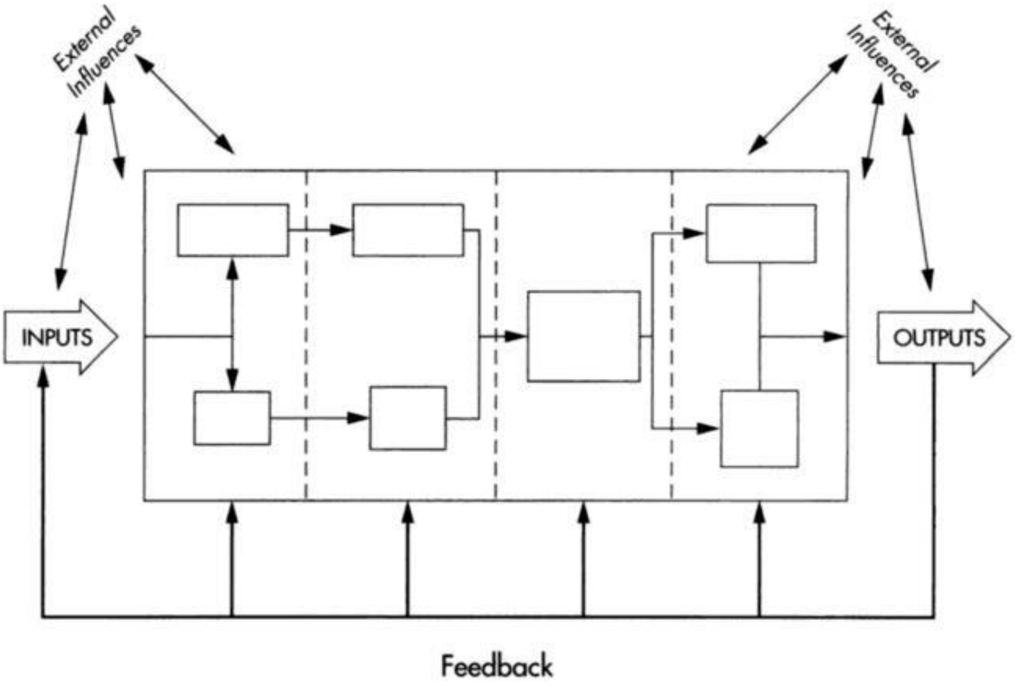

Figure 6.4: **A basic system environment (Dettmer, 1997:4)**

The researcher has discussed how design process and methodology are devised in the formulation or creation of product; however, the built environment should not be misunderstood to be a static product. In the opinion of the researcher, the built environment contains more characteristics of a living organism – growth, decay, responsiveness – that it does an inanimate object or structure. For this reason, it becomes necessary to investigate in more detail what it is that architectural design methodology is seeking to create. In the paper ‘Design for adaptability (DFAD)’ by Kasarda et al. (2007:727), it is stated that a new design methodology was sought that characterises a product as a dynamic adaptable system. Therefore the objective is to model the product as a controllable system. This is representative of an understanding that, while design itself may be a process, so too is the product.

In the book *Sustainability: A systems approach*, Clayton et al. (1996:xiv) state that a transition towards a more sustainable way of life requires a ‘change in which problems are perceived and solved’. This change requires a move away from a closed systems approach, and towards an open systems perspective in which problems and solutions are multidimensional, dynamic and evolving.

In a technologically driven industry, symptomatic of our current Information Age, innovation occurs where market need and technological know-how overlap. For the 21st century, one of the greatest challenges to business manifests itself in risk management. As a result, in this technological and innovation-driven industry, the need for a systems approach is intensified (Barkhuizen et al., 2012:203).

The challenge with an open systems approach resides with the need to integrate and incorporate information from multiple domains into a single decision-making process. Decision making becomes more complex when there is not a single problem, but an intertwined web of problems (Barkhuizen et al., 2012:204). Clayton et al. state that trying to map all relevant information into a single domain contains three primary problems, namely a) oversimplification and thus loss of information; b) lack of contribution to dynamic interaction of complex systems; and c) utilising a single index which requires assigning values and weighting to contributing factors through a choice of methodology. This methodology is often imperceptible by the time information has been processed and decisions reached (1996:12).

Analysis makes sense of a system by placing focus on the sum of its parts, its sub-systems. This takes form as the common method to understand a complex system. This focus, however, can lose sight of the relationship between parts (Barkhuizen et al., 2012:204). According to Du Toit (2011:40), a systems approach does not break a system down into its smaller parts, but takes a broader holistic view to take into account greater numbers of interactions. A systems approach provides a multidimensional framework in which information from different disciplines can be integrated, and considers contributing factors as interacting in the world as systems. This requires application of general principles of systems analysis to observe patterns of interaction between systems (Clayton et al., 1996:12). Systemic thinking therefore combines analysis to identify the elements, with synthesis to establish the repeating pattern of their relationship (Barkhuizen et al., 2012:204). The need is also established for a decision-making process that that can accommodate flexibility and change in a number of non-equivalent dimensions (Clayton et al., 1996:14). The systems approach can therefore be explained as (Du Toit, 2011:39) holistic in nature by taking into consideration all the elements of the system and the relationships between them in a beginning-to-end approach.

The researcher recognises this systems approach as being the most appropriate to sustainable development due to the nature of the sustainable model as featured in Figure 6.2. The second iterative model demonstrates that sustainable development resides at the core of multi-elemental relationships. It is therefore not the result of a linear process, nor of the summarised investigation of its parts. A holistic approach is required.

In investigating systems theory, the following models are identified, namely the soft system model, and the theory of constraints.

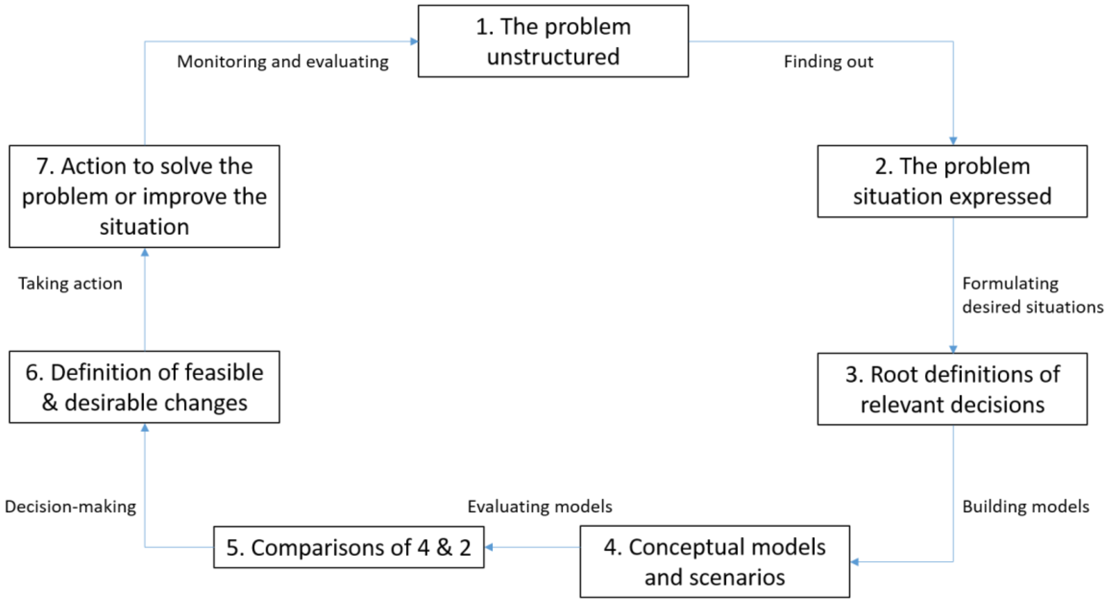

Figure 6.5: The Soft System Model (Du Toit, 2011:43)

In the soft system approach, as indicated above, a problem is expressed and the root definitions of the system identified. Conceptual models are then devised serving as a range of alternative solutions. These are then compared with each other and evaluated. The most appropriate conceptual model is selected by virtue of which best addresses the key issues and yields the most feasible result (Du Toit, 2011:45).

The theory of constraints thinking process is composed of logical tools, and at its core bases itself upon the categories of legitimate reservation, which can be summarised as follows (Dettmer, 1997:32):

1. Clarity
2. Entity existence
3. Causality existence
4. Cause inefficiency
5. Additional cause
6. Cause-effect reversal
7. Predicted effect resistance
8. Tautology.

These categories have a number of uses, but were primarily designed for the purpose of verifying the validity of cause-effect logic.

According to Dettmer (1997:11), Goldratt's Theory of Constraints is a prescriptive theory allowing for identification of aspects responsible for limiting or holding back a system, as well as devising a strategy for resolution of the problem. This theory basis itself on identification on system-level change factors (Dettmer, 1997:5):

- What to change? (Where is the constraint?)
- What to change to? (What should we do with the constraint?)
- How to cause the change? (How do we implement the change?)

Goldratt (1990) and Dettmer (1997:12) list the following principles of the systems theory of constraints:

- Systems thinking is preferable to analytical thinking in managing change and solving problems.
- An optimal system solution deteriorates over time. A process of ongoing improvement is required to update and maintain effectiveness of a solution.
- The system optimum is not the sum of the local component optima.

- Knowing what to change requires a knowledge of the system's current reality, its goal and the magnitude of the directional difference between the two.
- System optimisation requires resolution of the core problems, which are far less evident than individual undesirable effects. Elimination of these individual undesirable effects is representative of a sustainable solution, i.e. treating disease rather than symptom.
- System constraints can be either physical or policy.

In applying the identification of change factors and Theory of Constraint (TOC) principles, the five focusing steps were developed (Du Toit, 2011:42; Dettmer 1997:12):

1. Identify the system's constraints;
2. Decide how to exploit the constraints;
3. Subordinate everything else;
4. Elevate the constraint; and
5. Return to step 1, but beware of 'inertia'.

In evaluating and interpreting the two various systems decision-making processes, Du Toit (2011:49) states that both models require a holistic approach to problem solving as opposed to addressing individual elements and processes in isolation. The soft systems model describes how a problem can be broken down into systems, sub-systems and their elements while providing guidelines for addressing multiple interpretations of interrelated problems that may exist. The theory of constraints model emphasises the importance of maintaining adherence to the principal goal and to focus on optimisation or improvement of a process with the aim of achieving this. Du Toit furthermore states that by applying either systems approach, it can be determined whether a problem is 'a symptom of another problem or whether it is the root cause' (2011:50).

In applying the systems theory process to decision making, it is necessary to maintain holistic awareness and adherence to the principles of systems process. The aim of a process is to support the end goal and enforce decision making that will enable achievement of this goal.

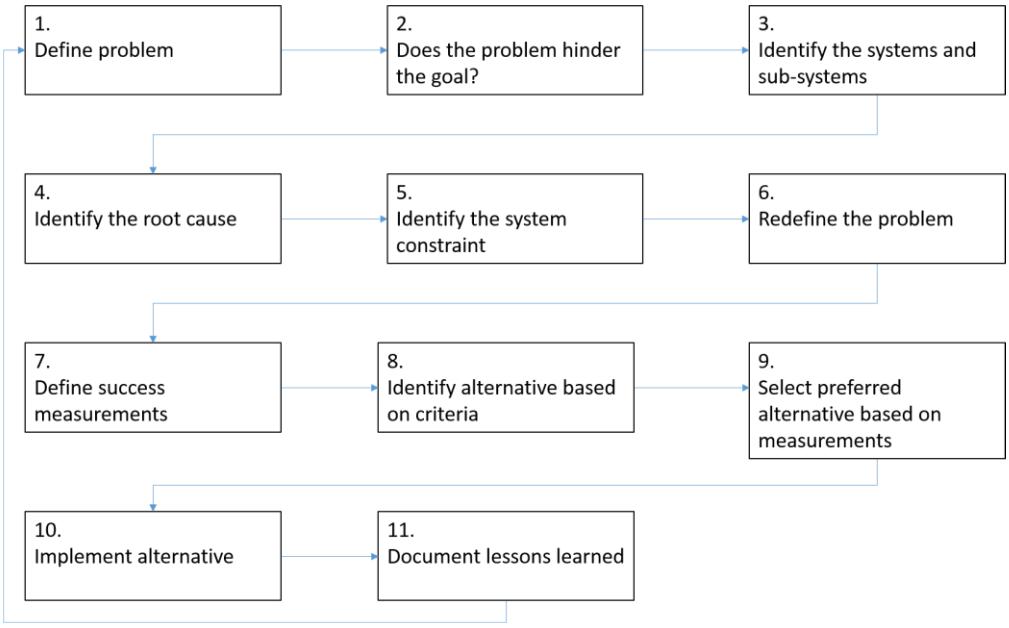

Figure 6.6: A systems approach to decision making (Du Toit, 2011:54)

An integrated approach requires that the system approach first be implemented. Based on Figure 6.6, once the problem is identified the decision-maker and team should objectively define the problem and determine if it will obstruct the achievement of the goal. In defining the problem, it is important to identify the system that the problem forms a part of as well as the sub-systems involved. The decision-maker and the team should then collaborate and integrate efforts to analyse whether the problem is a core problem or merely a ‘symptom’. Alternative solutions should be proposed, and effectiveness of each determined through means of objective quantification or measurement according to success criteria. Following implementation of a solution, lessons learnt should be documented and recorded to enable knowledge building and solutions optimisation (Du Toit, 2011:53).

6.1.3.3. Integrating design and systems processes

When regarding Figure 6.2 (section 6.1.2.2), it is the opinion of the researcher that the partly linear, partly cyclical nature of the design process is primed towards the application of a partly cyclical systems approach. In both processes there is a requirement to identify constraints as problems, following which some iterative testing is required in the pursuit of offering a solution. There are, however, some identifiable differences.

In establishing the basis for comparison between design and systems processes, it is necessary to reiterate what ultimate goal each is aspiring to in the context of this thesis:

sustainable development. While design and systems approaches have been investigated based on problem solving and implementation, this is in pursuit of creation of architectural interventions (buildings) as physical manifestations of a process and not as monuments to static product. In the context of sustainable development, it is noted that long-term (intergenerational) equity remains a principal goal and as such the building life cycle, allowing for processes of evaluation, must be considered in decision making.

Table 6.1: Characteristics of design and systems process towards decision making

	Process characteristics	Design	System
1	Defining the problem	Requires subjective interpretation of the design brief and societal influence, with objective analysis of site constraints.	Requires objective identification of the applicable systems and sub-systems in play.
2	Defining the goal	Pursuit of ordered equilibrium between typological preference and interpretation of constraints.	Holistic approach to problem solving through option analysis towards the most predictably desirable result.
3	Identifying and selecting alternatives	Testing occurs following stage of ordering. The success of testing will determine whether alternatives or iterations are required.	Alternatives are pursued and identified prior to any form of implementation or solutions ordering.
4	Defining success criteria/measurement	The meeting point between subjective typographical ordering, satisfaction of the brief and statutory constraints.	Offering of a solution through selective response to the identified core system constraint.
5	Implementation	Manifested in (architectural) building product and finite structure.	Manifested in directed decision making with the aim of holistic problem solving. This can take the form of product or policy.
6	Responding to problem life cycle	Design product persists in operational phase. This makes re-evaluation and testing possible through user experience. Using of the product is cycled back towards interpretation for possible further re-ordering. Testing in hindsight.	The 'solution' offered is not predictable in form, and might be invisible as policy, for example. Success in the long term is not easily interpreted unless the lessons learnt are specifically studied and recurring core problems are identified.
7	Documentation of lessons learnt	User experience and empirical evidence is garnered through product use.	Rigorous documentation forms a part of the systems process in order to establish grounds for structured knowledge preservation and transfer.

It is possible to determine, from the above comparison, that while both processes are focused on problem resolution with the aim of offering a tangible solution or product, key differences are prevalent. The design process is subjectively undertaken through the necessity to incorporate interpretation of the brief, societal factors and site constraints. The systems process does not make allowance for interpretation but instead objective option analysis through definition of a core problem and system constraint. It is also observed that the systems approach takes a firmer stance in proactive decision making through early identification of alternatives based on rigid success criteria in resolution of the core problem, following which the alternative with the greatest opportunity for success is pursued. The subjective nature of the design process requires testing through implementation of design decision making. This makes for a largely reactive process requiring interrogation post-finalisation. It is of course possible to introduce intermediary (yet still reactive) stages of interrogation through introduction of reviews at proposal stages (post-design concept), detail stages (post-final design proposal), as well as post-implementation.

The design process must consider that the product does not exist in isolation, and therefore requires further investigation post-implementation from a user perspective. This provides the means to (reactively) enact re-interpretation of new or evolved problems towards re-ordering and re-making. Sustainable development demands a responsible approach towards life cycle requirements and intergenerational equity, and therefore any proposed methodology towards this end must represent this goal.

The nature of these process differences therefore requires the formulation of an integrated design-systems process with specific focus towards sustainable development in the built environment. The core differences as comparatively stated above must therefore be addressed in the pursuit of a proactive approach with acute sensitivity towards product life cycle and user experience. In establishing which characteristics listed in Table 6.1 are of greatest importance, the researcher provides the following investigation based on the prevalent normative position and applicability in architectural processes for sustainable development:

Table 6.2: Defining the objectives of an integrated systems-design process

Integrated systems-design process:
The researcher's normative position

Objectives	**Design Process**			**Systems Process**		**Suitability towards sustainable development in the built environment**
	Strongly Agree	Agree	Neutral	Agree	Strongly Agree	
Defining the problem			▨			Combination of qualitative and quantitative approach is suitable. Identification of applicable systems, objective identification of constraints and subjective interpretation of design brief.
Defining the goal			▨			Holistic approach required. Option analysis to achieve preferential result based on subjective interpretation of design brief. Balance sought between typological inclination of design and resolution of design problem.
Identifying and selecting alternatives				▨		Proactive identification of alternatives preferred as opposed to designing in hindsight. Process to be aided through early identification of applicable systems prior to implementation of integrated design process.
Defining success criteria/measurement			▨			Pursuing appropriate response to core system constraint to be addressed in achieving balanced typographical orderings and satisfaction of constraints.
Implementation			▨			Holistic problem solving through selective decision making towards formulation of design product and operational policy. Creation of an architectural solution as opposed to a finite intervention.
Responding to problem life cycle		▨				Recognises persistent operational nature of architectural solution (occupation) and the continually affected user experience. Contextual factors (climate, etc.) quality of life of users, and performance efficiency of product is required to be re-evaluated during life cycle.
Documentation of lessons learnt			▨			Knowledge preservation and transfer critical in future planning processes in order to benefit future projects, as well as incurred and continual user experience in pursuit of optimised operations and utilisation of design product and policy.

Table 6.2 provides a basis to understand how the requirements of an integrated systems-design process differ from each objective in isolation. When applied to the specific normative position of the researcher in the context of shaping the built environment, the process is given greater direction and focus. While equal importance (neutrality of normative position) is afforded to most characteristics of each system, preference is attributed to the design process in recognition of the problem life cycle, while the systems process is favoured in the early identification of alternatives (option analysis). In doing so, the integrated process requires the 'architect' of the problem-solving process to embark upon objective clarification of core systems problems against selective criteria. This sets the stage for evaluation according to previously identified criteria of sustainable development (as identified in Chapter 5 section 5.2.2), in order to design pre-emptively and with a focused approach. In addition, the future life

cycle of the architectural solution is required to recognise its long-term responsibility towards occupancy and operations (sustainability), and the inevitability of future re-evaluation and re-interpretation according to evolving user requirements and contextual changes.

The integrated systems-design process, adapted from Leupen (1997), in Figure 6.3 above, is summarised in the following model:

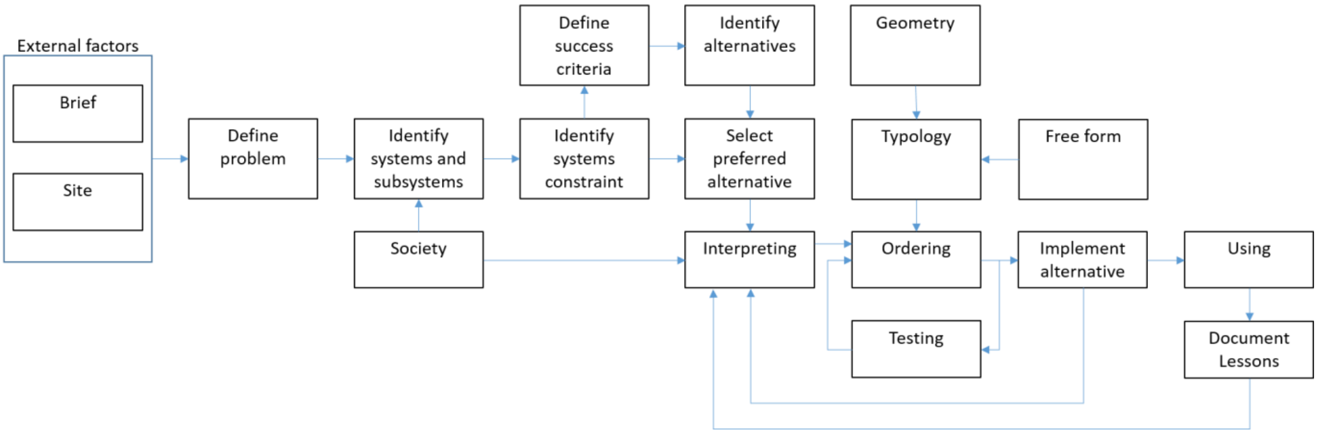

Figure 6.7: Integrated systems-design process for architects.

In the above process model, characteristics of systems and design processes have been combined hierarchically. These have been so ordered with the aim of proactively identifying criteria for success based on systems constraints and definition of the problem, as well as favourable alternatives to better inform the interpretation stage. The influencing factors of ‘Site’ and ‘Brief’ have been nominated as external factors to reflect the prevailing condition that the design process generally places no mandate or control over these. Both are imposed on the problem, and therefore have to be critiqued objectively in defining the core problem and dominating system constraints. Through identification of success criteria and the testing of the proposal, it would be possible to evaluate if these external factors are conducive towards project success, at which point either revision of the brief or choice of site would begin the process anew. The ordering stage is therefore sufficiently informed by not only a rational identification of the problem, but also clear selection of alternatives and with typological preferences. The implementation stage is therefore the product of qualitative and quantitative interrogation. In this process, should the appropriate criteria for success have been identified prior to interpretation, for example sustainable development criteria, the life cycle and implementation of the proposed solution would be benefited. In recognising that human need and ecological constraints are ever-evolving, a record of decisions and lessons learnt is then formally documented for the benefit of future projects as well as re-interpreted for continual re-assessment during the solution life cycle.

In order to address the aspect of life cycle operations and adaptability in the long term, it becomes necessary to understand the means through which this analysis and basis for interpretation is achieved, that of knowledge building and transfer.

6.1.4. Knowledge-building, knowledge building

‘In a knowledge-based economy, the new coin of the realm is learning.’

\- *Robert Reich*

This thesis proposes that the concept of ‘knowledge’ constitutes a necessary inclusion into the sustainable development model as featured in Figure 6.1 and Figure 6.2. This follows identification of knowledge as a key criterion in the alignment of sustainable development with the Information Age (Chapter 5 section 5.2.2.). Furthering the understanding towards effective implementation in the built environment, the importance of knowledge creation, preservation and transfer requires additional elaboration in this chapter with specific focus on architectural implementation. Knowledge and the ability to utilise it are considered to the most important sources of organisational competitive advantage. However, there remains a prevalent need for knowledge-based theory that differs from existing organisational theory (Nonaka, 2003:2).

As with systems theory, determining the best course of action for decision making first requires identification of the core problem. In the case of a sustainable built environment, the core problem is to satisfy the long-term needs of humankind within the ecological limits of the planet. As discussed in Chapter 3, the needs of man had previously been addressed in the original definitions of both sustainability and triple bottom line theory as being intertwined with social, economic and environmental factors. The ultimate aim is to achieve an equitable solution that responds to all pillars. Through investigation, this thesis recognises in Chapter 5 that to remain truly sustainable, knowledge is key to the sustainable development equation in order that decisions of today have merit towards, as well as benefit the practices of tomorrow. Knowledge is identifiable as a pillar of importance at this current stage in human evolution due the fact that information and the capacity to process it is enabled on a larger scale than ever through ICTs in the Information Age.

This importance bears direct relationship to the proposed systems-design model of Figure 6.6. This importance is typified in a number of key stages of the model. To understand the role of knowledge, it is important to understand the concept. As has been mentioned previously in this chapter, knowledge is categorised into three important phases:

1. Knowledge creation
2. Knowledge transfer
3. Knowledge management and preservation.

These phases of knowledge building are necessary to understand in order to highlight their relative position and influence within the integrated systems-design process, and better delineate the influence on a future proposed design methodology.

With the evolution of knowledge-based development, as observed in our current knowledge cities, development of our urban environments is tasked with a strategic mission to encourage and nurture focused innovation, science and creativity within the context of an expanding knowledge economy and society (Yigitcanlar et al., 2008:63). Knowledge cities are thus seen as integrated cities, which physically combines the function of a 'science park with civic and residential functions' (Yigitcanlar et al., 2008:63).

The core aim of integration of knowledge in the process is towards suitably aligning sustainable design with knowledge-based development. This section will therefore elaborate on each of the three phases with specific reference to a) their role in the integrated systems-design process, as well as b) alignment to knowledge-based development in the formulation of an architectural solution.

6.1.4.1. Knowledge creation

In establishing the role of this knowledge pillar – referring to Figure 6.2 – towards sustainable development and architecture, the researcher recognises that it is not only the intervention or product that is under scrutiny, but also the formative process. For this reason, the way in which knowledge is created and implemented is an important basis for investigation.

As discussed in Chapter 5 section 5.2.2.7 (investigating the knowledge criterion), knowledge comprises two forms, explicit and tacit knowledge. Explicit knowledge is easily transmitted between individuals in a formal and systematic process, while tacit knowledge is harder to formalise since it is rooted in an individual's actions or experience (Nonaka, 1998:41). This creates a need for social interaction, and an enabling environment.

According to von Krogh et al. (2000:2) 'knowledge creation' requires support rather than attempts to manage or control it. This forms the basis for knowledge enabling, which is defined as a set of activities that positively affect knowledge creation. This knowledge enabling includes facilitating relationships and conversations as well as sharing of local knowledge.

When investigating the knowledge criterion (Chapter 5 section 5.2.2.7.), a fundamental pillar in the proposed new model for sustainability (Figure 6.2), it is recognised that forms of knowledge are contextually specific. Nonaka et al. (1998:40) define 'place' as an enabler, fulfilling a role as a shared space in which relationships may emerge. It is therefore furthermore argued by von Krogh et al. (2000:7) that effective knowledge creation depends on an enabling context, or in other words a space that fosters emerging relationships. Knowledge is embedded in place, and support of the process of knowledge creation requires the necessary context or 'knowledge space' (von Krogh, 2000:7). Existentially, this space is a context which harbours meaning, as well as providing a platform for collective and individual knowledge. In architectural terms, the concept of 'place', which will be explored later in this section, carries specific connotations and opportunities, and therefore creates a case for the management of appropriate (knowledge) space-making, conducive to the pursuit of enabling knowledge creation.

Nonaka et al. (1998:42) refer to knowledge creation as a spiralling process between explicit and tacit knowledge, with the interactions between them creating conditions for knowledge creation. To further understand the process of outlining knowledge creation, the SECI model was developed to define four steps in the knowledge conversion process.

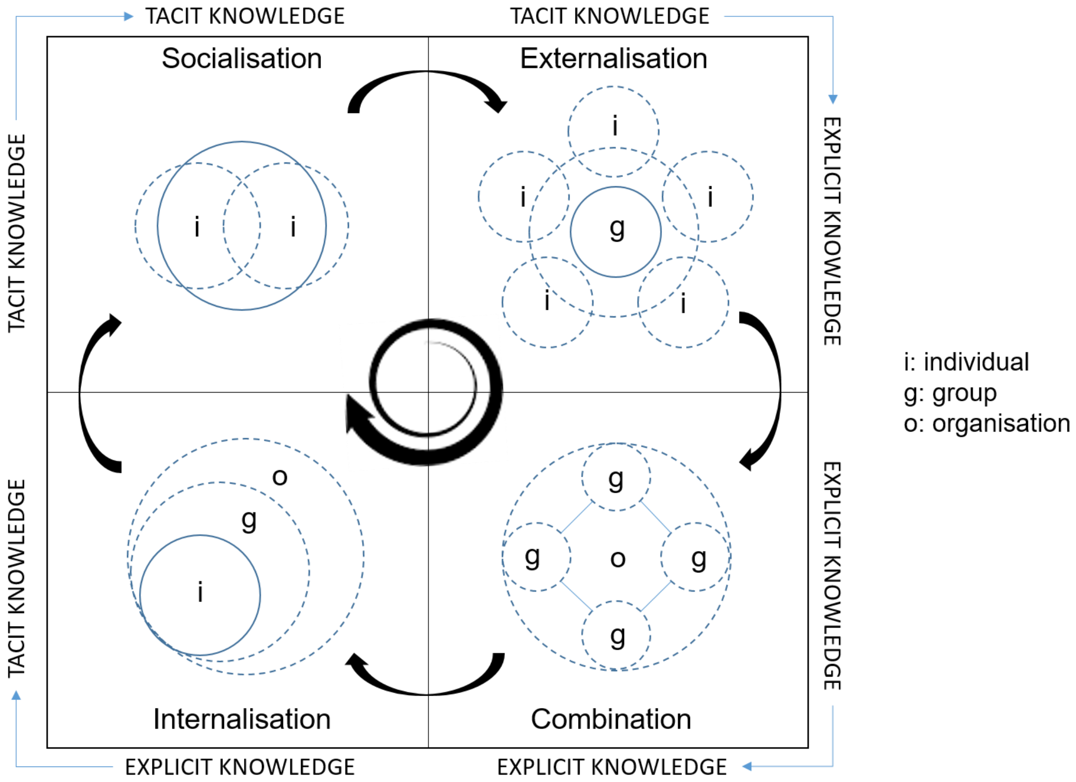

Figure 6.8: Spiral Evolution of Knowledge Conversion and Self-transcending Process (SECI) (Nonaka, 1998:43)

The SECI model comprises the following four conversion modes (Nonaka, 1998:43):

1. Socialisation: the sharing of tacit knowledge between individuals through direct interaction. This capturing and dissemination of knowledge involves physical proximity. The process of transferring ideas means to share personal ideas and create a common place.
2. Externalisation: the expression of tacit knowledge and its translation into forms that are comprehensible by others. This process is defined by the processes of articulating tacit knowledge, as well as translating it.
3. Combination: the conversion of explicit knowledge into more complex forms of knowledge. This phase relies on three processes: capturing and integration of explicit knowledge, dissemination of knowledge and processing of knowledge to make it usable.
4. Internalisation: Conversion of the newly created knowledge into tacit knowledge. This requires identification of relevant knowledge for an individual within the greater organisational knowledge. Two dimensions are prevalent in internalisation: explicit knowledge is embodied in action and practice, and

explicit knowledge is embodied through (virtual) simulations or experiments to trigger learning.

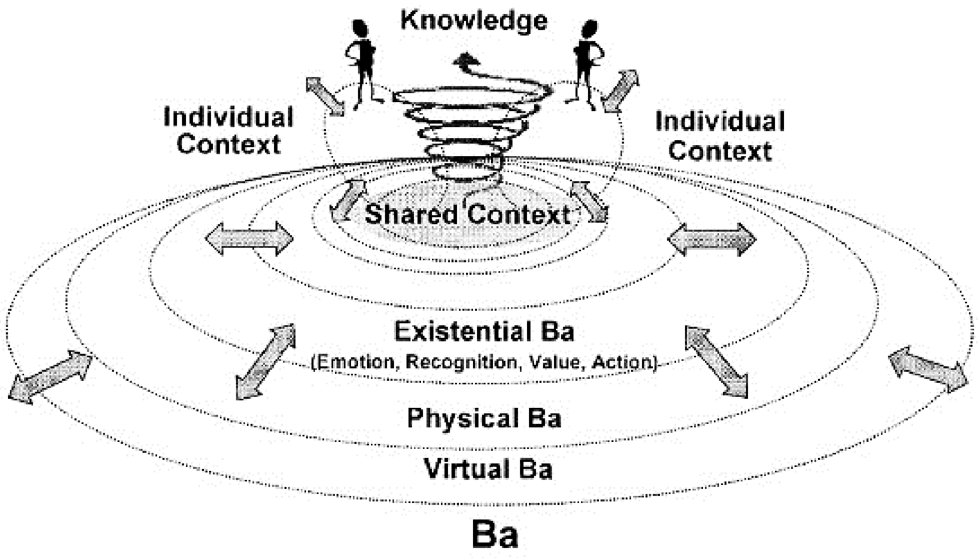

Figure 6.9: Conceptual representation of ‘ba’ (Nonaka, 2003: 7)

By revisiting SECI theory in the proceeding paper ‘Knowledge-creating theory revisited’, Nonaka et al. (2003:9) affirm that the SECI process assists in understanding that tacit and explicit knowledge act dialectically due to the contrast between theory and routine. The externalisation of experience based on context creates differences between internalised and externalised knowledge. Nonaka et al. (2003: 7) in a conceptual representation of place (context), or ‘*ba*’ (Japanese word for place) refers to a nested theory of place in which the following sub-contexts exist, in order of broader hierarchy:

- *Ba*
- Virtual *ba*
- Physical *ba*
- Existential *ba* (emotion recognition, value, action)
- Shared context
- Individual context.

The researcher observes that the introduction of ‘virtual’ into the theory of place marks an interesting evolution of concept within a decade of research, emphasising the increased importance of the Information Age to which this thesis makes reference. The virtual place therefore has marked impact on the importance of proximity in knowledge creation; however, this does not remove the established social convention of physical interaction from the process – an important factor in our built environments and the understanding of architectural place. In the opinion of the researcher, however, it reiterates the role of environments to enable knowledge creation in all conceptual and experiential contexts. Therefore as new boundaries are drawn, the knowledge creation process is conceptualised as spiral and infinite. This therefore moves the dialectic concept of knowledge creation away from that of a static theory (Nonaka, 2003: 7).

In addressing the role of knowledge creation in the architectural process, the researcher refers to Von Krogh et al. (2000:8) who offer a similar system of context-based knowledge creation by identifying five knowledge enablers:

1. Instil a knowledge vision.
2. Manage conversations.
3. Mobilise knowledge activists.
4. Create the right context.
5. Globalise local knowledge.

In addition to the identified enablers, the following organisational knowledge creation steps are identified (von Krogh et al., 2008:5):

1. Sharing tacit knowledge;
2. Creating concepts;
3. Justifying concepts;
4. Building a prototype; and
5. Cross-levelling of knowledge (transfer and record).

The knowledge creation process is initiated by tacit knowledge sharing of a problem leading to formulation of a product concept or concepts. This concept is thus justified through the potential involvement of exterior opinions. Arguments for and against the concept are made (dialectic process) through discourse and analysis of research data. At this stage, a concept is developed into a prototype, which is potentially then again reverted to a process of re-justification. Following this process, responsibility for acquiring knowledge is assumed by the developers and shared at large (von Krog, 2008:6). The relationship of knowledge creation steps and enablers is represented in the Table 6.3:

Table 6.3: Knowledge enabling: the 5 x 5 grid (von Kogh, 2000:10)

Knowledge-Creation Steps

KNOWLEDGE ENABLERS	Sharing tacit knowledge	Creating a concept	Justifying a concept	Building a prototype	Cross-levelling knowledge
Instil a vision		✓	✓✓	✓	✓✓
Manage conversations	✓✓	✓✓	✓✓	✓✓	✓✓
Mobilise activists		✓	✓	✓	✓✓
Create the right context	✓	✓	✓✓	✓	✓✓
Globalise local knowledge					✓✓

Through interpretation of the knowledge creation and enabling processes of this section, the researcher observes commonalities with the proposed integrated systems-design process (Figure 6.7), as well as significance towards the responsibility of architectural product. Knowledge creation is integral to the design process, and represented in both concept formulation as well as operational assessment of life cycle performance. In order for operational feedback loops to exist in a building's lifespan, knowledge creation enablers must be present together with which knowledge creation steps may be employed. Steps for knowledge creation are thus incorporated into the integrated systems-design process as follows:

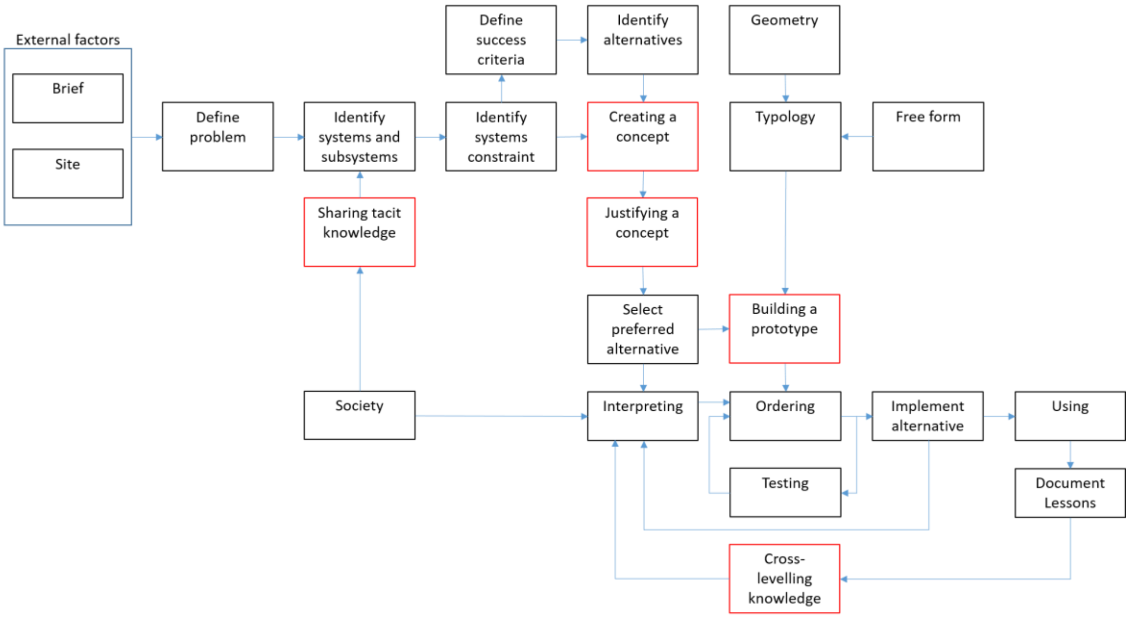

Figure 6.10: Incorporating steps for knowledge creation in the integrated systems-design process

6.1.4.2. Knowledge transfer

Most closely associated with matters of strategic management and organisational theory, knowledge transfer is defined as the process through which an individual or unit in a network is affected by the experience of another (Argote et al., 2000:3) and is manifested through changes in knowledge or performance of the recipient (Inkpen, 2000:149). Szulanski (2000:10) states that knowledge transfer is seen as a process in which an organisation recreates and maintains a complex set of routines in a new setting. Furthermore, the more complex the problem, the greater likelihood for a response in the form of additional deliberation, recourse to non-standard skills, allocation of supplementary resources, and escalation of decision making to higher hierarchal levels (Szulanski, 2000:11). Knowledge transfer occurs through a variety of mechanisms. These include personnel movement, training, communication, observation, technology transfer, reverse engineering, replicating routines, publications and patents (Argote et al., 2000:3).

With the advancement of ICT in the 1990s and the emergence of increased globalisation of corporate activity and business, the way in which work was ‘done’ was fundamentally advanced. This created the phenomenon known as dispersed or ‘virtual’ team-working (Sapsed et al., 2005:834). Using virtual or dispersed team-working as an example, working through ICTs was deemed an effective response to the needs or remote enterprises to enjoy global presence, to be flexible and responsive, and to be benefited by cost advantages and extended working hours (Sapsed et al., 2005:835). However, it is noted by Sapsed et al. (2005:835) that the majority of literature at the time responding to the process of dispersed team-working placed significant emphasis on the enabling role of ICT, specifically advances in information transmission and processes – at times arguing that geography and dispersion were now irrelevant in the execution of work – while the specific role of knowledge transfer was largely overlooked.

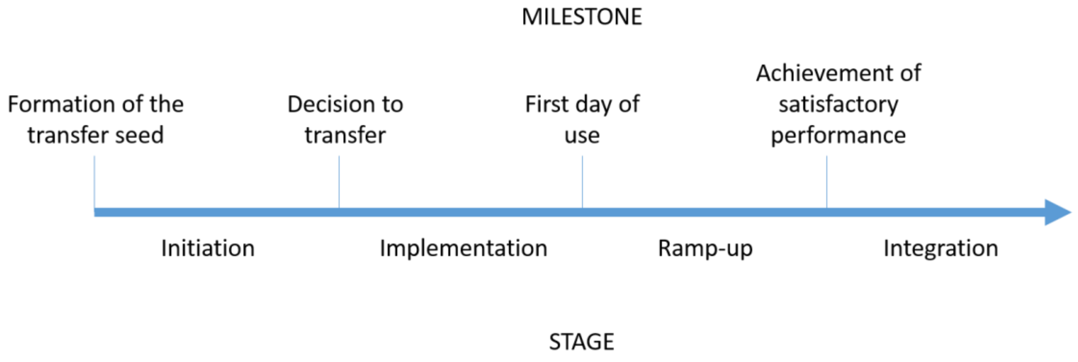

Figure 6.11: The process of knowledge transfer (Szulanski, 2000:11)

The transfer process comprises four distinct stages (Szulanski, 2000:11):

1. Initiation;
2. Implementation: The initial implementation effort of a new practice;
3. Ramp-up: Towards satisfactory performance; and
4. Integration: Follow-through and evaluation efforts to integrate the new practice with other practices of the recipient.

In addition to the abovementioned steps, the initial implementation and ramp-up stages involve a two-step process of 'learning before doing' either by planning or experimentation (Szulanski, 2000:12).

The process approach to transfer of knowledge distinguishes itself from a result, event or product approach (Szulanski, 2000:23). In reference again to Figure 6.10, the importance of knowledge transfer is made evident by the presence of an information feedback loop. In this feedback loop, implementation of the intervention is undertaken, this intervention is used and the lessons learnt are documented. Once documented, this newly acquired knowledge is then reintroduced into the model for re-interpretation, re-ordering and further testing. Through overlay of the knowledge transfer process into the integrated systems-design process, it is observable that the stages of transfer are congruent to the systems-design process, providing scope to the stage within which each step is applicable. In establishing that the precursor to final integration of knowledge transfer is the milestone attributed to the 'achievement of satisfactory performance', it is evident that a basis for quantifying success is required. This quantification is required to form a part of the internalised information feedback loop in order that reiterative implementation or future variation may be re-assessed as a function of a building solution's life cycle. The integrated systems-design process is then amended accordingly to include the knowledge transfer process and the quantification of successful performance, as represented in Figure 6.12:

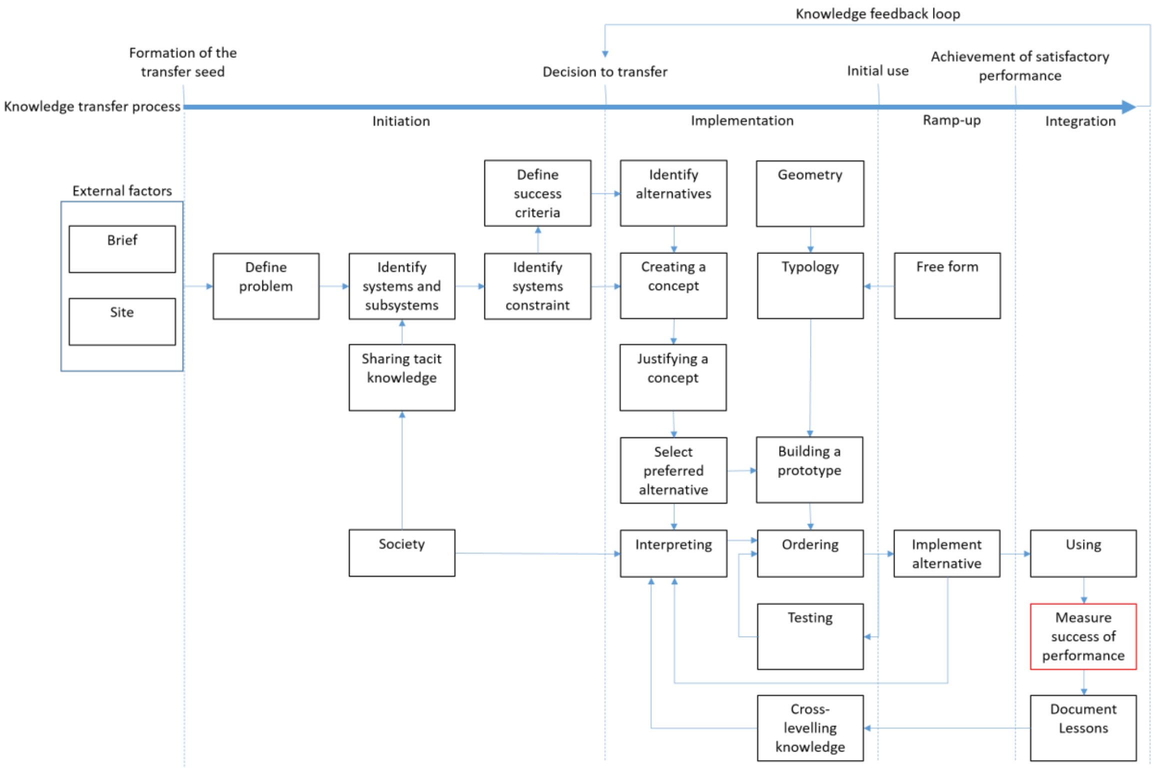

Figure 6.12: The integrated systems-design process inclusive of the knowledge transfer process

6.1.4.3. Knowledge management and preservation

Probst states (1998:17) that the goal of knowledge management is to improve organisational (social) capabilities through better use of individual and collective knowledge resources. The delivery of a knowledge management strategy provides services to meet the requirements for the creation, dissemination and utilisation of knowledge to fulfil predetermined objectives (McKay et al., 2004:889). As is the focus of Chapter 4 of this thesis, developments in ICT create advantages as well as bringing with them certain challenges. The most challenging aspect of the Information Age is the amount of information and knowledge and its management (Davidavičienė et al., 2010:822). It is therefore important for people and organisations alike to keep and ensure the passing-on of knowledge; however, the core problem can be identified as how to select, store and actualise experience in a suitable form to ensure the preservation of experience.

In establishing the 'building blocks' of knowledge, Probst proposes the following 'practical' knowledge management model, yet qualifies this by stating that in the absence of a single 'right' model, the appropriate criterion of evaluation resides in questioning how useful it is to a chosen question (identified goal) (Probst, 1998:18):

- Compatibility: establishing a shared language and good fit with existing and available concepts.
- Problem orientation: make a contribution to the solution of identified core problems. Solutions must be tested against their usefulness and applicability, and not remain hypothetical.
- Comprehensibility: a selection must be made of terms and ideas of knowledge management that are relevant to the successful solution of the identified problems.
- Action orientation: analysis should enable managers to evaluate the impact of their instruments and strategy on the overall knowledge base in order to lead to focused action.
- Appropriate instruments: focused interventions require proven instruments. Definition of instruments demands their skilful use, however.

In understanding the above model, Probst (1998:19) furthermore states that these criteria are represented in an inner and outer circle arrangement of building blocks. The inner circle of a larger knowledge management strategy consists of identification, acquisition, development, distribution, preservation and use of knowledge. The outer circle is representative of the above mentioned activities, with the inclusion of goal-setting and measurement.

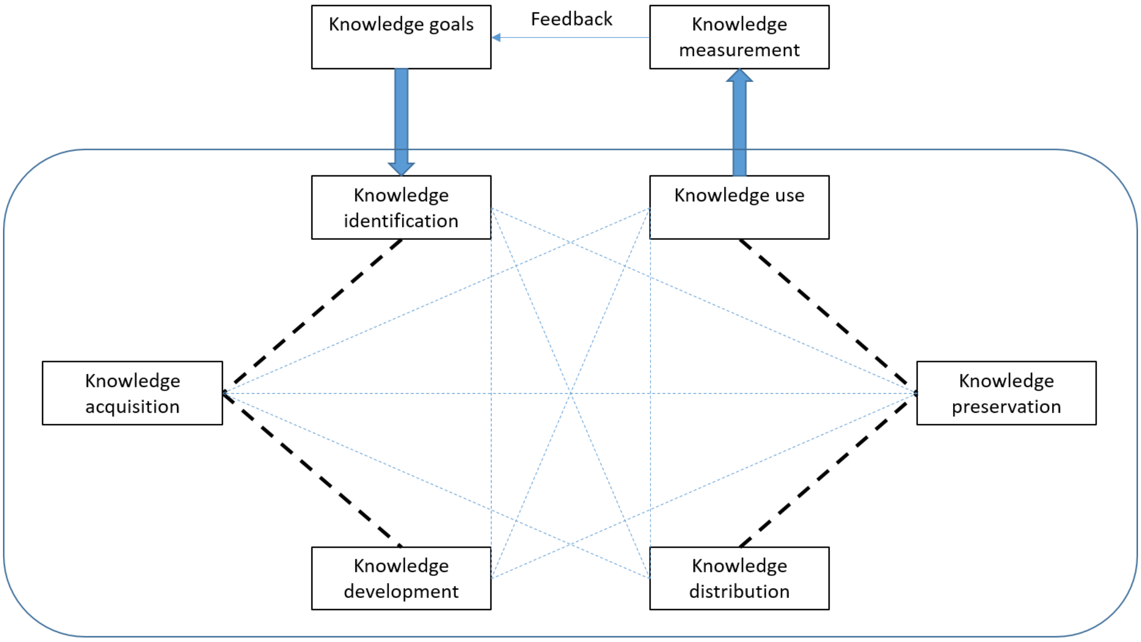

Figure 6.13: **The building blocks of knowledge management (Probst, 1998:19)**

The definition of the building blocks towards effective knowledge management therefore carries with it the advantages of structuring the management process into logical phases, suggesting effective points for intervention and providing a framework for understanding the sources of knowledge problems (Probst, 1998:20).

The researcher furthermore emphasises knowledge preservation as a key component in the systems-design process due to the need to ensure that knowledge is retained for future use as a part of a sustainable life cycle of architectural interventions.

As is observed in Figure 6.13, knowledge preservation forms a part of overall knowledge management, and is understood as the process of knowledge retrieval from people and the transfer to organisational memory (Davidavičienė et al., 2010:822). The loss of knowledge presents negative effects on the socio-political system of an organisation or process, requiring that when important knowledge is detected (or created) it should be documented to allow its transfer, particularly where a predecessor is not available (Faust, 2007:1). In order to avoid its loss, the process of selecting valuable knowledge for preservation must be formed towards ensuring its suitable storage and regular re-introduction into the knowledge base (Probst, 1998:26).

The researcher identifies knowledge preservation within the integration process (Figure 6.12) as ‘document lessons learnt’. This preservation of knowledge emphasises the explicit form of knowledge. The requirement therefore exists to create contexts that are also conducive to social interaction and sharing of tacit knowledge. Transference and preservation of tacit knowledge is, however, acknowledged to be consistently difficult, while introducing autonomy to the process is necessary to preserve knowledge long enough to facilitate later learning and transference (Ranft, 2006:62). The creation of knowledge environments assists in formalising social interaction to the point where focused intention is achieved. The intention is thus to create a social construct of a similar nature to that of an organisation as opposed to that of an informal gathering or crowd. Organisations represent an artificial formation that is established and functions for a specific purpose (McKay et al., 2011:890). In establishing the difference between the two social constructs, McKay et al. (2011:890) state that that each is a collection of individuals, but differ in the way they react to stimuli, acquire information, modify behaviour and innovate. The crowd may comprise spontaneous and disconnected activity while the actions of the organisation are purposeful and coordinated. This is important to the proposed systems-design process since the formulation of core goals is intrinsic to its formative structure through definition of both the problem and the criteria for success, therefore aligning the social construct with that of an organisation within the step of ‘cross-levelling of knowledge’.

As can be observed in Figure 6.12, by following the formulation of project goals the knowledge feedback loop is initiated. In order for the process to yield results of repute and validity as a function of scientific method, the researcher recognises that conditions for knowledge creation must be consistent and replicable. It is therefore necessary to include knowledge evaluation into the process so as to ensure documentation of knowledge is applicable and contextually appropriate. Coffey and Hoffman state that acquisition of knowledge as a process involves numerous steps, including knowledge elicitation, representation, implementation, and then validation or verification (2003:38).

As stated by Coffey and Hoffman (2003:42), verification of knowledge requires investigation at both a conceptual and mechanical level. Conceptual verification is concerned with fact checking, suitability of content, removal of errors or redundancies and overall structure of retrieval and arrangement of knowledge. Mechanical verification is concerned with checking that all components are accounted for and that the links are functional and work. The knowledge circle, as indicated in Figure 6.13, indicates that not all knowledge acquired is necessary, recognising that some discard is required based on knowledge evaluation. This determination of appropriateness through ‘knowledge planning’ is based on contextual suitability and influence (knowledge environment), as well as knowledge evaluation and verification. The researcher observes parallels with the architectural process based on this importance of context. Furthermore, the practical application of knowledge therefore contributes to a knowledge base which may be interrogated and evaluated. This represents a fundamental step within the implementation stage of the integrated systems-design process. (Figure 6.12).

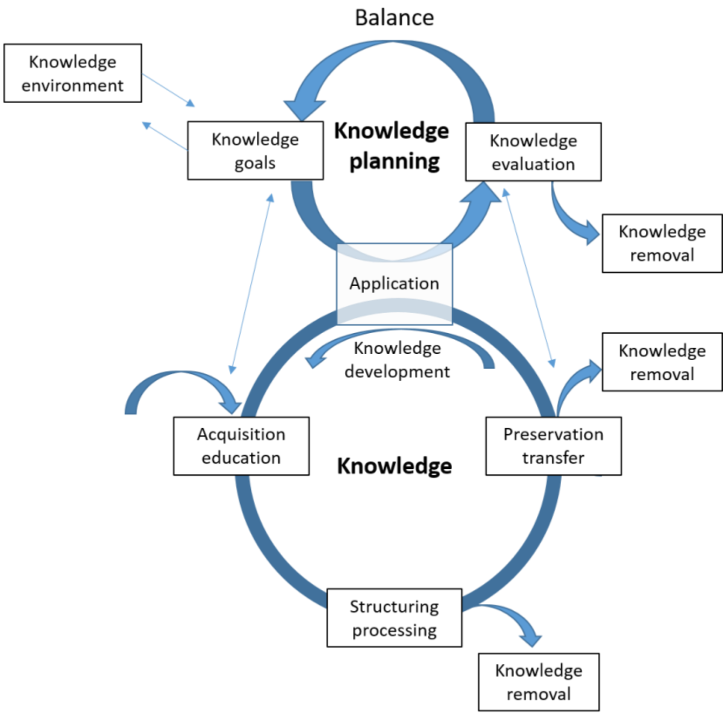

Figure 6.14: Knowledge circle, inclusive of knowledge management (Faust, 2007:2)

The integrated systems-design process, inclusive of the knowledge category as contained within the proposed sustainable development model, is therefore adapted to include the conditions for evaluation and validation of knowledge with the aim of knowledge preservation for proliferation in the knowledge feedback loop, as indicated in the following iteration of the integrated systems-design process (Figure 6.15) below:

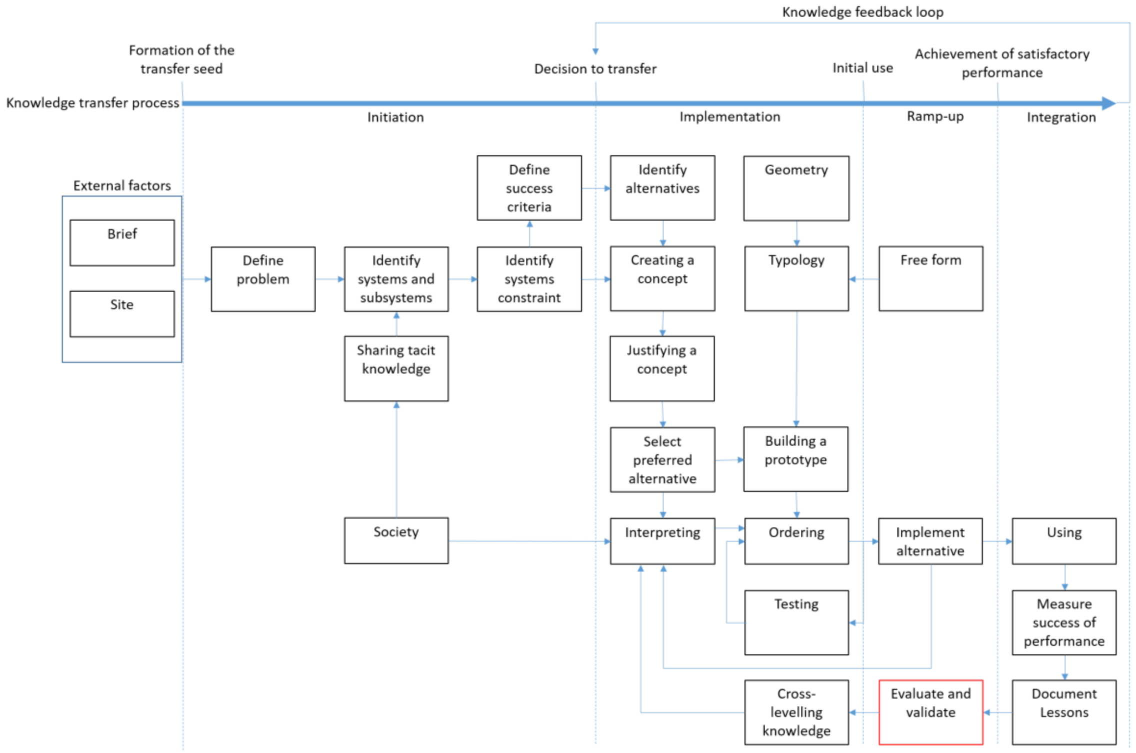

Figure 6.15: **The integrated systems-design process inclusive of knowledge evaluation and validation towards suitability of preservation**

6.1.4.4. Built environment applications in knowledge-based development

KBD has been previously addressed in this thesis as the subject of objective research and definition (Chapter 4 section 4.2.3).

Having established how knowledge is created, transferred and preserved (sections 6.1.4.1. to 6.1.4.3.), it is thus necessary to understand how this may be applied in real terms in meeting the needs of our developing knowledge-based societies. In doing so, the foundation will be made for more focused applications towards the building environment.

Smart cities have been previously addressed in this thesis (Chapter 4 section 4.1.7.4), and have been identified by experts as an emerging market with enormous potential, which is expected to drive the digital economy forward (Hernández-muñoz et al*.,* 2011, 447). However, Herndandez-Muñoz et al. furthermore state that most current urban city developments are based primarily on vertical ICT solutions leading to an unsustainable plethora of systems and market islands (2011:447). In making the case for the needs for further evolution of technological capability towards Future Internet (FI), and that the need for urban scale, experimentally-driven research is becoming more important in the field of ICT development, difficulties arise in modelling the diversity and complexity of environmental conditions to achieve realistic simulation. This results in the scenario that simulation results (explicit knowledge) can give only limited information about solutions feasibility (Hernández-muñoz et al., 2011:456). The need for knowledge feedback loops inclusive of tacit knowledge is therefore recognised by the researcher. Knowledge-based development therefore manifests itself in our urban environments through the evolution of smart cities towards the emergence of knowledge cities.

Knowledge cities offer one of the effective paradigms for the sustainable cities of the future (Yigitcanlar, 2008:63). To reiterate the rise of importance of knowledge to the progress of our knowledge cities in recent years, Yigitcanlar states that even though references to knowledge cities can be traced back decades, and some ancestral cities have had a strong and documented association with knowledge and wisdom, specific attention to knowledge-based urban development has only recently occurred (2008:63), made evident by the emergence of targeted research. Knowledge cities play a fundamental role in knowledge creation and nurturing, economic growth, and development (Yigitcanlar et al., 2008:64). Knowledge cities draw upon knowledge and information economies but also emphasise that vibrant socio-cultural activities associated with conserved natural environments, quality built environment, tolerance and multiculturalism, transparent and effective governance, and enriched human capital play key roles (Baum et al., 2007:10). The concept of human capital is further explored in recognition of creative capital as a source of better economic growth. Creative capital is derived through focused knowledge, in the assertion that this will result in the development of ‘better’ labour with the establishment of a creative class (Baum et al., 2007:11).

The concept of knowledge cities has received growing international support and interest from organisations, city administrators, research communities and practitioners over recent years. Major organisations such as the World Bank (1998), OECD (2001), European Commission (2000) and the United Nations (2001) have adopted knowledge management frameworks in their organisational strategy regarding global development. This strongly reiterates the strength of the link that has emerged between knowledge management and urban development (Yigitcanlar et al*.,* 2008:64). Knowledge cities harbour knowledge and culture forming a blend of theory and practice within their extents (Work Foundation, 2002). As societies continue to become increasingly knowledge based, the nature of city development changes. This is because activities in the knowledge sector are growing in importance and require supportive conditions and environments (Yigitcanlar et al*.,* 2008:64).

The following framework is offered by van Winden et al. (2007:529) in order to assess, compare and analyse the development of the knowledge-based economy in an urban context. This framework is divided into two cores representing a) structural characteristics of urban regions, and b) progress towards the knowledge economy. In order for this framework to be adequately interpreted, certain assumptions are made (van Winden et al., 2007:529). Firstly it is assumed that a strong relationship exists between components. Secondly, there is a feedback mechanism in recognition that the development of progress indicators will affect the foundations. Lastly, quality of governance (organisational capacity) influences both the foundations as well as the progress indicators.

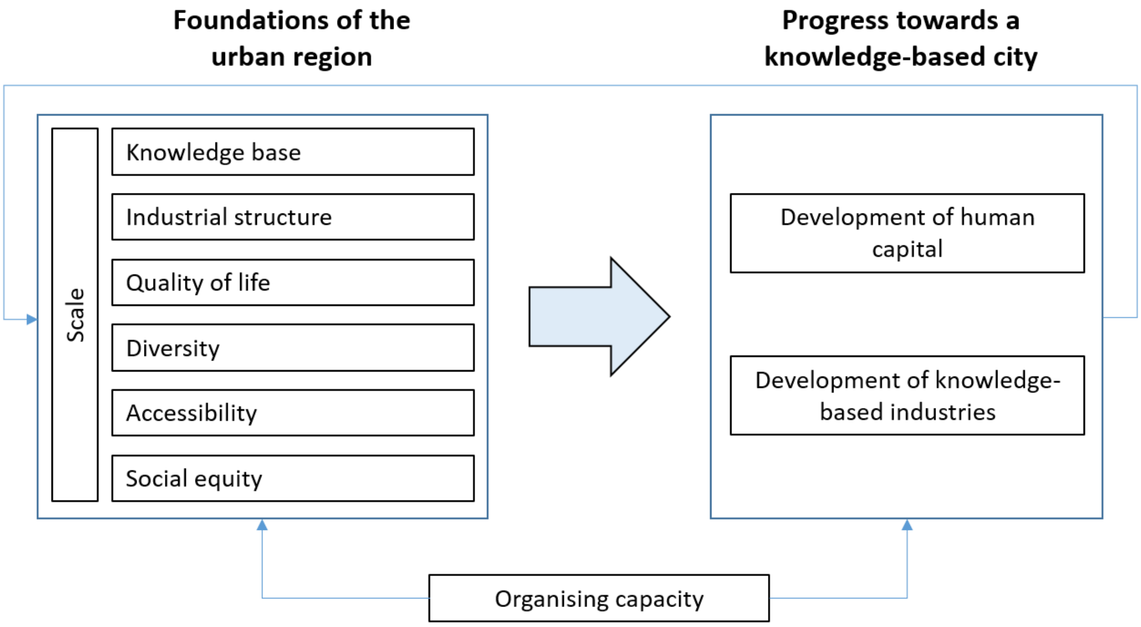

Figure 6.16: Cities in the knowledge economy: a framework of analysis (van Winden et al., 2007:529)

As derived from van Winden (2007), Yigitcanlar et al. (2008:64), define the layers that comprise a knowledge city as:

- Knowledge base: includes educational institutions and R&D activities.
- Industrial structure: affects progress and development.
- Quality of life and urban amenities: ensures that the knowledge city is attractive to knowledge and creative workers to build a strong knowledge base.
- Urban diversity and cultural mix: are instrumental in encouraging creativity.
- Accessibility: encourages and facilitates the transfer of knowledge.
- Social equity and inclusion: minimises social disparity.

- Scale of a city: larger knowledge cities may offer a greater knowledge pool, greater diversity and overall choice.

In this instance, it is determined that organisational capacity specifically affects the components forming the ‘foundations of a knowledge city’, with emphasis on development of human capital and knowledge industries comprised in the category of ‘tools for development’.

The tools for development of human capital and knowledge industries are derived from Yigitcanlar et al. (2008:65) as:

- Technology and communication: facilitate public access and sharing of complete and transparent information through high levels of technology, essential to a knowledge economy. Amended by the researcher to ICT to encompass definitions as contained in Chapter 4 sections 4.1.3, 4.1.4. and 4.1.5.
- Creativity and culture: creating a high level of social amenities and community development, while considering culture and creativity as enablers of dynamic socio-cultural activities and infrastructure.
- Human capital: development of strategies that facilitate investment and development of producers of human capital. This includes the establishment of institutions or policies which are intended to educate and inform stakeholders.
- Knowledge workers: making the environment attractive to the creative class of knowledge workers. These are understood to shape the performance of local and national economies through problem solving, learning and innovative skills.
- Urban development clusters and spatial relationships: spatial relationships provide opportunities for social relationships and knowledge sharing. This provides a context within which building of networks, dispersion of knowledge and sustainable development can occur. The broader benefits of clustering are observed through ease of accessibility to major infrastructure, and the formation of cultural hubs.

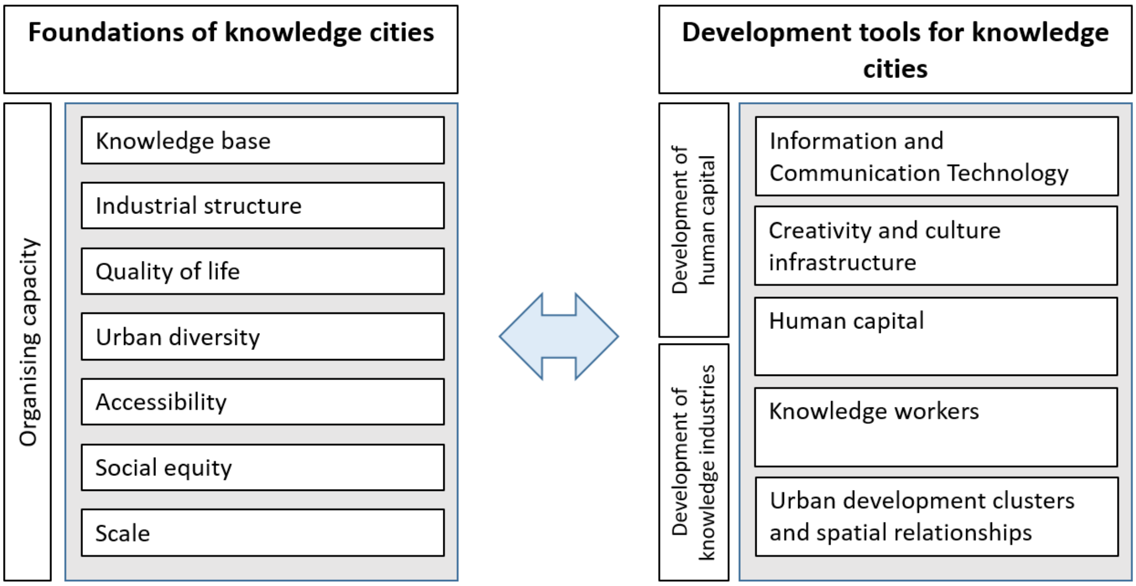

Figure 6.17: Knowledge city framework of analysis (Yigitcanlar et al., 2008:65)

Technology and communication are noted as fundamental to the success of knowledge cities (Yigitcanlar et al., 2008:65), emphasising that this era of knowledge development towards sustainable development is particular to the Information Age, as addressed by the researcher in Chapter 4.

Knowledge is becoming a key resource for cities, although, in the analysis of the performance of a city in providing quality of life, a variety of other factors are important to address such as environmental quality, safety, quality and availability of services, and open and fair government. (Yigitcanlar, 2011:357). In order to adequately cater to the multifaceted and complex performance of a city in the knowledge economy, the concept of knowledge-based urban development has emerged (KBUD). The aim of KBUD is to increase a city's competitive edge, attract talent and investment, and ultimately provide a high quality of life (Yigitcanlar, 2011:357).

Perry (2008:24) describes three dimensions of KBUD, each differing on their emphasis on the importance of knowledge and space. These are identified as:

- Process: knowledge is central and subject to change due to external pressure or influence.
- Product: urban is implied and peripheral.
- Acquisition: knowledge is intrinsic to KBUD and wider economic, cultural and social processes.

Fernandez-Maldonado and Romein (2010) state that effective KBUD requires balance between the following three dimensions: a) economic prosperity; b) socio-spatial equality; and c) organisational quality. Yigitcanlar et al. (2011:359) expand upon this to define four dimensions of importance of KBUD as a new development paradigm of the global knowledge economy:

1. Economic prosperity
2. Socio-spatial order
3. Environmental sustainability
4. Good governance.

According to Yigitcanlar et al. (2011:359), interrogation according to these dimensions supports the design of knowledge cities to encourage creation, transfer and application of knowledge in an economically secure, socially equitable, environmental sound and well-governed human context. This conceptual framework is represented below:

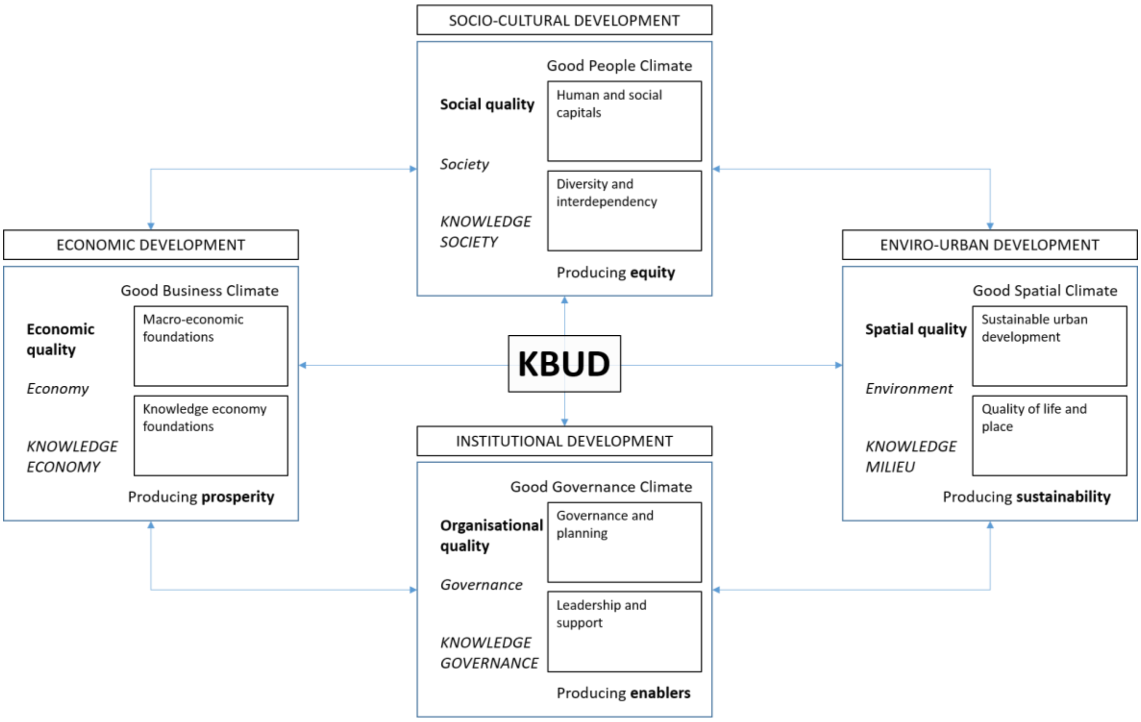

Figure 6.18: Conceptual framework of KBUD (Yigitcanlar et al., 2011:359)

It is important to include this description of KBUD in this thesis in order to establish congruency to the process of an integrated approach. The researcher, however, notes certain important differences that provide a basis for asserting the appropriateness for the proposed model of sustainability as described in Chapter 6 section 6.1.2.2. It is observed in the above figure that the eventual goal to which the four dimensions are applied is denoted as KBUD. In order to achieve this goal, sustainable development is seen as a contributor, separate from socio-economic development. This is contrary to understood and widely accepted definitions of sustainable development, as previously documented in this thesis (Chapter 3), which serve as a basis for the study. However, this conceptual framework asserts that knowledge has a contributory role to play in all formative dimensions to knowledge-based development, and that true achievement of KBUD is not possible without addressing and planning for sustainable development. The relationship of knowledge, as a concept and the ultimate goal of sustainable development in the Information Age, is therefore reinforced.

Through this investigation, in the context of long-term sustainable development for the built environment, the researcher proposes that this goal requires alignment with the creation of environments representative of the need for appropriate knowledge-based development. The manifestation of this goal is furthermore identified as that of the knowledge city, entrenched in the concept of KBUD. These knowledge cities furthermore reinforce the classification and introduction of knowledge as a key criterion within the revised model for sustainable development as proposed in this thesis. In recognition of the above knowledge city framework of analysis, the KBUD conceptual framework, and of the fact that an integrated systems-design approach is proposed (Chapter 6 section 6.1.3.2.), the researcher furthermore recognises that the role of knowledge is fundamental not only to the manifestation of the solution (foundations of knowledge cities) – represented by operational awareness of the life cycle of an architectural intervention and intrinsic knowledge feedback loops following implementation – but also in the process by which a solution is derived (development tools).

The architectural intervention or solution is not, however, always guaranteed or required to be of a city scale. In fact the nature of the architectural profession whereby a contract is entered into with a particular owner of a particular site is often contradictory to that notion. While that point will be addressed later in this chapter, it is thus furthermore necessary to continue the focus of the approach towards a singular intervention, particular to that of the traditional scope of involvement of an architect.

6.1.4.5. Knowledge building

Knowledge is proposed by the researcher as a core contributing pillar in revised sustainable development theory (Chapter 6 section 6.1.2.) through response to the needs of knowledge-based development, carrying with it certain connotations for architectural product. As was discussed in Chapter 6 section 6.1.4.1., knowledge creation is contextually affected. Interpreted literally, this statement places significant responsibility on built environments to respond to the varying levels of context responsible for sharing of ideas and dialectic process of knowledge building. The following questions arise:

1. How is sustainable architecture of the future conceptualised and implemented to enable and embody KBD?
2. Is the formative framework for KBUD suitably applicable in the pursuit of singular buildings?

In addressing the first question, it continues to be necessary to answer it on two levels: process and solution (product). As derived from the integrated systems-design process, as proposed by the researcher in Figure 6.15, the ‘process’ is represented not only in the formative conceptualisation and design, but also in knowledge feedback in implementation and operation. This elevates the process beyond that of development of a product, towards the creation of a building solution as a part of a system. Knowledge-based development is thus embodied through formalised integration of knowledge creation, transfer and application. In terms of the ‘building solution’, it has been stated previously that a key component of knowledge creation is place-making (Chapter 6 section 6.4.4.1.). The goal is therefore to establish deliberate design intent in creating environments that are capable of fostering explicit (hard data, ICT infrastructure) knowledge, as well as tacit (experience, networking, sharing of ideas) knowledge. It is fundamental therefore that sustainable architecture acknowledges this goal in addition to the greater social, economic and environmental requirements, opportunities, and constraints that contribute to optimum quality of life (denoted ‘human need’ within the proposed model of sustainable development).

The formulation of sustainable architecture must therefore ensure that the application of sustainable development principles and criteria, as proposed in this thesis, are compatible with the requirements of the Information Age as embodied in the combined definitions of quality of life and knowledge-based developments. Table 6.4 establishes a matrix of influence of the core and ancillary criteria of sustainable development, as proposed by this thesis, to the previously identified indicators for quality of life and KBUD.

Table 6.4: Matrix of influence: Sustainable Development in the Information Age

Matrix of influence: Sustainable Development in the Information Age									
		Core criteria of Sustainable Development							
		Economy		Environment		Society		Knowledge	
		Ancillary criteria of Sustainable Development							
			Physical infrastructure		Policy		Culture		Space and technology
Quality of life indicators	Environmental quality			✓	✓			✓	
	Safety				✓	✓	✓		
	Availability of services	✓	✓		✓				
	Open government				✓	✓		✓	
Foundations of knowledge based urban development	Social equity	✓				✓		✓	
	Scale		✓	✓					✓
	Accessibility	✓			✓			✓	✓
	Industrial structure	✓	✓						✓
	Place-making			✓		✓	✓	✓	✓
	Urban diversity	✓		✓		✓	✓	✓	✓

The researcher observes that the core and ancillary criteria have a holistic impact on the requisite indicators for quality of life and knowledge-based development. It is therefore deduced that the proposed model for sustainable development in this thesis provides a suitable basis for combining with the integrated systems-design process in the conceptualisation of a sustainable architecture through a formalised design methodology.

According to Campbell (2009:195), a large shadow market of knowledge has already formed in cities around the world. In addressing the second question, the researcher recognises that foundations of KBUD must be evaluated in its influence on singular buildings and not solely at the scale of a city or urban environment. The future of the built environment therefore lies in the establishment of architecture that is beyond that of an intelligent building (product) residing within a smart city (sum of its parts). In the age of knowledge-based development, the responsibility is to produce enabling architecture: knowledge buildings.

Knowledge buildings enable the capacity for knowledge creation, transfer and preservation while responding to the holistic needs for sustainable development. Knowledge buildings are therefore fundamental to answering the call for an architectural solution, instead of product. Through application of the proposed sustainable development model (Figure 6.2), the researcher proposes that not only is the architectural process equipped to develop a quantifiable methodology of approach, but also the means to integrate informational feedback loops to the architectural solution itself. This therefore results in a shift of paradigm in the architectural professional from that of a building executor (project completion), to that of a knowledge-building custodian (project life cycle).

6.1.5. The impact of computing on the process

The researcher recognises that industrial production, when combined with modern ICT, is currently heading into a future of more rapid, more flexible and smarter automation. This level of automation is referred to as cyber-physical systems, which have the potential to drive manufacturing into the digital age and contribute to what many are calling the 4th Industrial Revolution (Schlick, 2012:55). As automation becomes learnt, and decision making is reduced (or optimised) to a computerised algorithmic application, it has significance for the future of the world in the making of things, and the question arises: Is design beyond the realm of automation?

There might yet exist a paradox in the development of a systems process or design methodology embodied with the aim of simplifying the process into a repeatable formula through, among other steps, the application of constraints, response to contextual conditions and calculation of efficiency. A future where built environments are as vulnerable to the pervasive influence of computer logic and 'parametricism' towards form giving is therefore highly conceivable. In his book focused on the growing dependence on, and effect of, technological dependence in the 21st century, Carr (2016) states that 'the speed and exactitude of the machine may cut short the messy and painstaking process of exploration that gives rise to the most inspired and meaningful designs'. Michael Kilkelly, in his article 'Are computers bad for architecture?',[47] refers to the parametric approach as working only when the problem is well understood. At the early stages of design, where the problem is still being formed and requires some abstract thought process, the precision demanded by the computer is not always suited.

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[47] 'Are computers bad for architecture?' by Michael Kilkelly, 2015. http://www.archdaily.com/618422/are-computers-bad-for-architecture. [Viewed 10 March 2016].

When referring to the problem of automated creativity, there has long existed a belief that computing could never overshadow human achievement because of a lack of creativity,[48] as could be noted in a 1992 statement in Fortune magazine from Sony co-founder Masaru Ibuka that 'a computer isn't creative on its own because it is programmed to behave in a predictable way'.[49] However, this same article makes reference to the fact that technology is playing an increasingly important and defining role in the creative medium of music, where composers of today are surrendering parts of the creative process to computerised algorithms. However, today this still remains a part of the process with computing forming an ancillary or support role to the human process principally by virtue of its capacity for big data management. That being said, the capacity for intuitive thought-processing or 'deep thinking' in computers took a major step forward in 2016 when the (Google-funded) DeepMind computer program, AlphaGo, defeated the world's number one Go player – a board-game with more possible configurations than atoms in the universe and based on intuitive problem solving that requires creativity and strategy – achieving the 'holy grail' of scientists and marking a huge milestone in the evolution of Artificial Intelligence.[50] The realm of intuitive problem solving has now officially arrived in digital format, setting the stage for rapid improvement and permeation within our societies.

The researcher (architect) thus concedes that the proposed systems-design process, contained in this thesis, which serves as a basis for a revised design methodology, is no less suited to automated computer logic as it would be to the human process. However, while advancements in industry interventions such as computational and *generative design*[51] are being developed for commercial availability, the eventual

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[48] 'Can machines write musicals?' by Areille Pardes, 2016. http://www.vice.com/read/can-machines-write-musicals [Viewed 10 March 2016].

[49] 'The real genius behind Sony' by Ibuka, Brenton, & Schlender, 1992. http://archive.fortune.com/magazines/fortune/fortune_archive/1992/02/24/76101/index.htm [Viewed 10 March 2016].

[50] '*Human board game champion again outwitted by Google program*' by Charles Riley and Sophia Yan, 10 March 2016. http://money.cnn.com/2016/03/10/technology/alphago-google-deepmind-go-lee-computer/ [Viewed 17 March 2016].

[51] 'Generative design mimics nature's evolutionary approach to design. Designers or engineers input design goals into generative design software, along with parameters such as materials, manufacturing methods, and cost constraints. Then, using cloud computing, the software explores all the possible permutations of a solution, quickly generating design alternatives. It tests and learns from each iteration what works and what doesn't.' http://www.autodesk.com/solutions/generative-design [Viewed 2016-09-08]

computerisation of the entire architectural process remains, for the time being, on the horizon.

6.1.6. Physical determinism – the capacity of the built environment to contribute to the revised model for sustainable development

In this section, the researcher investigates how the built environment enables the advancement of the proposed sustainable development theory, with particular emphasis on architecture and buildings (solutions). In Chapter 3 the researcher observed that existing and past concepts are not sufficiently equipped to promote sustainable development in the Information Age, as well as providing focused methodology for implementation for articular architectural interventions. It has been already addressed in this chapter (section 6.1.4.3) that the proposed sustainable development concept as described in section 6.1.2.2 provides a suitable basis to address the requirements of quality of life as well as knowledge-based development that are characteristic of the Information Age. In addressing these requirements, the researcher identifies the following aspects of building design and performance to be integrated into a proposed design methodology later in this chapter:

- Advancing beyond green building design: Evolve the quantitative process beyond ecological focus, towards a more holistic and integrated solution.
- Flexible design: Predict causes of change and establish readiness to respond in process, product or operation. Accommodate and predict advancements in technology, building performance, occupant requirements, etc. over a building's operational life span.
- Adaptability to contextual factors: Incorporate changing macro-scale requirements to ensure healthy mixed-use urban environments are created.
- Sustained occupancy: Recognise a building is only necessary if it continues to be of use and offers quality of life.
- Economical implementation and operation: Benchmark project feasibility during planning and operations in recognition of the building life cycle.

By addressing the points above, the researcher proposes that broader sustainable development principles are better applied to provide focus to a singular architectural solution or knowledge building. Thus not only is sustainable development adapted to cater to the needs of the Information Age and the knowledge societies it is composed of, but also to erode the vagueness of concept that affects implementation in the architectural profession (Chapter 3). The researcher furthermore notes that while the above topics are determined to be of benefit to the body of knowledge in this thesis, further research for each aspect is possible. The researcher therefore intends to provide a concise summary of each to better facilitate understanding of implications of sustainable development for products of the built environment in the context of this thesis.

6.1.6.1. Advancing beyond green building principles

There are many existing examples of building, product and landscape design that dramatically reduce resource and energy usage while achieving the same functions, and even improving quality of life at a lower cost. As stated by Birkeland (2005:1), the moral imperatives, practical needs and demands, eco-solutions and fiscal resources already exist. What is required instead is a move from traditional remedial approaches to preventative systems-design solutions that restore the ecology, foster human health, and prioritise universal well-being over private wealth accumulation (Birkeland, 2005:1).

Green building design was investigated in Chapter 3 of this thesis as an ecocentric approach to the conceptualisation and delivery of a finite building product but lacking in overall response to sustainable development criteria. As stated by Guy et al. (2001:140), the Green Building emphasis on environmental efficiency through technological innovations in building fabric and servicing systems is representative of quantitative rhetoric. Success is thereby expressed in numerical reduction of building energy consumption, and in concepts such as life cycle flexibility and cost-benefit analysis. A finite approach to building delivery is required to be traded for a process approach in building and operational life span. In recognising that sustainable development is additionally representative of societal, economic, and knowledge criteria, green building design must be recognised as but a part of the solution.

New advances have been made in ratings tools to facilitate a dialogue in the socio-economic context, such as the socio-economic tool of the Green Building Council.[52] This tool defines itself as a separate optional category for rating socio-economic

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[52] ‘Socio-economic category PILOT’. https://www.gbcsa.org.za/green-star-rating-tools/socio-economic-category-pilot/ [Viewed 27 March 2016].

achievements in green buildings,[53] with a focus towards recognising challenges such as poverty, unemployment, inequality, lack of education and skills, and health.[54] The emphasis in this approach is to propagate the scoring system approach and quantification of success. This is recognised by the researcher to be a growing acknowledgement that the green building debate is further extending towards greater technological, social and economic proficiency of architectural product. While not advocating sustainable development as the ultimate goal, green building design is regarded as the realm within which socio-economic matters are addressed. As has been the focus of this thesis, the core debate is required to re-centre on sustainable development, of which green building design forms a part.

Debates about sustainable architecture are, however, shaped by different social interests, based on different interpretations of the problem, and characterised by quite different pathways towards a range of sustainable futures (Guy et al., 2001:146). Design therefore needs to shift from a paradigm of ‘transforming nature’ to one of ‘transforming society’ towards sustainability by improving the life quality of, and relationships between, all living things, communities and the natural/built environment (Birkeland, 2005:6). This means designers in all fields are required to:

- Re-examine human needs, and set appropriate goals which prioritise ecological sustainability and social equity.
- Rethink the basic nature, methods and goals of the design process itself.
- Integrate knowledge from other fields concerned with human and ecosystem health.
- Promote new technologies, systems of production and construction methods that do not rely on natural capital, fossil fuels and harmful chemicals.

Green building design ultimately remains an accessible process in design development based upon its quantifiable approach through available ratings systems and performance evaluation criteria. Green building design must therefore recognise the

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[53] ‘Green Building Council announces South Africa’s first socio-economic impact certification’, 2015. https://www.gbcsa.org.za/news_post/green-building-council-announces-south-africas-first-socio-economic-impact-certification/ [Viewed 27 March 2016].

[54] ‘Technical manual Green Star SA: Socio economic category pilot’, 2014. https://www.gbcsa.org.za/wp-content/uploads/2013/10/Socio-Economic-Category-PILOT-March-2014-REVISED-FINAL.pdf [Viewed 27 March 2015].

greater context of implementation towards sustainable design practice as an ongoing transformational process in which the interests and challenges for various stakeholders are located (Guy et al., 2001:146). The goal of the researcher in developing a supportive design methodology within this thesis is therefore to elevate the quantification process to embody holistic principles of sustainable development within a systems-based architectural solution.

6.1.6.2. Flexible design

With emphasis placed on the creation of an individual architectural intervention or solution within an urban environment, long-term flexibility remains of importance. Haubelt et al. (2002:854) state that with the term ‘flexibility’ a new design dimension is introduced, that of an embedded system that quantitatively characterises its feasibility in implementing various possible alternative behaviours. This is important to note when designing systems that are able to adapt their behaviour during operation. This could be due to, for example, new environmental conditions or responding to different behavioural requirements. In pursuit of achieving advanced sustainable design, Kasarda et al. state that design for flexibility is based on the hypothesis that a product life ends where it is unable to adapt to change, broken or out of style, or rendered inefficient due to technological obsolescence (2007:727). Rajan et al. (2003:1) define flexibility as the degree of responsiveness or adaptability for any change in a product design. The following benefits are furthermore attributed to flexible design (Rajan et al., 2003:1):

- Reduction in redesign cost;
- Enabling faster response to user feedback; and
- Allowing for faster updates to products and achieving higher levels of performance in a shorter span of time.

As stated by Gotthard, modularity in design based on principles of design for flexibility, may be accommodated in the design process during specification of components, and case-based studies (2004:1). Modularity, while contributing greatly to flexibility, also assists with early estimation of cost, and complexity of assembly and integration. Gotthard additionally substantiates modularity as being truly flexible by stating that components of an element set composed of modular units allows for flexibility based on interchangeability of units, accommodating both short- and long-term modification (2004:6). Lipson et al. state that designs that exhibit modularity have higher adaptability and, as a consequence, better survival rates under changing requirements (2001:11).

For the purposes of thorough understanding, the researcher recognises that while modularisation of components of design is possible and even warranted at times, it is important to assess flexibility according to unique design instances that may require unique solutions.

The researcher hereby identifies two methodologies to be investigated for applicability in flexible design processes in architecture. These methodologies, while based in the realm of industrial product design and manufacturing, contain the necessary 'building blocks' for identification of risk factors, and predictive modelling as a basis for quantifiable decision making.

As a first basis for investigation the established industry method of Failure Mode and Effect Analysis (FMEA)[55] aims to identify potential failure modes caused by design or implementation deficiencies. Rajan et al. (2003:2) note that this process is instituted retroactively, and is therefore not suited to preventative or predictive evaluation of possible future changes in a product. This process is divided into two steps, namely decomposing the product, and performing a Change Mode Effects Analysis (CMEA). Decomposing the product is concerned with disassembling the product into discernible components such as modules or parts. The main factor to consider in design for flexibility is contained in analysing the probability of occurrence and the readiness of a system or organisation to react. According to Rajan et al. (2003:2) the following table is suited to performing this analysis, with the goal of attributing to a product a quantifiable value defined as the Change Potential Number (CPN):

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[55] Established in the 1940s by the US military, FMEA was further developed primarily by aerospace and automotive industries to be used by numerous industries thereafter. FMEA is a step-by-step approach for identifying and prioritising all possible failures in a design, manufacturing, or assembly process, product, or service. http://asq.org/learn-about-quality/process-analysis-tools/overview/fmea.html [Viewed 27 March 2016].

Table 6.5: Generic CMEA basic columns, Rajan et al. (2003:2)

Change Mode and Effect Analysis for potential changes in product design							
Modules / parts	Potential change mode	Potential effects of change	Design flexibility	Potential cause(s) of change	Occurrence	Readiness	Change Potential Number (CPN)

In the CMEA table above, the indicated columns are derived from Rajan et al. (2003:2) by the researcher and interpreted for applicability to the building design process. For purposes of reference, use of the term ‘products’ is assigned to ‘buildings’:

- **Modules / parts:** For the purposes of the design process where the product is not yet formalised but is being conceptualised, this column is best substituted for the initiation stage of the integrated systems-design process as defined by identification of ‘system and sub-systems’. This may also be termed by definition of building ‘function’.
- **Potential causes of change:** Causes for change may be obtained from client/user needs for the product, input from experienced designers/collaborators in the product segment, and performance goals.
- **Potential changes:** Potential changes are documented in terms of product functions or parts, as well as the changes involved with these functions and parts.
- **Potential effects of change:** documentation of perceived or predicted effects of change. Effects may influence the product itself or interrelating components of the product.
- **Design flexibility:** Based on the potential effects of change, the extent to which the change will affect the entire product is scored. A low score represents a low incumbent flexibility, hence resulting in total redesign and therefore a new product. A high score indicates that the change will have no parametric effect on the core product and therefore indicates a high level of flexibility.
- **Occurrence:** Based on the potential causes of change, this column also scores the probability of occurrence. A low score signifies no probability of occurrence and future design changes, whereas a high score indicates a high probability of occurrence and need for future design changes. Part of this assessment of changes involves two sub-categories, as derived from Rajan et al. (2003:3):

  - **Opportunities or drawbacks in the present design:** based on ongoing user and client/operator feedback. This is consistent with the proposed feedback loop in the initiation and implementation stages of the integrated systems-design process.
  - **Time-dependent change:** This is inclusive of technological change and obsolescence over time, future plans for evolution of the product, and future expectations from operator and/or user. Impact of evolution of use may be linked to broader contextual influence.

- **Readiness:** The level of preparation that a product and operator may require to implement necessary change. A low score is indicative of lack of preparedness. This could be due to insufficient knowledge and information, shortfall in technological capability, lack of accommodating infrastructure, organisational flexibility and financial readiness. A low level of preparedness incurs a higher cost to accommodate change.
- **Change potential number:** The CPN is defined by Rajan et al. (2004:5) as:

$$CPN = \frac{1}{N}\sum_{i=1}^{N}\frac{[(Ri + Fi) - Oi + 8]}{27}$$

Where *F* is design flexibility; *O* is the occurrence; *R* is the readiness; and *N* is the maximum number of potential change modes, potential effects of change and potential causes of change.

By applying the above method, an objective basis for predicting change and assessing product flexibility is possible. The assessment and measurement of flexibility thus allows for informed decision making and planning, as well as the basis for documentation of lessons learnt which is integral to the knowledge management process in design.

By comparison, the design methodology DFAD as proposed by Kasarda et al. (2007:727) characterises a product as a dynamic adaptable system while modelling the product as a controllable (closed) system with a feedback loop. This requirement for a feedback loop, which is incumbent on a closed loop system, makes this methodology directly compatible with the proposed integrated systems-design process of this thesis. By interrogating this methodology, it is therefore possible to formally incorporate design for flexibility into the architectural process.

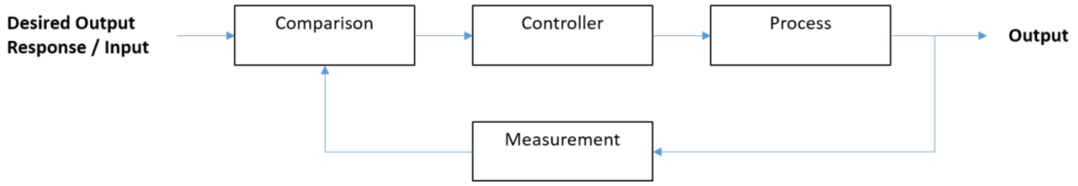

Figure 6.19: Block Diagram of closed feedback loop system (Kasarda et al., 2007:729)

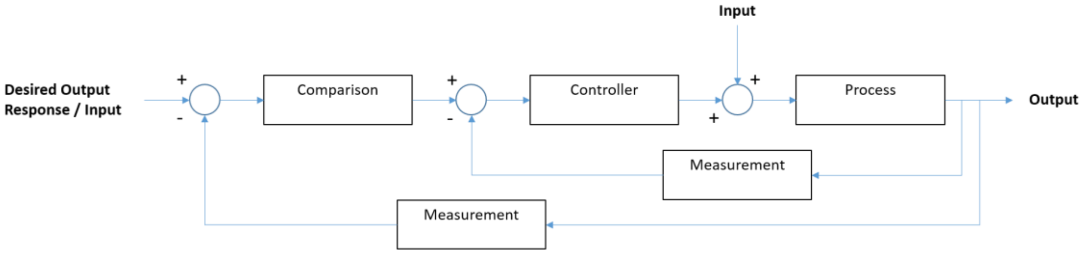

Figure 6.20: Multiple input system, derived by the researcher from Kasarda et al. (2007:729)

The basic components of a dynamic system as indicated above are block diagrams, referencing single and multiple input scenarios. These represented components are further described as follows (Kasarda et al., 2007:729):

- **Signals**:
  - Input, or desired output response
  - Output, or actual output response

- **Measurement or sensors:** How signals are detected and measured
- **Comparator:** Comparison of input and output signals to detect and compare magnitude of discrepancies
- **Process:** Aspect of system performance that requires control
- **Controller:** How change is put in effect
- **Control system:** Control algorithm and components to modulate the change.

According to Kasarda et al. (2007:730) the control system is powerful in product development application since the building blocks of this approach are straightforward and flexible in describing and modelling the system under analysis. The flexibility to create models based on empirical data facilitates quantitative modelling of difficult system components in product development that may be perceived to be intangible, such as client preference and technological obsolescence.

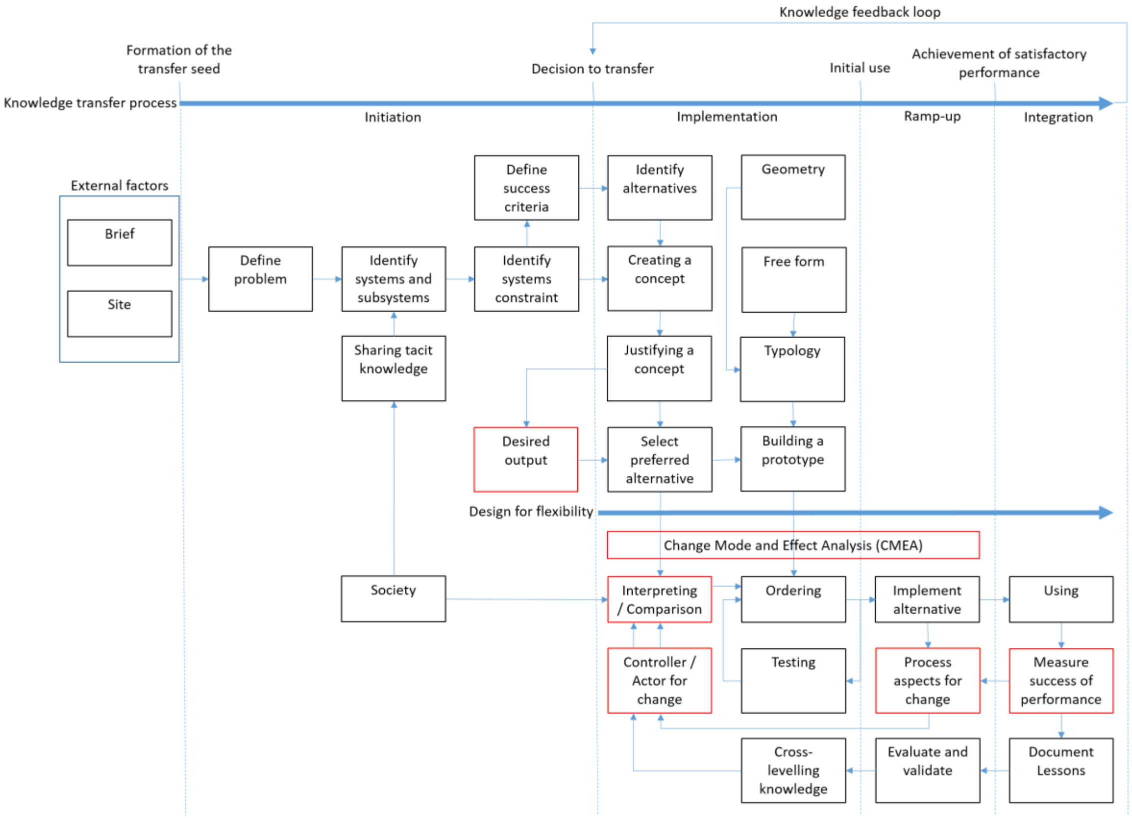

Figure 6.21*:* **Integrated systems-design process inclusive of considerations for flexible design**

In order to adequately achieve flexible design in the architectural process as can be seen in Figure 6.21, the researcher has incorporated key considerations and activities as derived from the closed feedback loop system (Figure 6.21). This integration is representative of a multiple input scenario whereby it can be observed that progress towards an architectural solution is a function of concept selection and justification, ordering of components and typology, and direct social input. The following stages are incorporated:

- **Desired output:** Preliminary design construct based on clear definition of concept and pre-emptive desire for solution. Requires definition of not only what the design concept needs to do, but what it needs to be.
- **Interpreting / comparison:** Interpretation remains a necessary step in the process by assimilating information and constraints and directing this input with purpose towards a solution. Comparison runs concurrently where new input is received during product life cycle via information feedback. Through comparison, initial solution is measured against the proposed deviation or variation in order to ascertain extent of required adaptation, i.e. total system or isolated component.

- **Process aspects for change:** Following ordering of inputs and the implementation of preferred alternatives through design iteration, variables are identified that require change to meet with evolving success criteria.
- **Controller / actor for change:** Once variables are identified in the change process, the means with which these variables are adapted, removed or replaced are identified.
- **Quantify success of performance:** While a necessary step in the established process, the quantification of success through user experience has new significance in the identification of aspects that require change or adaptation. The factor of user experience is addressed in greater detail in the next section.

It is furthermore observed that design for flexibility is clearly positioned within the defined knowledge feedback loop. This is in direct support of the requirement for control and modulation of change in the (proposed) solution. Recognising that a building is a sum of its parts, the researcher has included the CMEA process within the implementation and ramp-up phases. This enables the systems-design process to analyse components that bear risk of obsolescence, such as ICT infrastructure and intelligent building components and green building technologies.

The CMEA methodology is not intended to interrupt the sequence, nor be directly influential over specific stages in the systems-design process. This is because the creation of new technologies that pre-empt obsolescence of components is not always possible to predict. Instead CMEA is intended to be influential over the formative stage of the knowledge feedback loop process at the discretion of the designer.

6.1.6.3. Addressing user experience in the process

In the proposed model for sustainable development (Figure 6.2), human need is identified as a core requirement in successful implementation. By virtue of this requirement, the research asserts that without satisfying the core needs of humankind in our built environments, these architectural interventions – which inevitably cost the planet a measure of its resources – cease to be necessary or even sustainable. Vischer similarly states that the building exists to support the activities of the users it shelters (2008:231). Vischer furthermore points out that user experience in the built environment can be summarised into three criteria, which in turn create a framework for assessment. These criteria are concerned with the way in which a building supports its user – defined as either an individual, group or organisation – psychologically, functionally, and physically (2004:236), manifested linearly in the way users are affected and respond to their environment.

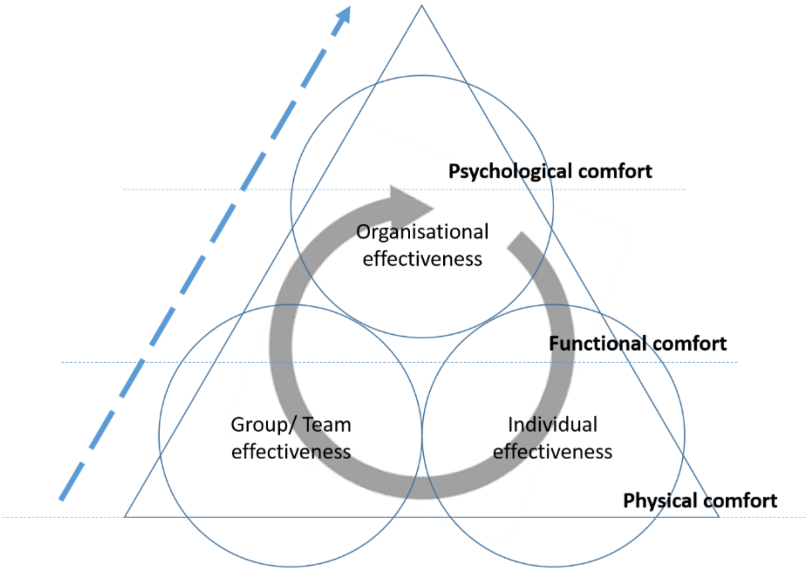

Figure 6.22: Analytic framework for assessing the user experience (Vischer, 2004:236)

Ensuring that our built environments promote an equitable and profitable existence for their end users is thus mandatory if the ecological cost of their creation is to be justified. In addition, built environments manifest themselves as prime examples of interactive product design. Thus in the realm of interactive product design, Battarbee et al. (2005:5) state that user experience is a key term, yet is used in many different ways. User experience encompasses all aspects of an end user's interaction with a service or a product,[56] as well as the quality of experience a person has when interacting with a specific design.[57] While most recently more popularly associated with human-computer interaction, user experience associates itself with the design of interactive products which accommodate experiential qualities of technology rather than product qualities (Hassenzahl et al., 2010:353). When attempting to create an experience, the prevailing approach is to design situations, or levers for interaction rather than predicated outcomes, whereas a product provides a basis for encouraging interaction that may be experienced in different ways depending on context (Forlizzi et al., 2000:420). User experience is not be confused with usability or user interface, however. These terms

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[56] 'The definition of User Experience', by Don Norman and Jakob Nielsen. https://www.nngroup.com/articles/definition-user-experience/ [Viewed 6 April 2016].

[57] 'User Experience Network: About UXnet'. http://uxnet.org/ [Viewed 6 April 2016].

are instead integral components of user experience. While usability is important, on its own it is not sufficient to guarantee a product's success (Battarbee, 2005:6).

In the realm of user experience for interactive technologies and products, a positive experience is associated with the fulfilment of universal psychological needs such as competence, relatedness, popularity, stimulation, meaning, security, and autonomy (Hassenzahl et al., 2010:353). Experience remains a staple of knowledge-based development, by virtue of the fact that knowledge has been previously researched (section 6.1.4) to comprise either tacit or explicit experience. However, Hassenzahl et al. state that experience is also ubiquitous, mostly unconscious but still accessible to the person experiencing it (2010:353). Furthermore it is subjective in nature, context-dependent, and temporary (2010:362). Battarbee et al. state that designers' approach to user experience is achieved through application of hedonistic, emotional, and practical benefits associated with products (2005:5). A recent shift towards User Experience Design refers specifically to the relationships between people and interactive technologies and products, reflecting a broadening of focus from work-related tasks to lived experience (Wright et al., 2004:3). The characteristics of usability, according to Shackel, are described as being effective, flexible, learnable and satisfying to use (1990:27). Wright et al. (2004:5), however, state that it is no longer sufficient to produce a system that only satisfies these characteristics.

The researcher additionally observes that in many ways the creation of physical knowledge-based environments is similar to the creation of a digital web-based landscape. In both the built environment and the Web, the 'product' is required to satisfy functional specifications and content-based requirements. Garrett (2010:62) states that functionality is concerned with defining the feature set of a product, while Alexander (2006:265) states that it as a property given to an artefact in order to create a practical effect. Functionality can furthermore be divided into two categories (Alexander, 2006:265):

1. **Technical functionality:** the properties of an artefact that make it do the job in itself; and
2. **Interactive functionality:** ergonomic and communicative functionality that concerns itself with the properties of the artefact that interact with its users.

However, functionality alone does not make a product usable (Alexander, 2006:265). Content, therefore, is concerned with determining and sourcing what information is useful in the use of that product. How functionality and content are presented and made available defines the quality of user experience, while recognising that usability is dependent on the context within which it is designed and used.

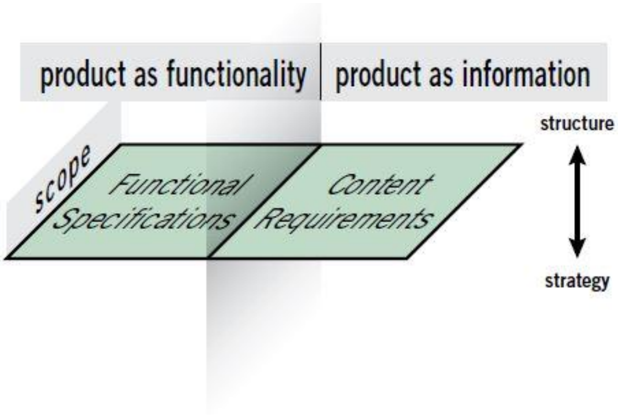

Figure 6.23: Functionality and content in design (Garrett, 2010:62)

The system that defines a point of contact for interaction must, as a minimum requirement, be useful in the lives of those using it. When considering the implications on architecture, usability is one of the most important yet neglected aspects of building performance (Alexander, 2006:262). Based on a case-study investigation of the application of usability concepts in the built environment, Alexander concludes the following (2006:269):

- User experience is representative of all aspects of the end user's interaction with an organisation, its services, its products and its facilities.
- Usability focuses on the ease and efficiency with which a facility is used.
- Usability is concerned with effect rather than effect rather than product.
- Usability is a continuing process.
- Usability is a time-, place-, context- and situation-bound concept.
- Increased functionality does not result in improved usability.

Function and content of product are important factors in design development; however, these are not tailored to optimising user experience if developed individually and exclusive of contextual influence. A framework in which design approach may be undertaken and incorporated therefore requires further exploration.

Battarbee et al. (2005:6) state that currently there are three main approaches to applying and interpreting user experience in design. These are summarised as follows:

- **The measuring approach:** This is used primarily in development and testing. It is based on the notion that experience is measured, understood and improved through gauging emotional reaction.
- **The empathetic approach:** Design begins with a rich understanding of a user's desired experiences and only then designing products and concepts to support them. Experience is thus emotional in nature, but experiences should be connected to the desires and motivations of the end users.
- **The pragmatist approach:** experiences are temporary constructions that develop from the interaction between people and their environment. Depending on the end user's actions and interactions, experience fluctuates between states of cognition, subconsciousness and storytelling.

The researcher observes that the pragmatist approach is most closely aligned with the design approach in architecture by virtue of contextual and social influence on experience. While the first two approaches rely on emotion as the primary indicator for user experience, the pragmatist approach is broader in its scope (Battarbee, 2005:7). Wright states that the pragmatist approach is a practical act, establishing the basic concepts for describing experience as well as a methodology for making these concepts useful in the lives of people (2004:78). Forlizzi and Ford (2000:422) state that, in order to design a good product and related experiences, it is critical to understand the end user. The user-product interaction process, as defined in the Figure 6.24, incorporates three components: user, product and context of use.

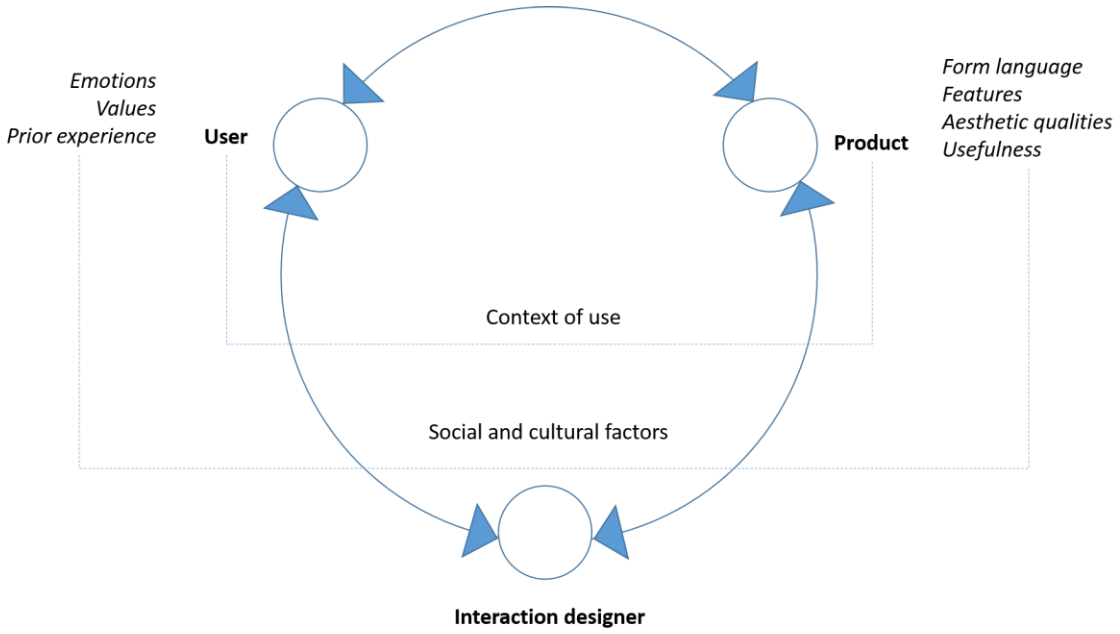

Figure 6.24: The role of the interaction designer in understanding experience (Forlizzi et al., 2000:473)

Forlizzi et al. (2000:473) conclude that, by understanding experience, designers are able to use this as a source of information for creating products that enhance quality of life. The role of understanding and designing for optimum user experience is thus reinforced in the researcher’s proposed model for sustainable development (section 6.1.2) towards satisfying human need and quality of life, and thus serves as a fundamental ingredient in quantifying success criteria and developing a related design methodology.

With contributions from design, business, cognitive and social science and other disciplines, a number of models and theoretical approaches have been developed to understand experience. These are described by Forlizzi and Battarbee (2004:262) in three categories:

- **Product-centred models:** These provide information to assist designers with the process of creating products to create compelling experience by describing the issues that must be considered in their design and evaluation.
- **User-centred models:** These assist designers and developers to understand users by investigating the actions and aspects of experience that are deemed relevant during interaction with their products.
- **Interaction-centred models:** These are concerned with exploring the role that products serve in establishing an informational link between the designer and user. Design is based on understanding how people engage with products and

the world. A distinction is made between passive and active, and immersive experiences, with a focus on the ways in which form and behaviour support feedforward and feedback.

Vischer states that the user-centred theory utilises support of human activities as a measure of built-environment effectiveness (2008:234) and assumes that inadequate support is therefore conducive to a negative experience. He furthermore explains that the user-centred model asserts that time has a direct effect on how well built space supports its users, and that relationships between buildings and users change over time, requiring continuing renewal of the built-environment experience that is being studied. Developing a user-centred approach is favoured by Vischer with the aim of producing built environments that increase environmental support for human experience and activities, and incorporating building feedback from users to the building supply chain (2008:239). The goal of the user-centred model is thus to develop theory to support design of the built environment around the user experience and the user-building relationship.

The researcher, however, observes that this process of interaction between user and product is, however, not exclusive to the user-centred model. In the context of this thesis and the role that knowledge plays in the revised model for sustainable development (section 6.1.2), as with findings by Forllizzi and Battarbee (2004:262), the researcher identifies the interaction-based model as the framework of significance to user-product interactions and the experiences produced as a result. This model is additionally more representative of architecture as a solution born of a systems approach, inclusive of a reciprocal relationship between user and environment. Types of user-product interactions are furthermore described as being composed of three types (2004:263):

- **Fluent:** Automatic and skilled interactions with products;
- **Cognitive:** Interactions that focus on the product resulting in knowledge; and
- **Expressive:** interactions that assist in forging a relationship between user and product.

The design process requires understanding of the basic interactions and experiences that the design solution seeks to offer. Forlizzi and Battarbee (2004:266) address this need for understanding by emphasising the importance of determining a) the current issues of the context where the product is to be used; b) the experiential improvement offered to the user; and c) the means with which the product is easily adaptable and usable. Whereas design considerations for flexibility have already been addressed (section 6.1.6.2), the researcher recognises that specific identification of context-based factors requires inclusion in the initiation stage of the integrated systems-design process as a means to determine the defining systems and sub-systems determinant in later concept formulation.

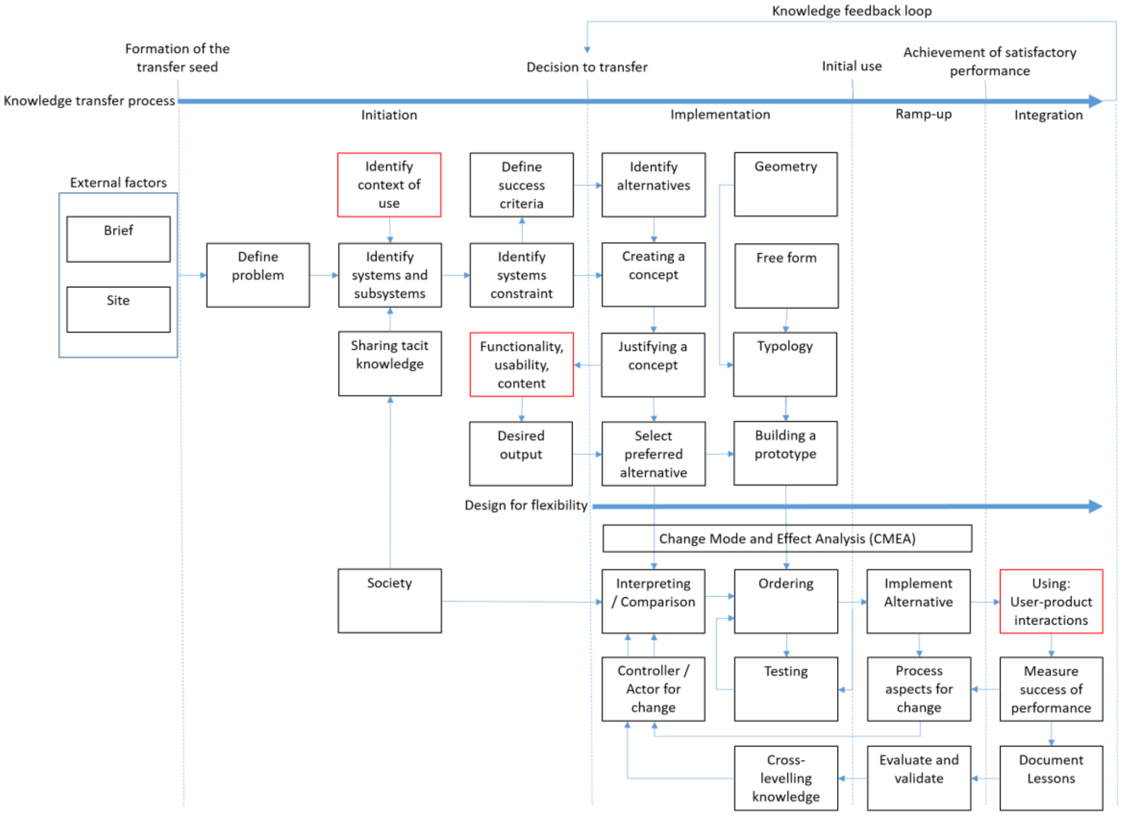

Figure 6.25: Proposed integrated systems-design process inclusive of design criteria for optimum user experience

In section 6.1.4.3 the researcher stated that the paradigm of design professionals must evolve from that of a building executor to a knowledge-building custodian. This requires that the planning process is necessary in the life cycle of the building in order that the needs of its users may be documented, measured, evaluated and reintegrated through flexible design to re-inhabit the building's form and function. The role of the user is primarily represented in Figure 6.25 as part of the integrated systems-design process in the integration phase, notably in the 'using' step. However, optimising and documenting user experience is not something to be thought about retrospectively, but must therefore be pre-emptively planned for and purposefully incorporated in the operational life cycle of a product. For this reason the components of user experience, namely context of use, functionality, usability and informational content are integrated into the proposed process in the initiation, implementation and integration stages. As a function of the pragmatist approach, design decisions are inclusive of a user experience that interacts with the environment being created. In order to introduce concepts and products to the user through participatory design activities, prototyping is identified as an effective tool for objective evaluation of concept proposal (Forzilli et al., 2005:266). The researcher recognises that functionality and usability are important actors in the development of a prototype, containing specific physical traits required, integrated in devising product typology and form giving. However, usability and user experience are still integral to the 'using' stage, thereby influencing the quantification of success, product flexibility and requirements for adaptation. It is furthermore important to emphasise that the 'implementation' and 'integration' stages remain within the defined information feedback loop of the design process, and hence are subject to life cycle re-evaluation. The importance of user experience in process and product therefore ultimately concerns itself with the creation of a supportive built environment which enhances human activity (Vischer, 2004:239) and quality of life.

6.1.6.4. The role of BIM

BIM has already been briefly discussed in Chapter 4 section 4.1.7.6 where it was stated that it offers a 4D solution to the architectural process, representative of the informational backbone that makes up our knowledge societies of today. The reason for its inclusion in this chapter is to re-address its role within the integrated systems-design process, inclusive of the project initiation, implementation, ramp-up and integration stages within an informational feedback loop. It is also necessary to evaluate the role of BIM in project life cycle involvement, enabling the role of architects as knowledge-building custodians, as referred to in section 6.1.4.5.

BIM is a virtual process that combines and encompasses all aspects, systems and disciplines of a proposed solution within a digital model, enabling accurate and efficient collaboration of stakeholders. As the model is created, team members are able to constantly refine and adjust the design and its associated specifications to ensure accuracy and correctness before the physical project is implemented (Azhar, 2011:242). BIM has therefore revolutionised the way in which buildings are conceived, designed, constructed and operated (Azhar et al*.,* 2015:15). To elaborate further, BIM is also regarded as an expanding collection of concepts and tools which have been attributed with transformative capabilities within the architectural, engineering, construction, and operations (AECO) industry (Sucar, 2010:65). BIM, therefore, is more than software. It is defined as a process and software. The end goal or solution is thus the result of creating intelligent digital models, as well as effecting changes to workflow and project delivery processes (Azhar, 2011:242). In addition to the beneficial implications on project efficiency, BIM supports the concept of integrated project delivery between people, systems and organisational structures throughout all phases of the project life cycle (Glick et al., 2009:4).

In his book *The impact of building information modelling – Transforming construction*, Crotty (2012:6) describes two aspects of BIM as hugely important. Firstly, the achievement of far higher quality design information than with conventional tools through the use of intelligent, parametric 3D building models and secondly, the achievement of higher quality, more efficient communication among the systems of the project team members through clear and effective data exchange standards. In the BIM concept, geometric entities associated with 3D computer-aided drawings are also provided with symbolic or abstract 'meaning', and thereby qualitative as well as quantitative data (Yan et al., 2008:2).

The applications of BIM on architectural process are furthermore described by Azhar as follows (2001:243):

- **Visualisation:** 3D computer-generated graphics and renderings are easily generated.
- **Fabrication:** facilitates shop drawing or various building systems.
- **Code reviews:** for purposes of review of statutory regulations compliance.
- **Cost estimating:** material quantities and data are automatically generated and scheduled.
- **Construction sequencing:** materials and building components are given phasing data and schedule of implementation.
- **Conflict and collision detection:** building components and services occupy the same 3D virtual space, making simulation and interrogation of building systems possible for purposes of clash avoidance.
- **Energy efficiency simulation:** incorporation of site locality, orientation and building materiality makes it possible to determine thermal loss, solar heat gain, natural lighting efficacy etc.
- **Forensic analysis:** a BIM is possible to adapt to generate graphical illustration of potential failures, evacuation plans etc.
- **Facilities management:** a BIM represents the physical built form from the standpoint of operations and therefore becomes a digital user's guide with integrated component data and maintenance schedules.

- **Better customer service:** communicating complex concepts in a 3D visualisation and virtual environment.
- **Life cycle data:** requirements, design, construction and operational information used in facilities management.

The benefits to project stakeholders are also evident in the manner with which collaborative involvement at various stages is made possible. The matrix below, derived from Azhar et al. (2015:22) indicates the applications of BIM for various stakeholders during key milestones in the building design and life cycle process. The researcher has furthermore included the metropolitan authority (public sector) as a stakeholder. As stated by Wong et al. (2010:297), the role of the public sector is critical in the implementation of BIM, dictating in some cases the extent of informational roll-out, as well as determining the extent to which this process is allowed to unfold in various regions or countries. For the effective implementation of BIM in any country, the government is required to give a specific mandate and make policy on the adoption of BIM in all projects (Wong et al., 2010:296), which in turn is the backbone for formulation of standards (Wong et al*.,* 2010:297). Additionally, due to the fact that all buildings themselves are subject to policy and statutory regulation, often dictating what kind of building is permitted in the first place, it is the position of the researcher that input from this institutional body is therefore of importance to the process.

Table 6.6: BIM applications for project stakeholders

BIM Application	**Owners**	**Designers**	**Constructors**	**Facility Managers**	**Municipal authority (public sector)**
Visualisation	X	X	X	X	X
Options analysis	X	X	X	X	
Green building analysis	X	X			X
Quantity surveying		X	X		
Cost estimation	X	X	X		
Site Logistics	X	X	X		X
Phasing and 4D scheduling		X	X		
Constructability analysis		X	X		
Building performance analysis	X	X	X	X	
Building management	X	X		X	

The matrix above illustrates two key concepts that deviate from the original table as devised by Azhar et al. In this matrix it is understood that statutory regulations now broadly dictate certain energy efficiency criteria for building design in many parts of the world, which has been provided for under the category ‘green building analysis’. Secondly, it makes reference the fact that the designer maintains a role or interest in the building management. As stated by Succar (2010:69) and Penttilä (2006:403), BIM is a set of interacting policies, processes and technologies that generate a methodology to manage the essential building design and project data in digital format throughout the building’s life cycle. This supports the concept proposed in this thesis that the designer is enabled to fulfil a role as custodian of the digital building information model for purposes of project life cycle analysis, building adaptability and sustainability. BIM also allows for close association with concepts such as Product Lifecycle Management (PLM), and Integrated Project Delivery (IPD) which are usable as defining a new way in which to approach the design, documentation and management of the built environment. Processes based on 4D PLM and IPD models are thus created to effectively manage a project starting from planning, designing and construction, and continuing during utilisation (Popov et al., 2006:91; Glick et al., 2009:2).

The benefits of the characteristics described above illustrate that BIM has many common objectives and capabilities to facilitate an integrated systems-design process. This is by virtue of its ability to achieve the following:

- The ability to design within a virtual context representative of real-world site conditions and climate;
- Quantifiable extraction and scheduling of project-related data such as materiality, areas and zoning;
- Integration of multiple disciplines’ information for holistic analysis and evaluation of project systems and sub-systems;
- The ability to visualise and model building typology according to architectural preference and suitability;
- The ability to communicate sophisticated concepts in a graphical and easily understood format to encourage user and stakeholder involvement in the design process;
- The ability to incorporate extensive detail and information into the ordering process for real-time evaluation of component and systems integration implications on product;
- Creation of various prototypes and options for analysis and testing;

- The ability to simulate and interrogate a proposed solution within changing contextual and environmental circumstances;
- The ability to use virtual prototyping technology as a predictive tool to aid in future flexibility and test scenarios;
- The ability to make use of the digital building information model following implementation in order to incorporate user-experience feedback and evaluate the resultant impact of building customisation and adaptation;
- The ability to document lessons learnt in digital form for purposes of knowledge building;
- The ability to extract quantifiable data as a basis for measurement of success; and
- The ability to isolate and identify key contributors to project under-performance or problems – these could be in the form of building components, systems or user experience.

The characteristics listed above indicate a high level of synergy with the integrated systems-design process, making BIM a key process and contributor to effective implementation and operations of future sustainable building solutions. Azhar et al. (2009:278) state that the combination of sustainable design strategies and BIM technology has the potential to transform traditional design practices and produce high-performance facility design. This is a feature of the design process and architectural cognitive landscape that was previously unavailable and impossible before the advent of the Information Age. According to Succar (2008:357), organisational studies on the subject demonstrate that there is a large divergence and variation in the way in which BIM can be implemented as a catalyst to reduce industry fragmentation and improve its efficiency. This therefore contributes to the necessity for a systematically-defined BIM framework that extends beyond the realms of knowledge enquiry and organisation, and positions BIM as an integration of product and process modelling (2008:358).

As a strategy for implementation, Jung et al. (2011:127) describe as practical the creation of a framework that effectively incorporates BIM processes in terms of property, relation, standards and utilisation across different construction business functions throughout project, organisation and industry perspectives.

Figure 6.26: BIM Framework, (Jung et al., 2011:127)

Thus the case for a model of sustainable development inclusive of criteria for knowledge-based development is evident, and a BIM-based integrated systems-design process is proposed by the researcher as the ideal tool to facilitate this through its inherent capabilities in information management and application. By integrating BIM into the process and product with clear definition of goals, a framework for effective implementation is achieved. Howard et al., however, advise that it is important to define design intention at an early stage in order that later modelling allows intent to be preserved throughout the process (2008:273). The requirement for a standardised methodology of approach is therefore apparent, and will be addressed later in this chapter.

6.1.7. Measuring success

Within the integrated systems-design process for sustainable development, 'success' is addressed in two stages: defining success criteria, and quantification of success or performance. The identification of criteria is included at the initiation stage in order that systems and constraints applicable to the design problem may be identified prior to early concept development. Identification of criteria for success is an important early process stage. However, the world for which a design is executed at a particular time may not be equitably served in the future due to, for example, changing contextual, environmental or technological factors. It is for this reason that the design solution developed through prototyping, interpretation, and ordering of components and sub-systems must be evaluated during the integration stage in order to understand what aspects require adaptation. Measurement of success is therefore a backbone of future flexibility and existing system optimisation.

As stated by Kates et al. (2001:641), sustainability assessments provide decision-makers with an evaluation of global to local integrated nature-society systems for the purposes of facilitating action for the long and short term. At this stage, the researcher therefore reiterates the following delimitation: the aim of this thesis is not to develop an assessment tool, for example, but to recognise the importance of success measurement in the design and operational processes of design to the benefit of the user and the product. The results of this research may then provide the basis for application of various existing measurement tools in parallel, or future singular tool development.

This stage is equally important to the development of a design methodology. The researcher observes that with initiatives such as the Green Star rating system, popularity of approach towards complex design concepts is assisted through simplified and iterative quantification of (time- and space-dependent) decision correctness. Two questions are thus raised by the researcher. Firstly, could the stages and criteria of the proposed integrated systems-design process be simplified and measured in order to evaluate success of implementation for both designers and users? Secondly, in addition to the systems-design process, can the core and ancillary criteria of the revised model of sustainable development (see section 6.1.2.2) be integrated to ensure that they are equally represented in the initiation, implementation, ramp-up and integration stages? In order to address these questions, an understanding of methods for measurement of success is required.

Evaluation of success is possible on a number of levels. For example, as was addressed in the previous section on user experience (section 6.1.6.3), success based on ‘quality of life’ can be emotively judged. ‘Experience’ is a subjective quality that is contextually and temporally based. Qualitatively, this requires analysis into people’s value orientations and their personal interpretation of a problem (de Vries et al., 2009:1006). The need to quantify success is important, however, as it introduces objectivity into the process which not only serves as a rating of past performance but also enables identification of components that may require future change (future flexibility). This quantitative step introduces model-based interpretation which creates opportunity for scenario building (de Vries et al., 2009:1006) and prototyping.

Quantification represents a need for objective and replicable assessment. As early as 1953 Hayashi offered a description of quantification as the categorisation of patterns and assignment of numerical value in order to assess as indices, with classification as a means of phenomena prediction (1953:121). The quantification approach can be characterised in a variety of available methods, such as by developing mathematical models of systems, controllers and input and output information for product types (Kasarda, 2007:732). In order to begin the quantification process, a principle goal is required by which defined indicators and criteria can be assessed.

De Vries points out that, in a framework for sustainability assessment, a balance between the subjective individual or collective experience, as well as the objective scientific and natural resources is sought. The middle ground is therefore sought between natural and social sciences (2009:1009).

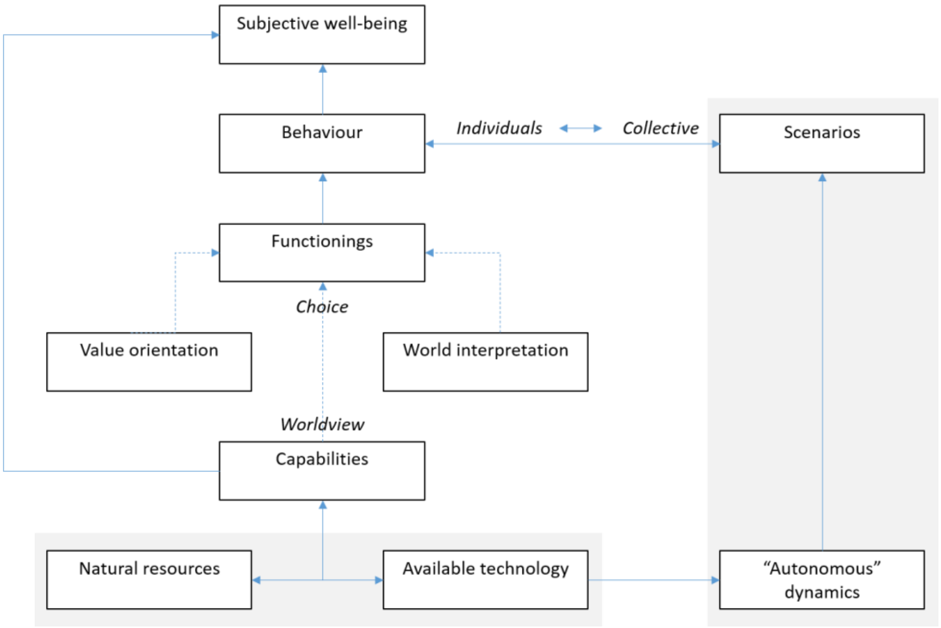

Figure 6.27: Conceptual framework for sustainability assessment (de Vries et al., 2009:1008)

In order for measurement to occur, the goals-oriented concept of value must also be explored. On this basis, De Vries et al. (2009:1009) state that value is a prescriptive conviction about desirable behaviour and goals in a long-term perspective. Values can be ranked according to various methods and make up a means to definitively compare the desired result with the actual result. Values, however, are not predictors of behaviour (de Vries et al., 2009:1010). Value is derived as a weighting (belief) of desired result, and as such is guided through analysis and rating of sustainable development criteria or indicators.

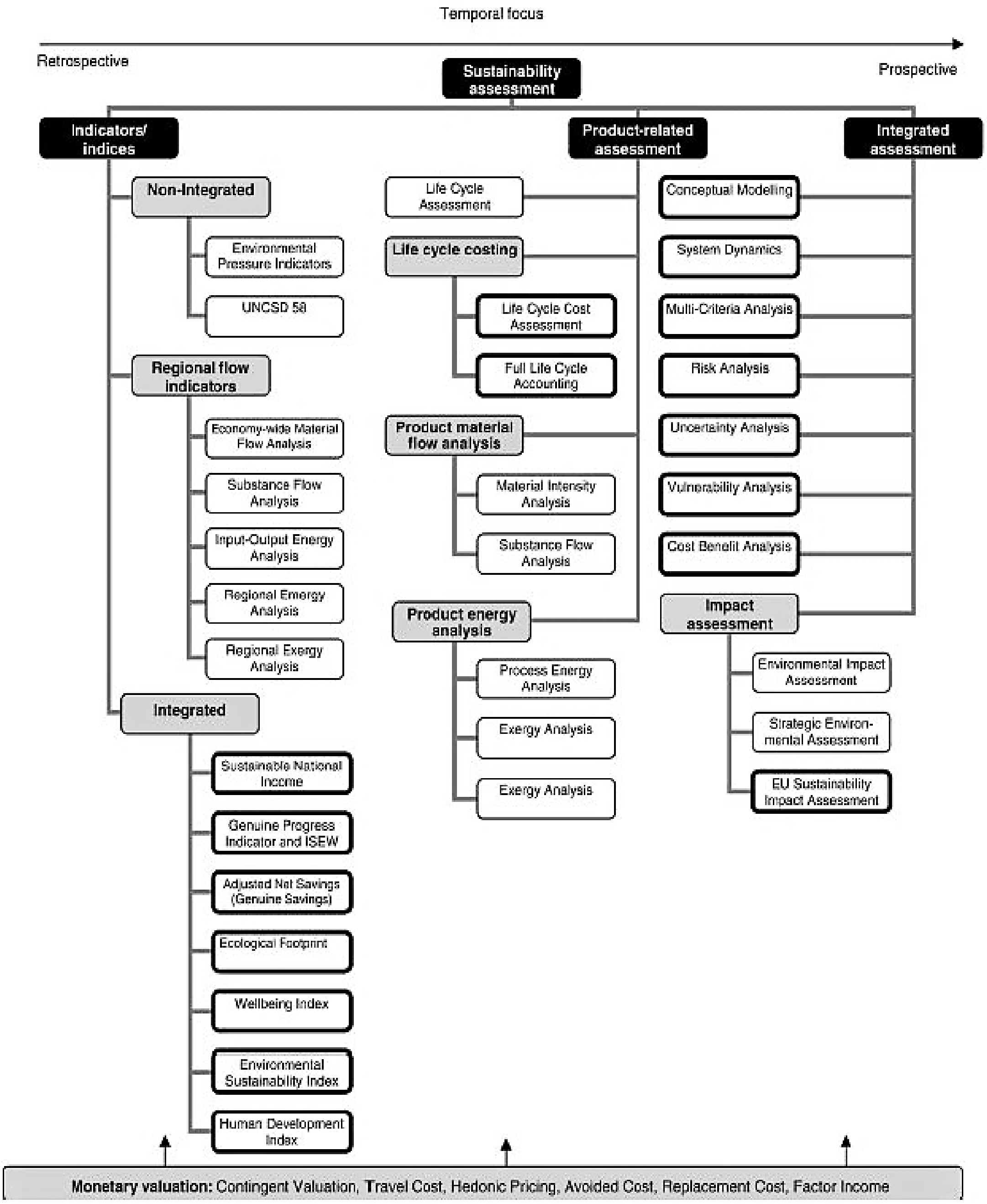

Figure 6.28: Framework for sustainability assessment tools (Ness et al., 2007:500)

Ness et al. (2009:196), offer a more detailed framework by comparison. This recognises that an assessment is representative of a retrospective and prospective temporal focus, and object-based focus. The assessment is indicative of a variety of assessment tools, segregated into three concurrently running categories: indicators, product-related assessment and integrated assessment. The object of focus is therefore either spatial, referring to proposed change in policy, or at the product level. Tools indicated in thick borders are representative of being capable of integrating nature–society systems into a single evaluation.

The above framework (Figure 6.28) has been developed to contribute to the overall discussion and discourse on sustainability assessment tools primarily based on temporal and object-based investigation. Sustainability measurement is therefore not limited to the execution of a single 'tool'. In addition, there is a contradictory need for both specific and broader-based investigations providing for diverse ranges of situations and scenarios requiring evaluation. Proper evaluation is therefore possible only when all contributory parameters are considered simultaneously (Ness et al., 2007:506).

In order to pursue assessment of a specific object or problem, quantification of results is required as a basis for standardisation. Quantification, however, is divisible into two categories of approach: assessment and rating. A variety of building industry assessment tools and ratings methods have emerged around the world over recent decades. Assessment tools provide quantitative performance indicators for design alternatives, whereas ratings tools determine the performance of a building as a score. These include quantitative impact assessment tools for selection of materials and technologies, simulation tools to predict energy consumption and IEQ (Seo et al., 2006:v). Predictions are sought in order to study phenomena that cannot be tested prior to implementation (Hemez et al*.,* 2001:6). Singh et al. (2012:287) state that the construction of composite indicators involves the selection of various tools or methods during different stages of development. Development of composite indicators is considered to be a valid approach for evaluating sustainable development due to the ability to focus attention and simplify the problem. An integral systematic approach to indicators measurement is necessary to achieve replicable methodologies of approach (Singh et al., 2009:191). On this basis, by applying sustainable development indicators to the integrated systems-design process it is therefore feasible to develop a design methodology equipped with the means to not only prospectively monitor sustainable development solutions, but also retrospectively assess them. In Chapter 5 section 5.2.2 of this thesis, eight sustainability criteria were established, namely:

- Economic criterion
- Spatial and technological criterion
- Political criterion

- Social criterion
- Cultural criterion
- Physical infrastructure criterion
- Knowledge criterion
- Ecological criterion.

These were subsequently incorporated into the revised model for sustainable development in the Information Age (Figure 6.2, section 6.1.2.2) as sustainable development indicators (core and ancillary). Sustainable development indicators are useful in this manner for the following reasons (Singh et al., 2012:282):

- To assess and evaluate performance;
- To provide trends on improvement as well as highlighting declining trends; and
- To provide information to decision-makers to formulate strategies and communicate achievements to stakeholders.

As derived from Ding (2007:4) a selection of available quantitative building performance assessment methods is listed below. This is based on shared suitability of use within the integrated systems-design process, inclusive of their potential (limited) applicability to the eight defined sustainable development criteria (section 6.1.2.2).

Table 6.7: Summary of building performance assessment methods and applicability within proposed scope of sustainable development

Assessment Method		Origin	Characteristics	Sustainable Development Criteria Potential
BEPAC	Building Environmental Performance Assessment Criteria	Canada, 1993	- Assessment method using point system. - Similar but more detailed and comprehensive than BREEAM. - Limited to new and existing office buildings.	- Environmental - Space and technology
CASBEE	Comprehensive Assessment System for Building Environmental Efficiency	Japan, 2004	- Applicable to stages of development in pre-design, new construction and renovation. - Determines environmental capacities based on a concept of closed ecosystems.	- Environmental - Physical infrastructure

Assessment Method		Origin	Characteristics	Sustainable Development Criteria Potential
			- Includes considerations for regional character.	
CEPAS	Comprehensive Environmental Performance Assessment Scheme	Hong Kong, 2001	- Applicable to all types of new buildings. - Eight performance categories (criteria). - Employs and additive weighting approach. - Designed to serve as a 'yardstick' for common assessment scheme for buildings.	- Environmental - Social
CPA	Comprehensive Project Evaluation	United Kingdom, 2001	- Utilises a financial and economic approach to assess projects during development. - Multi-criteria analysis of environmental and social impacts of a project. - Checklist format of evaluation that requires independent auditing.	- Economic - Social - Policy
DQI	Design Quality Indicator	United Kingdom, 2003	- A toolkit used throughout development process to capture opinions of all stakeholders. - Aims to improve the design of buildings through provision of feedback and capturing perceptions of design quality. - Assesses building in three categories: functionality, build quality and impact. - Assisting clients in defining aspirations to which a project's success will be measured.	- Social - Cultural - Knowledge - Environmental
Eco-		Netherlands,	- Explicitly and comprehensive	- Environmental

Assessment Method		**Origin**	**Characteristics**	**Sustainable Development Criteria Potential**
Quantum			based on life cycle assessment.	- Knowledge - Economic
EPGB	Environmental Performance Guide for Building	Australia, NSW Department of Public Works and Services	- Assess buildings through framework of five categories. - Considers resource consumption and loading. - Buildings are rated and given a single indicator for building performance.	- Environmental - Knowledge
GBTool	Green Building Challenge	International, 1995	- The most comprehensive international framework. - Consists of more than 90 individual performance assessments. - Four levels of weighting. - Inclusive of regional variations and adjustment.	- Environmental - Physical infrastructure - Social - Economic - Space and Technology
GreenStar		Australia, 2003	- Rating system comprising nine categories, on a scale of 0 to 6 stars. - For use in most building types, new, existing, additions and renovations. - Requires self-assessment and organisational audit. - Simple checklist format. - Rating applicable to design, and as-built stages of development.	- Environmental
LEED	Leadership in Energy and Environmental Design	USA, 2000	- Certification process to develop an industry standard. - Self-assessing systems awards rating of silver, gold and platinum. - Simple checklist format. - For use in most building types,	- Environmental

Assessment Method		**Origin**	**Characteristics**	**Sustainable Development Criteria Potential**
			new, existing, additions and renovations. - Comprising five areas of sustainability. - Applicable to individual buildings and precinct design.	
SBAT	Sustainable Building Assessment Tool	South Africa, 2001	- Performance criteria that acknowledge social, economic and environmental issues. - Divides 15 performance areas into five performance criteria. - Integral part of a building process based on the typical life cycle of a building.	- Environment - Social - Economic
SPeAR	Sustainable Project Appraisal Routine	International, Arup, 2002	- Project assessment methodology. - Enables a rapid view of project sustainability through graphical format. - Identifies opportunities to optimise performance on a scale of -3 to +3. - Four main categories of assessment: environment, social, economic and natural resources.	- Environmental - Space and technology - Policy - Social - Economic - Physical infrastructure

Interpretation and combination of these methods and tools therefore allows for a quantification process associated with most criteria of sustainable development as defined by this thesis. Ding states that the use of single-dimension evaluation techniques is no longer adequate; instead more sophisticated models are necessary for the purposes of handling multidimensional arrays of information (Ding, 2007:25). It is furthermore observed by the researcher that a holistic multidimensional assessment method, specifically applicable to the proposed criteria for sustainable development, will be useful to the profession in the future. This is therefore identified as necessary for future research.

Measurement of success is therefore dependent on quantitatively and qualitatively establishing the rigour and effectiveness with which an architectural solution achieves its desired performance according to the defined sustainable development criteria. Since the aim for quantification is shared between post-implementation assessment and predictive decision making, it is intrinsically linked to the informational feedback loop within the design process and the solution (product) life cycle. A need for clear methodology is evident, consolidating the integrated systems-design process and the model for sustainable development (composed of its indicators).

6.1.8. Summary

Through investigation in previous chapters of the global status quo regarding sustainable development principles, the impact of the Information Age and the emergence of knowledge-based societies, and the role that the built environment has to play in both of these paradigms is identified in the development of a new model for sustainable development. This new model therefore proposes the means to consolidate and integrate identified criteria of importance for specific application for the built environment and to inform the architectural design process.

As a function of this model, core criteria of sustainable development were based on the established three pillars of sustainable development, but found to be inadequate in their responsiveness to the human-centric needs of the Information Age. Hence the core criteria were identified as:

- Social
- Economic
- Environmental
- Knowledge.

In addition to the core criteria, ancillary criteria were identified, providing focus to built environment applications, with each occupying the ‘middle ground’ between associated core criteria. These criteria were identified as:

- Policy
- Culture
- Space and technology
- Physical infrastructure.

By interrogating the problem of sustainable development through this model, the problem focused on intervention for human development and equity, responsive to statutory, environmental and ecological constraints and opportunities. Additionally it understood that intervention based on the model is required to be re-interpreted with evolution and change to human need. Human need is not temporally or spatially confined, especially in the digital age, prompting the need for a process of implementation that is conducive to this systems-based life cycle approach.

The process of implementation is furthermore attributable to a design process for intervention by built-environment design practitioners, such as architects. However, analysis of the design process revealed that this approach is not suited to the complex problem of developing a system. The requirement for an integrated systems process therefore provides the applicable basis for inclusion of formative information feedback loops, as well as recognition of the project deliverable not as a product, but as a process. The formulation of the integrated systems-design process therefore makes this deliverable practical and achievable by integrating with, and augmenting the architectural approach.

It was furthermore recognised that in order to establish a process that is complementary to the requirements of knowledge-based development, integration of information and knowledge building is integral to the process itself. This equips the design practitioner with the means to sustain an active role in project delivery before and during project operational life cycle. Integration of knowledge management processes within the integrated systems-design process furthermore establishes the means for internalised feedback loops which are essential to the systems process, as well as priming the project for execution on a basis of utilising BIM to its highest potential.

By addressing user experience as a core consideration of the experience, the process is equipped with the ability to include qualitative, experiential information within the goals for project success. Understanding that building functionality does not guarantee usability plays a significant role in the sustainable feasibility of a project, as well as the ability to remain flexible and responsive to changing contextual circumstances.

Integrating a knowledge management basis for quantitative and qualitative decision making, establishes the ability to systematically address and implement decision making on a systems level. This results in the ability of the process to isolate and address sustainable development criteria on a multidisciplinary level. It is furthermore recognised that, with this quantitative and qualitative approach, an evaluation of performance and success can be included within the process itself, establishing the means to include ratings and assessment tools, thereby demystifying design for sustainable development through multidimensional interrogation and evaluation. This methodology therefore does not seek to replace existing evaluation tools, but integrate these into the responsible application of the methodology dependent on the nature of the design problem. What is does intend to do is force the discourse to not merely rely on the limited scope of one evaluation tool, but to assess the problem holistically and combine tools where necessary. This will also allow for future research in the development of evaluation tools that serve a more integrated and holistic purpose.

The sub-problem of this chapter is therefore addressed by establishing that the ability to implement sustainable design is represented by the need for this integrated systems-design process. This process establishes the means to address sustainable development criteria, user-experience and human-product interaction, as well as the knowledge-based requirements in project implementation and operations. This process is furthermore a suitable basis for exploration of an applicable methodology of approach.

6.2. Addressing hypothesis four:

Hypothesis: A new integrated systems-design methodology for architectural design is required, implementing the integrated systems-design process and the proposed new model of sustainable development.

6.2.1. Introduction

This section represents the consolidation of research and the formulation of a new strategy towards industry implementation. Having defined a revised model for sustainable development based on the requirements for knowledge-based development in the Information Age, as well as having established the basis for an integrated systems-design process, the researcher will propose a systems-design methodology for use in architecture.

This section begins with an investigation into the impact that digital and IT-rich environments have on our physical environments, the purpose of which is to determine how the architectural design approach may be affected through the presence of ‘ambient’ intelligence that defines, and often governs, our user experience. In an age where access to information and the ability to perform various tasks is not bound by geographical limitation, it is important to understand what this means to the architect in creating functional and usable environments.

Following this, the integrated systems-design methodology is defined. Using the pre-establish framework for a systems-design process as a basis, the methodology is divided into its core stages which are then described sequentially. These stages are broken down into their respective steps, where each is described in principle (while referring to previous research where appropriate), as well as explained on a basis of theoretical implementation. This methodology is furthermore described graphically, illustrating the feedback loops it contains where applicable. Furthermore, the methodology is addressed with simultaneous recognition of proposed sustainable development criteria, establishing the basis for continual evaluation and integration of the project constraints and opportunities.

The establishment of this integrated systems-design methodology and its potential for practical implementation will be addressed through an investigation of the future trends for the industry, which is partially speculative, based upon the opinion of the researcher. In so doing, the opportunities unlocked by creating a knowledge-inclusive model for sustainable development will be discussed, including the broader role that is afforded to policy-makers and city planning through a digitised database of interactive systems, the impact on smart city management, and the progressive role of industry and design professionals in future.

6.2.2. Planning for ubiquitous intervention versus operational awareness: addressing the issue of contextual specificity

> *‘The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it*.’
>
> \- Weiser (1991:3)

In a 2016 interview with Steve Case,[58] co-founder of AOL and author of the book *The Third Wave: An entrepreneur’s vision of the future*, it is stated that we have recently found ourselves within a ‘third wave’ of social revolution. This ‘third wave’ is a construct

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[58] ‘Steve Case: the ‘third wave’ of the internet will transform our institutions’, by Hope Reese, 2016. http://www.techrepublic.com/article/steve-case-the-third-wave-of-the-internet-will-transform-our-institutions/ [Viewed 04 May 2016].

of the IoE, where every part of our lives will rely on internet connectivity. This wave is therefore not defined by hardware or software, but by partnerships, in particular between business and government, therefore changing the way our institutions integrate the internet into our daily lives.

Ubiquitous computing is regarded as the third wave of computing (Gerritsen and Horváth, 2010:765). It is transforming the way humans interact with digital information through rapid interactions with technology embedded in everyday life, but also indirectly changing the way we communicate and collaborate (Liu and Milrad, 2010:1). These emerging human-computer interfaces will ultimately be enabled to automatically detect context and direct information without disrupting the activity inherent in any real and dynamic environment (Intille et al., 2005:1941). As computer systems become ubiquitously embedded within our environment, it also important that these systems become increasingly aware of user context (Rondoni: 2003:2). Abowd and Myanatt (2000:29) state that the proliferation of computing into our physical world offers more than the ubiquitous availability of computing infrastructure but instead suggests new paradigms of interaction inspired by constant access to information and computational possibilities. The goal of ubiquitous computing in the past two decades has therefore been the augmentation of human activity through technology, assisting in everyday life and not overwhelming it (Abowd and Myanatt, 2000:30).

According to the course of action theory, every activity is situated in and associated with the context in which it occurs, and the interactions between actors and their environments are an asymmetric coupling (Poizat et al*.*, 2009:14). Studying behaviours in physical and naturalistic environments therefore allows researchers to better understand how to create technologies to respond to the complexity of life (Intille, 2005:1941). In this approach, this same information therefore also allows similar possibilities in the shaping of our naturalistic environments to offer a sustained high quality of life. In a study on domestic activity, Poizat et al. (2009:18) state that it is important to design a system with the ability to a) manage interruptions in relation to task priority and how it may change dynamically to the situation; b) support the dynamic of the action, reasoning, and interactions of the end user at different temporal scales; and c) handle the ambiguous context. The relationship between ubiquitous computing and derived behavioural response and analysis makes for a future of information and knowledge-based possibility in built-environment performance in support of human activity. Context-aware computing is therefore central to the ability of ubiquitous computing to be perceptive, interpretive and reactive (Galloway, 2004:388).

One of the challenges when implementing ubiquitous technologies in our everyday lives is the means by which behaviour is searched and interpreted. Ubiquitous computing therefore requires common points of reference round which discussion can occur and new interfaces can be developed. The creation of PlaceLab (Intille et al., 2005:1945) is one such experimental environment that has been developed to gain insight into these challenges, making use of multi-modal sensors activation data and the record of lessons learnt. In this experiment, it is recommended that a library of activity be maintained in our contexts, documenting behavioural patterns and preference. This system is therefore a learning system, requiring data for decision making. This requires conscious effort from place-makers and designers to integrate necessary infrastructure in design stages, and evaluation processes within the operational life cycle in order to interpret the evolving needs of end users and responding accordingly.

Due to the development of ubiquitous and pervasive technologies, research focusing on the design of interactive artefacts has become more concerned with studying and understanding the spatial properties of the physical world where interaction occurs (Ciolfi and Bannon, 2007:159). Designing for interactions between users and the ubiquitous technologies therefore requires a reconceptualisation of the point of interface as an assemblage of physical elements, the ‘place’ (also see section 6.1.4.1.) where experience occurs and the importance of context, and an understanding of the relationship between user and the physical space that is required to be augmented through technology (Ciolfi and Bannon, 2007:159, 178).

However, the future of computing and its role in user-product interactions requires a certain socio-cultural responsibility and sensitivity. The relationship between ubiquitous computing, policy and power, and social interactions is complex and in constant flux. Galloway states (2004:404) in recognition of this, that there is a need to ensure that responsible development, implementation and use of ubiquitous technologies is undertaken, without which we risk the control afforded to people in everyday life and an associated decrease in quality of life. There is currently a level of unease associated with the amount of information that is being gathered, stored and interpreted about people’s lifestyle and personal habits and traits. An invisible technologically driven monitoring system that is always watching and measuring every move that is made brings with it implications for personal privacy and the degree to which pervasive interaction is permissible. Such comprehensive monitoring and surveillance is not contained by space or time, with these technologies crossing both physical and social boundaries (Langheinrich, 2002:237). The invisibility of these technologies results in it being impossible for users to recognise or control their interactions with these technologies, thereby raising increasing privacy concerns. Ubiquitous technology researchers are therefore now suggesting greater visibility in the process. This is therefore recognised by the researcher as an important issue for the design of these augmented contexts and built environments.

With reference to Chapter 5 section 5.1.4.3, where the principle of living between (virtual) digital and physical worlds is investigated, this is again identified by the researcher as being of key importance in the application of future architectural design approaches. Following this investigation, the emphasis is therefore on the creation of hybrid or mixed-reality environments that combine elements of the physical and virtual (Galloway, 2004:390). As shown in Chapter 5 section 5.1.4.3., augmented reality continues to present itself as a suitable outlet for overlaying informational content onto our everyday experiences. The important aspect of this level of interaction is the level of operational awareness experienced by the user, thereby affording the user control of the flow of information. This is in contrast to the concept of 'amplified reality' whereby the information is intrinsic to an artefact or object, thereby embedding properties into that object. Amplified reality is therefore concerned with enhancing the expressions of objects and people in the world, whereby augmented reality alters the impressions of the user without there being any corresponding properties in the expression of the object being perceived (Galloway, 2004:391). The process of mixed-reality creation is therefore not exclusive to either the amplified or augmented reality approaches, requiring a complementary and shared approach. Information could not be communicated to the user in an augmented fashion if it were not embedded and thereby amplifying the environment or product to begin with.

Numerous projects and concepts are currently in development concerned with the application of ubiquitous computing on human life and experience, influencing our interactions and experiences in the real world through integration of technological input and information. These are summarised in, but not limited to Table 6.8:

Table 6.8: Summary of currently available augmented and amplified reality technologies for human-environment interactions

Project Name	Description	Spatial-temporal focus
Amble time	Overlays a digital map of the city with context-aware information. Usable with mobile computing devices. Dependent	Associating informational content and retrieval specific to point-based geographical location by GPS position at

Project Name	Description	Spatial-temporal focus
	on the informational database provided and licenced to it, limited to recreational and commercial consumption-related activity.	the specific moment of interaction, as well as possible activity within the physical locale (based on distance filter).
Google Glass	Visual and audible augmentation of reality by overlaying geo-location-based information with capacity to recognise context as well as respond to user instruction in recording, as well as displaying relevant and useful information.	Associated with individual and group-based experience of a singular context within which interaction occurs. Specific to singular location-based interaction at a specific moment in time.
Layar	Integration of digital information onto real-world objects and features. Augmented reality that transforms the nature of a physical object by revealing ‘hidden’ digital content. Looking at a menu, for example, will automatically bring up a video of the chef cooking the meal of interest.	Associated to specific and localised object recognition for direct user-experience augmentation, Translates only what is being looked at during that moment in time by affecting and enhancing user experience for a chosen activity.
Microsoft Hololense	Visual and audible augmentation on interactions with the immediate user-environment. Capable with not only overlaying information, but altering real-world experience through digital immersion and overlay on the physical world.	Associated to individual and group-based experience of a singular context within which interaction occurs. Specific to location-based interaction at a specific moment in time.
Sonic City	Wearable and context-aware computing driving perception of place, time, situation and activity applied to real-time, personal audio creation. Creates individualised experiences of place by composing musical tributes unique to the user pattern and behaviour associated with being in a certain context.	Associated information to journey-based user position and movement patterns in a city scale (pace heartbeat etc.) in the creation of audio based experienced of physical and digital place. Music comprises the passage of time, and as such space experienced with this input is also defined by passage of time.
Tejp	A means of personalising territorial experience through integration of location-based audio tags. Also for use in social sharing by users of the software who might interact with that same space.	A point-based tracking of user position providing users with the ability to attribute customised messaging and record to a particular place without temporal restriction. A form of audio ‘graffiti’.
Urban Tapestries	Allows users the ability to annotate their own virtual city (Galloway, 2004:396), by book-marking locations, content, and the	Embedding social knowledge into the digital landscape of the city. Location-based to physical context, allowing for a

Project Name	Description	Spatial-temporal focus
	'threads' that link individual locations to local contexts.	customised experience of place at a specific time through augmented reality technology.

As stated by Chung (2014:1291), the goal of ubiquitous computing is to achieve convergence of user-aware technologies and pervasive digital interaction. New content is constantly being created, much of it user-generated, which can be searched, indexed and consumed on multiple platforms. The challenge of these converged technologies, however, is the ongoing requirement for new algorithms, application paradigms, interaction methods and personalisation services. Additionally there is a growing need for organising and delivering converged information at the right level of detail and appropriate to the context of use.

The tendency of current discussions around computing (ubiquitous or not) is to discuss technologies as representational artefacts or objects rather than performative practices, arrangements and processes. These processes and practices are key to permitting certain objects to materialise or solidify from information to experience (Mackenzie, 2003:3). Galloway (2004:398) refers to post-structural thought in humanities and social sciences, relating to notions of decentred subjectivity, stating that attention is now on the space in between subjects. Therefore the product is the process, where focus is no longer on any particular individual subject. This requires an understanding of ubiquitous computing as not peripheral, but as phatic technology that is integral in a system that establishes and maintains social interactions and ongoing feeling of connectivity (Vetere et al., 2005:1). In this way everyday performance expands beyond that of physicality and structure, and instead concerns itself with fluid relationships between spatialisation, temporalisation, materiality and identification (Galloway, 2004:398).

The challenge is therefore to not only equip our environments with the means of collecting, storing and interpreting information for purposes of augmentation and amplification, but also the design processes involved in the creation of these user-interactive environments and products. This understanding equips the designer to approach the process from the point of view of establishing relational conditions for spatial and temporal intervention, developing informational augmentation and amplification of situations which contribute to knowledge-based development in the long term, while attributing contextual suitability to the desired architectural 'solution'. Operating in the context of the Information Age, this solution is furthermore representative of a systems process and not exclusively a material product.

6.2.3. Proposal for a sustainable development-based integrated systems-design methodology

The content of this section represents an assimilation and combination of research in this thesis to this point. The researcher has investigated what the contributors to a new sustainable development model are, as well as the need for evolution of approach by designers to adequately address considerations of knowledge-based development and process. In order for this methodology to be adequately implemented, the researcher has made the following assertions:

1. Sustainable development is concerned with ensuring that the needs of future generations are not compromised by actions of today, but are instead equitably enabled towards success and growth (Chapter 3 section 3.1.2.).
2. Intergenerational equity is contributed to through enabling of knowledge exchange (Chapter 3 section 5.1.3).
3. Sustainable development in the Information Age is human-centric. Human need has been irrevocably affected by pervasive integration of ICT (Chapter 4 section 4.2.5, Chapter 5 sections 5.1.4.1, 5.1.4.2 and 5.2.2).
4. User experienced is not confined to the realm of the physical, with social experience largely contained within digital and virtual realms representative of the Information Age (Chapter 5 section 5.1.4).
5. Integration of principles of knowledge-based development, ICT and sustainable built environments is possible (Chapter 5 section 5.1.5).
6. The core and ancillary criteria for sustainable development will serve as the means upon which identification of the problem and definition of success criteria will be based (Chapter 5 section 5.2.2, and section 6.1.2.2).
7. Design for sustainable development in an age of knowledge-based societies and development requires a systems approach (chapter 6.1.3).
8. The methodology will make use of the proposed integrated systems-design process (section 6.1.3.2).
9. The architectural solution represents the creation of knowledge buildings for which the design team remains custodian during their life cycle (section 6.1.4.5).
10. Knowledge buildings represent the integration of physical virtual place, and thereby the creation of knowledge-enabling environments must remain sensitive to this need when addressing user experience and systems design (Chapter 4 section 4.1.9, Chapter 5 section 5.1.4.3 and section 6.1.4.5).

11. The methodology is made possible through a BIM-based process and design for purposes of data capture and interrogation, as well as life cycle analysis (section 6.1.6.4).
12. This methodology is theoretical, requiring that certain external factors such as municipal policy, shift in architectural paradigm, larger project team stakeholder technical proficiency and BIM-based protocols be in effect. As a result this theoretical proposal is not yet representative of an already documented architectural project or solution that may serve as a case study.

Through selective reference to previous chapters the researcher will seek to elaborate assertions by avoiding, where possible, the need for reiteration or repetition of content in order to present and explain the methodology in a streamlined and concise format.

De Vries et al. (2009:1007) describe ‘methodology’ as a context-specific combination of formal, analytical methods and participatory methods. Furthermore, the objective of a methodology is to assist in the construction of more comprehensive and adequate models of sustainable development in order to formulate actionable strategies. Garrett (2010:58) furthermore states that defining the scope of a project is a valuable process that results in a valuable product. The process is valuable since it requires evaluation and prioritisation of potential conflicts and challenges during a period of early hypothesis. The product is valuable by providing a fixed reference point or goal to which a team may aspire. Defining project requirements thus removes ambiguity from the design process. Zuchella et al. (2014:86) state that the response of professional architectural approach to sustainable development requires a re-thinking of the strategic design approach, company partnerships and corporate governance. Architectural practice needs to develop strategies and models of business to effectively deliver sustainable development to their stakeholders (Zuchella et al., 2014:87).

The formulation of a usable methodology for sustainable development is subject to a number considerations as outlined in the research of this thesis:

- The scope of the methodology is subject to achieving a sustainable architectural solution representative of an intergenerational and equitable response to human need.
- Sustainable development is defined by the consideration of the following core criteria:
    - Ecological criterion

  - Social criterion
  - Economic criterion
  - Knowledge criterion.

- Ancillary criteria providing additional scope of application to the built environment are:

  - Political criterion
  - Cultural criterion
  - Technology and space criterion
  - Physical infrastructure criterion.

- Consideration of the criteria of sustainable development is pursuant on human-centric architectural solutions within the context of knowledge-based development.
- The pursuit of a suitable architectural intervention is through integration of product and process.
- The application of an integrated systems-design process is required.
- The integrated systems-design process is representative of a building not as a finite product but as a 'living' solution that is required to fulfil the needs of its users within a changing context over time.
- The integrated systems-design process provides for the following:

  - Definition of core problem
  - Identification of context of use
  - Identification of core systems constraints
  - Identification of success criteria
  - Prototyping and option analysis
  - Informational feedback loops
  - Knowledge management
  - Future flexibility
  - Identification of change controls
  - Interpretation of user experience and desired quality of life
  - Continual measurement of success during project life cycle
  - Building operational life cycle.

The proposed design methodology is representative of the need to apply the integrated systems-design process within the project scope (constraints and opportunities) as defined by the proposed model for sustainable development. The basis for this methodology is furthermore described in Figure 6.29 below.

This framework for a holistic architectural design methodology illustrates that the sustainable development criteria are directly relational to the overarching knowledge transfer process that informs all stages of the design, and not specific stages that risk temporal redundancy. The stages indicated therein are not representative of any particular architectural council defined work stages, as these differ around the world,[59,60] but are comprehensively inclusive of the total process life cycle in order that the design may be objectively undertaken without imposed limitations or regulatory shortcomings due to lack of process maturity.

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[59] The South African Council for the Architectural Profession (SACAP) refers to six work stages, namely: 1) inception, 2) concept and viability, 3) design development, 4) documentation and procurement, 5) construction, and 6) close out. http://www.gov.za/sites/www.gov.za/files/34788_bn195.pdf [Viewed 2016-09-08].

[60] The Royal Institute of Architects (RIBA) refers to eight stages in the plan of work, namely: 0) strategic definition, 1) preparation and brief, 2) concept design, 3) developed design, 4) technical design, 5) construction, 6) handover and close out, and 7) in use. https://www.architecture.com/files/ribaprofessionalservices/practice/ribaplanofwork2013template.pdf [Viewed 2016-09-08].

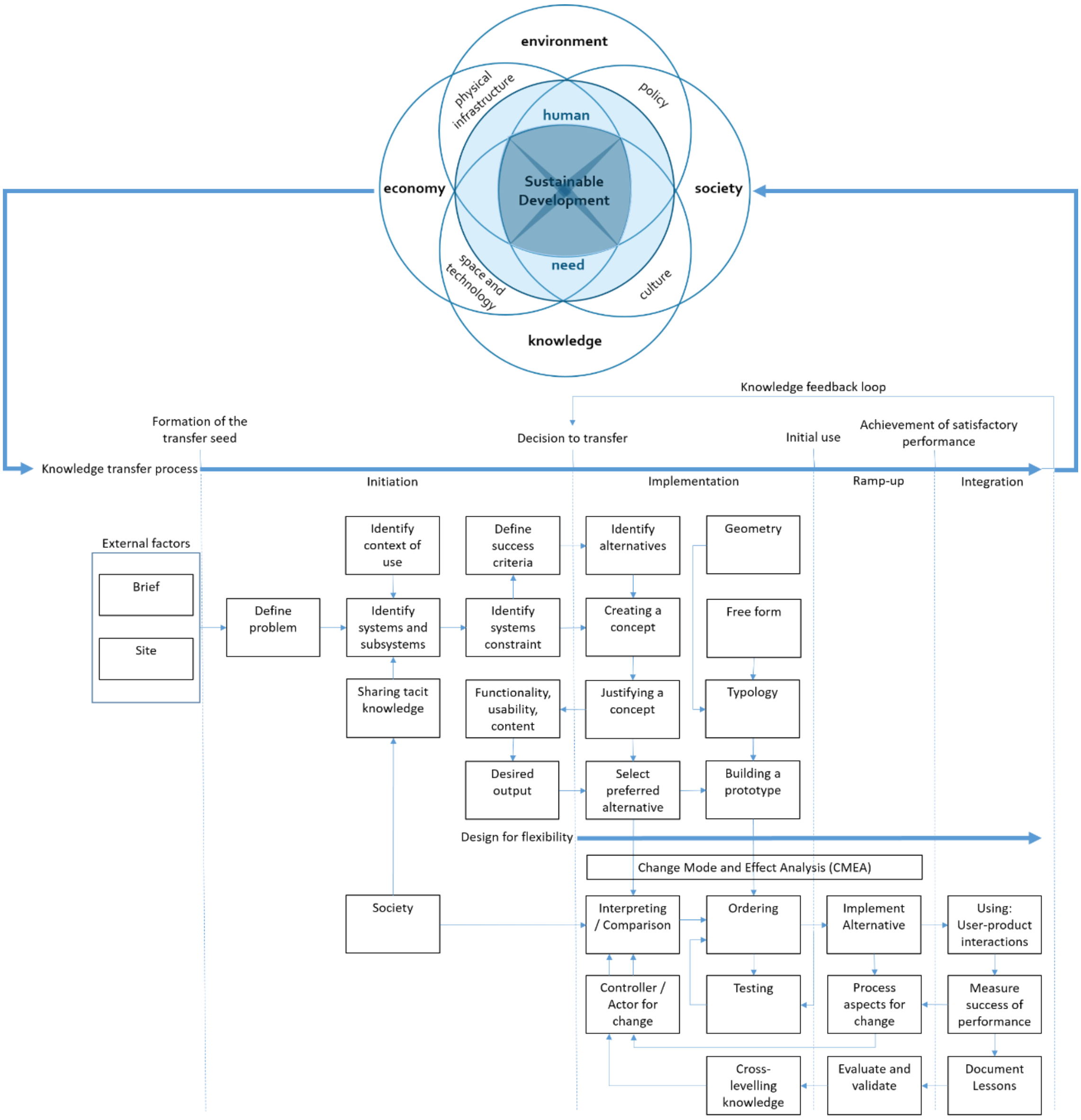


Figure 6.29: Framework of the integrated systems-design process for sustainable development

The goal is therefore not to design a finite ‘sustainable product’, but to design an architectural systems-solution that best represents the ongoing and changing needs of its users within a unique temporal and spatial context. By integrating the sustainable development criteria throughout, the solution would therefore be functionally representative of all associated constraints and opportunities. For this reason, the requirements of sustainable development are pervasive within the entire process, and not regarded with finality only at project inception, for example. The premise is that knowledge is representative of actionable information that is intelligently sought or handed-down, and interpreted. The requirements for sustainable development thus, without exception, infiltrate into the process as and when they are needed. For example, the status quo of physical infrastructure and the supportive conditions of the context might change in the period between project inception and implementation. This also embeds the requirements of sustainable development directly within the knowledge feedback loop, ensuring that life cycle implications for future equitable use are accommodated through continued re-interpretation and assessment.

The formulation of methodology is affected by two clear characteristics of the integrated system’s design process, namely a) the process is largely linear; and b) it is representative of a closed system loop.

Linearly, the methodology comprises sequential stage processes proceeding from top to bottom, namely inception, initiation, implementation, and ramp-up and integration. When compared to the framework for the integrated systems-design process, it is notable that ramp-up and integration have been combined into a single ‘stage’. This is because both comprise the steps necessary for achievement and measurement of satisfactory performance. Interrelatedness between tangible deployment of the solution (product) in the step denoted as ‘implement alternative’, the measurement of success during operation, and change control is therefore logically facilitated within a single stage.

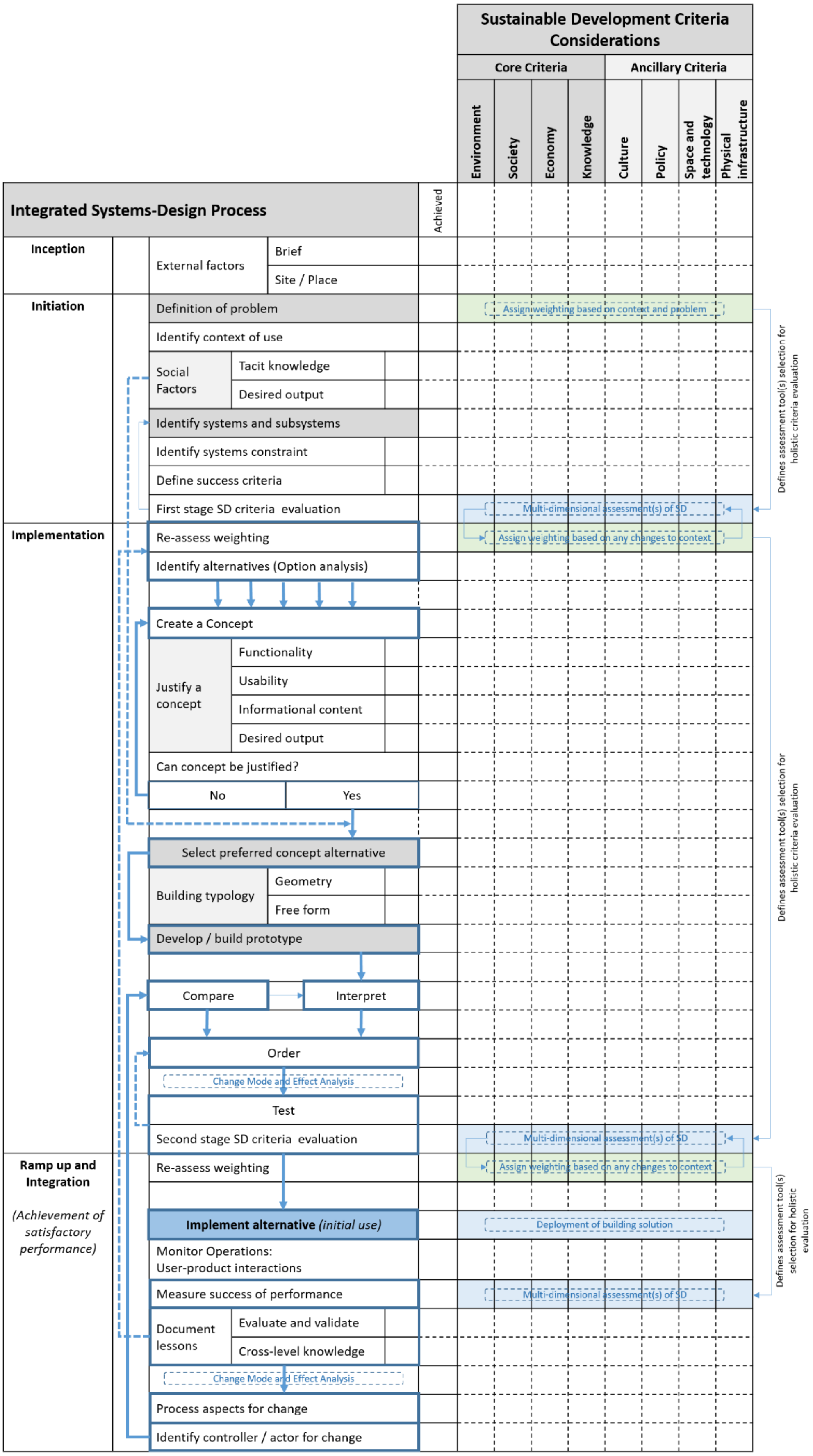
By virtue of the closed system loop, knowledge feedback is facilitated through the ‘return’ of information as various milestones (steps) are identified for their impact on decision making during option analysis, as well as identification for change-based requirements of the building solution through the implementation of alternatives. Change may comprise components, systems, function, etc. These change controllers and actors are then compared to existing systems and re-ordered for integration.

While the methodology progresses sequentially, criteria for sustainable development are integrated to ensure that a conscious effort to address each is made, as well as to serve two purposes. Firstly, the criteria are weighted for appropriateness based on contextual circumstances and the nature of the design problem. In some instances, for example in a highly urbanised environment, matters of ‘ecology’ might outweigh ‘spatial and technological’ factors. For this reason, evaluation is not a ‘one size fits all’ process. Secondly, and by virtue of this weighting, the design professional will be required to select a combination of assessment tools on a multi-dimensional basis, such as those listed in Table 6.7, whereby each criterion is appropriately addressed. This step of criteria weighting and process evaluation is thus integrated into each stage on the basis that contextual circumstances are prone to change over the life cycle of the project. This is intended to assign the success of each criterion with a quantifiable value or rating. This assessment will therefore inform either a reinvestigation of earlier steps be undertaken, or special interventions be taken to rectify the deficiency in the next stage such as, for example, by preparing for yet-to-be installed external infrastructure.

Finally, the researcher has opted for a progressive, yet partial, ‘check-box’ layout for ease of implementation. It has been previously stated in this thesis that green building rating systems are far more accessible and popular. The researcher is of the opinion, having made use of these in practice, that a major contributor of this popularity is due to a similar value-input format and perceived simplicity. This not only illustrates a map of the proceeding steps, but also allows for summarised record of approach to be maintained in a predictable and logical format, which is furthermore replicable and transferable between project stakeholders.

The methodology of approach is thus indicated in Table 6.9 below, and its sequence is explored in the flowing sections.

Table 6.9: Methodology of approach: integrated systems-design process for sustainable development



				Sustainable Development Criteria Considerations							
				Core Criteria				Ancillary Criteria			
Integrated Systems-Design Process			Achieved	Environment	Society	Economy	Knowledge	Culture	Policy	Space and technology	Physical infrastructure
Inception	External factors	Brief									
		Site / Place									
Initiation	Definition of problem			Assign weighting based on context and problem							
	Identify context of use										
	Social Factors	Tacit knowledge									
		Desired output									
	Identify systems and subsystems										
	Identify systems constraint										
	Define success criteria										
	First stage SD criteria evaluation			Multi-dimensional assessment(s) of SD							
Implementation	Re-assess weighting			Assign weighting based on any changes to context							
	Identify alternatives (Option analysis)										
	Create a Concept										
	Justify a concept	Functionality									
		Usability									
		Informational content									
		Desired output									
	Can concept be justified?										
	No	Yes									
	Select preferred concept alternative										
	Building typology	Geometry									
		Free form									
	Develop / build prototype										
	Compare	Interpret									
	Order										
	Change Mode and Effect Analysis										
	Test										
	Second stage SD criteria evaluation			Multi-dimensional assessment(s) of SD							
Ramp up and Integration *(Achievement of satisfactory performance)*	Re-assess weighting			Assign weighting based on any changes to context							
	Implement alternative *(initial use)*			Deployment of building solution							
	Monitor Operations: User-product interactions										
	Measure success of performance			Multi-dimensional assessment(s) of SD							
	Document lessons	Evaluate and validate									
		Cross-level knowledge									
	Change Mode and Effect Analysis										
	Process aspects for change										
	Identify controller / actor for change										

6.2.3.1. Stage 1: Inception

This stage is concerned with initial appraisal of the project, and evaluating conditions that are 'imposed' on a project, bringing with them certain constraints and opportunities that are required to be understood. These conditions are denoted as 'external factors', and summarised as the project brief, and site. This stage is observed by the researcher to be closely aligned to the inception stage of the Client-Architect Agreement (SAIA, 2008).[61] Within this work stage, the design professional is required to receive and appraise the client's brief, the site constraints, budgetary constraints, the need for additional consultants, and the programme of the project. In these steps, no work on developing a concept is undertaken; instead it remains a qualitative fact-finding exercise dedicated to the understanding the project intention, the client's desires and the limitations afforded by the site. These conditions generally fall outside of the realm of control of the professional team, notably the designer, and for this reason regarded as 'external' in their influence.

However, while these factors are external in nature, they must be investigated according to the sustainable development criteria in order to ascertain important information which may affect project feasibility. The basis for investigation may be drawn from the definition of criteria as outlined in Chapter 5 section 5.2.2. For example, within the environmental criterion, the site must be evaluated from the point of view of necessary ecological constraints and its relationship to the surrounding ecosystem. A social and economic investigation could prove that that the project is not needed in its context, it might prove to be a disruptive influence on local livelihoods, or even to be financially unviable. A knowledge-based investigation could highlight the social memory (tacit experience) preserved in the site which is of value to the context and which drives local decision making and contextual experience. Additionally, the rigidity with which the project resides in the physical realm versus the knowledge-based digital realm is required to be addressed. Therefore addressing conditions of 'site' is an assessment of 'place' (see 'knowledge creation', section 6.1.4.1). The degree with which the brief therefore requires an abstract, digital solution must also be addressed since, as has been addressed in this thesis in Chapters 5 and 6, the realm of user experience is not limited physically or geographically, and as such requires support and sensitivity of

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[61] http://www.design-lab.co.za/wp-content/uploads/2013/11/SAIAClientArchitectAgreement.pdf [Viewed 25 April, 2015].

approach. In addition, more practical constraints such as availability of local infrastructure and the spatial and technological opportunities offered would determine the extent to which future operations and knowledge transfer could be accommodated in the short, medium and long term. It is therefore anticipated that the inception stage will hold responsibility for assessment of these external factors according to all sustainable development criteria in order that the broadest objective understanding of the project may be ascertained prior to definition of the problem and concept formulation.

6.2.3.2. Stage 2: Initiation

> *'The precise statement of any problem is the most important step in its solution.'*
>
> \- Edwin Bliss

Following the investigation of external factors and appraisal of the brief, the initiation stage concerns itself firstly with definition of the problem. As discussed in sections 6.1.31.1 and 6.1.3.2, definition of this problem is required to focus intended efforts on the critical issues and to clearly delineate the base desire for project delivery on the part of client and/or stakeholders, coupled with the defining constraints of site and place. Through later formulation of the concept and, by association, the project 'hypothesis', the problem statement will therefore serve as a basis for justifying and validating the approach.

The identification of context of use follows logically from the definition of the problem statement. A critical component of this step is an understanding of temporal and spatial scale. The problem is clearly addressed according to the point in time that the brief was presented, and as such must remain cognisant of the risks involved with initial problem development and changing conditions that might occur as time passes. The spatial scale, which is addressed within the space and technology criterion, represents the intended reach of the project. It is required that the designer understands the extent to which the eventual solution will not only affect, but also be affected by stakeholders. This requires the designer to address the intended (or required) impact on the site, as well as surrounding areas. As a methodology for built-environment design, this process is therefore equally applicable to precinct-based design as it is for an individual building. The role of policy is of importance here as municipal and statutory influence both limits and forms the nature of the development. As local authorities gain more and more insight through information and knowledge-based development, the inner workings and requirements of precinct development are achieved at a higher level than ever previously possible, thus influencing strategies for urban development and cultivating a broader quality of life. This aspect is discussed in more detail later in this chapter.

In the digital age of knowledge-based development, geographical location is also no longer necessarily a limiting factor, and for this reason a built environment can equip itself to fulfil a role whereby broader sharing of experience is facilitated. The extent to which the digital realm is incorporated, either ubiquitously or within plain sight, is a decision that requires early consideration. The context of use is also subject to consideration within the range of sustainable development criteria, with each having a significant influence on the strategy of approach and eventual solution. Political, cultural, social, and economic context serve as significant role players, providing direction to the project. The degree with which the intervention or solution is accepted into use is largely dependent on these criteria.

An understanding of tacit knowledge is identified as the next step in the initiation stage. This entails establishing the degree to which the proposed project specifically conforms to prevailing knowledge conditions. Is the project representative of an existing functional awareness, or is the proposal a foreign concept for which orientation is required? This plays a significant role in strategising the extent to which technologies are to be employed to enable user-product interactions and usability. This also assists in establishing possible social barriers to the project, depending on the spatial scale of influence.

Desired output represents the intention of the project team, as well as integrated stakeholders for whom the project is intended. Grassroots integration of user-level and stakeholder requirements and desires are investigated in order that the project may better represent the context within which, and for which it is intended to exist. This is possible through public participatory programmes, surveys, as well as integrated design appraisal workshops. It is also possible to facilitate these digitally through web-based forums and conferences. This knowledge is thus transferred and recorded for later use. These requirements are intended to be interrogated and explored according to the defined sustainable development criteria.

‘Tacit knowledge’, and ‘desired output’ form parts of the step described as ‘social factors’. While society is recognised as a core criterion of sustainable development, the means with which these sub-indicators represent the social context, and thus the cultural and knowledge criteria contained therein, warrant specific exploration on this basis. Having recorded and managed the knowledge obtained, these factors will again be addressed later in the process (ramp-up and integration stage) to mitigate the risks associated with the temporal scale of the problem statement, as well as the selection of the preferred concept.

The next step is defined as the identification of systems and sub-systems. Design is representative of an integrated systems process (sections 6.1.3.1 and 6.1.3.2). Following identification and definition of a problem, the design team must decide if it will obstruct the achievement of the goal. The system is therefore described as a collection of interrelated, independent components or processes that act in concert to turn inputs into some kind of outputs in pursuit of some goal, and influenced by external factors that must be considered in the context of the system within which the problem exists. The design team is required to identify the system that the problem forms a part of as well as the sub-systems involved. The decision-maker and the team should then collaborate and integrate efforts to analyse whether the problem is a core problem or merely a symptom of a larger problem. It was also discussed that a system consists of the following elements, and so the investigation should include (section 6.1.3.1):

1. Components of input, process and output
2. Attributes of those components
3. Relationship between components and attributes.

By interrogating the design problem according to a systems-based analysis, the designer is then equipped to focus the approach on the core system requirement as well as understanding its relationship with contributing sub-systems. The role of sub-systems thus makes it possible to interrogate and weight the influence of the sustainable development criteria to the design problem at hand. Each subsystem is then interrogated at the level of its components, attributes and relationships. This removes vagueness from the process, thereby empowering the design team to pinpoint core problems and opportunities and the criteria required to address them.

Having addressed the systems and sub-systems at play, the next step is to determine the core systems constraint. This is different from the problem statement by placing a precise restrictive condition on the project as represented by a system. The constraint is therefore the element, factor or subsystem that restricts the project from achieving its potential relative to the intended goal. By understanding this, the design team is empowered to take decisive action and make appropriate decisions to mitigate or eliminate the constraint in pursuit of project success.

With the identification of key constraint(s), it is then possible to define the criteria for success. These therefore include specific interventions to overcome the available challenges that stand in the way of an optimal result. These success criteria require investigation according to the proposed criteria for sustainable development. In this way a focused approach can also determine if criteria are systems or component based.

Identification of success criteria furthermore incorporates the result of quantitative analysis. This is important since it is according to these success criteria that success of implementation will ultimately be measured in the ramp-up and integration stage. The design team is therefore required to maintain the informational database that comprises these success criteria for later analysis and assessment. The identification of success criteria furthermore represents the last step in research and analysis before giving way to formative decision making as represented in the implementation stage.

6.2.3.3. Stage 3: Implementation

The implementation process is concerned with turning research into concept. By interrogating constraints and opportunities involved with project brief and context, this information therefore transforms decision making into a tangible prototype born of option analysis and testing.

The first step in the implementation process is described as the identification of alternatives or option analysis. The alternatives do not yet represent formulated concepts, but instead directions of approach. These options are required to adhere to the identified contextual factors, systems constraints and success criteria, thereby informing decision making that would yield a desirable result. According to Hsee et al. (1999:576) all decisions are viewed as choices between alternatives, often resulting in implicit trade-offs. There is a distinct difference in approach, however, between situations whereby multiple options are evaluated simultaneously and can therefore be easily compared, and situations whereby alternatives are evaluated one at a time and in isolation. Hsee et al. refer to these situations as joint evaluation (JE) and separate evaluation (SE) modes respectively. However, they state that these alternative approaches can often yield inconsistent preferences. Furthermore, it is observed (Hsee et al., 2009:589) that when multiple alternatives are identified and available, JE is the generally predominant method that is employed. This is benefited by the fact that this can be simultaneously evaluated by the same single team of decision-makers and designers. Where multiple scenarios are not available, SE is employed. However, the asynchronous approach runs the risk of different decision-makers and design teams taking responsibility for evaluation. Hsee et al. (2009:589) conclude by stating that deciding upon which mode is better is dependent on the goal that is intended to be achieved through decision making. If the goal is to select the objectively most valuable option, then JE is the better approach. However, if the goal is to choose an option that is based on optimising consumption experience that also takes place in SE, then this is the preferred method.

There is no recommended requirement for a specific number of options in order to achieve finality in this step; however, the goal is for objective value-based selection. Value-based selection is not only conducive to preferential selection based on likelihood of success, but also forms the basis for later measuring of success for which value-based investigation forms an integral part (section 6.1.7). This therefore equips the process for future re-evaluation within the closed system information feedback loop. The researcher therefore proposes the application of a JE mode for multiple options evaluation. Each option or alternative will then be subject to hierarchal selection for advancement to the concept formulation step. This selection is representative of the fact that a design team may be limited in resources and hence able to address concept formulation sequentially though the identified alternatives.

Design processes facilitate the route to creative ideation, and this route hinges on successful concept generation (Yilmaz et al., 2016:137). Concept creation represents schematic planning pursuant to design intent. The concept design may be accompanied by a design concept statement, both of which are required to concern themselves with the design solution, as opposed to the design problem. Therefore the concept is manifested as a solutions proposal. The design problem is thus a quantifiable notion based on previous research, defining what is needed and for whom. The principle is therefore not to solely describe the design product, but also the approach. Design concepts can range from the pragmatic, to the symbolic and even emotional. In concept creation, a variety of ideas is thus considered where different areas of the design solution ‘space’ are explored (Yilmaz et al., 2016:139). The creation of concepts based on selected alternatives and option analysis is a representation of divergent concept creation, whereby a number of innovative ideas are proposed. Divergence, as stated by Yilmaz et al. (2016:152), is fundamental to early design stages, having an important role in later stages and exploration.

Design evaluation practices are important to the creative process where design stakeholders are required to assess proposed solutions prior to implementation. Outcomes of the justification process may lead to discarding of some concepts, but will frequently result in a series of investigations and creative processes aimed at strengthening the project. When addressing the concept design proposal evaluation process, Christensen et al. (2016:132) state that multiple evaluation logics operate simultaneously and predictably. To state that creative evaluation within the design process is based on consensus is therefore an oversimplification. Instead, evaluation is dependent on distinct social and individual conceptualisations of what constitutes an idea, as well as in relation to ontological assumptions according to which the concept is measured. This is indicative of a prevailing difficulty in the creative sphere to objectively test the suitability of concepts (2016:133). However, Dong et al. (2016:68) state that a range of decision-making tools exist, such as concept screening, and pair-wise comparison charts, which are representative of quantitative models for concept evaluation, selection and analytical thought. The process of deductive reasoning from established rules to a definitive conclusion and decision making in favour or against a concept is known as *generative sensing* (Dong et al., 2016:68). It is for this reason that the researcher has proposed quantitative concept evaluation in the next step, represented as ‘justification of a concept’. Concept justification is in turn subdivided into four categories of assessment, namely:

- **Functionality**: Represents the quality of a product to serve a particular purpose practically. Defined in two forms, namely technical and interactive functionality (see section 6.1.6.3).
- **Usability:** Focuses on the ease and efficiency with which a solution is used. It is concerned with effect of use and learnability, and is representative of a time, place, context and situation-bound concept (see section 6.1.6.3).
- **Informational content:** Represents the role of the ‘product as information’ and determines whether the concept proposal understands the knowledge-building role intended to empower users through interactive experience (see section 6.1.6.3).
- **Desired output:** Describes the design team intention for the project based on contextual understanding and criteria for success. This is likely to be informed

on a more detailed, sustainable and holistic basis than the previously defined desired output by project stakeholders.

These categories of justification test the concept proposal based on intended user experience, objectivity and pragmatism, requiring that the concept design satisfy all criteria in order to be deemed justifiable and practical for deployment into form-giving processes. This furthermore represents design process flow from concept divergence to convergence, through reduction of options analysis towards the focus of approach. Convergent thinking refers to cognitive activity in pursuit of a single or best solution, and is necessary to evaluate, synthesise and select the most promising ideas that will ultimately be used for the concept basis for the final design (Yilmaz et al., 2016:140).

While it is not the purpose of this methodology to define the preferred process of option analysis and consequent selection, two methods of evaluation are identified. Firstly, SWOT analysis[62] traditionally represents one such suitable recommendation conducive to deductive and objective reasoning.

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[62] Created in the 1960s by business gurus Edmund P. Learned, C. Roland Christensen, Kenneth Andrews and William D. Book in their book *Business policy, text and cases* (R.D. Irwin, 1969). http://www.businessnewsdaily.com/4245-swot-analysis.html#sthash.jNyRK13b.dpuf [Viewed 27 April, 2016].

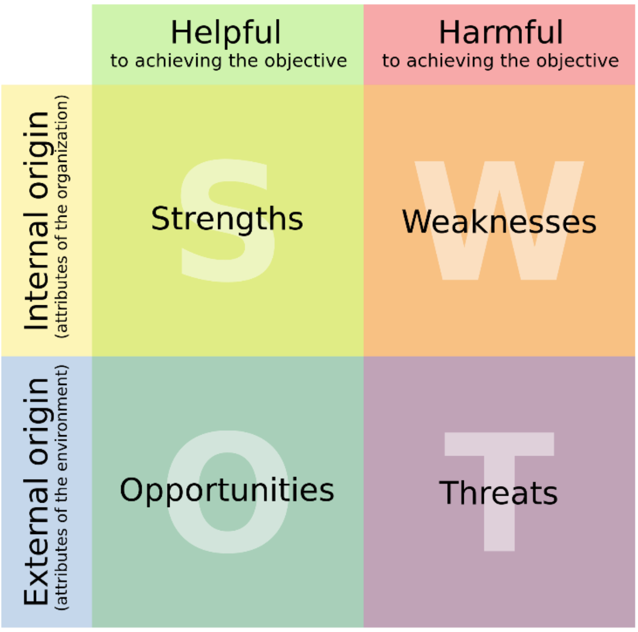

Figure 6.30: Graphical representation of SWOT analysis, comprising positive, negative, internal and external factors
Source: https://en.wikipedia.org/wiki/SWOT_analysis

Secondly, deductive reasoning is another option available for suitable interpretation of design evaluation and concept justification criteria. Generative sensing seeks to combine deduction with abduction[63] through a recursive loop in which propositions are invented as a means to explain the evaluation but are also tested. This is therefore a process of creating new hypotheses to explain, resolve or challenge evidence either in favour of or against a design concept. The pattern of generative sensing is shown below in Figure 6.31.

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[63] Abduction refers to the introduction of a mechanism for discovery through logical reasoning. This involves the introduction of hypotheses to explain evidence, as well as to render evidence irrelevant due to changing truth conditions through concept re-design (Dong et al, 2016:71).

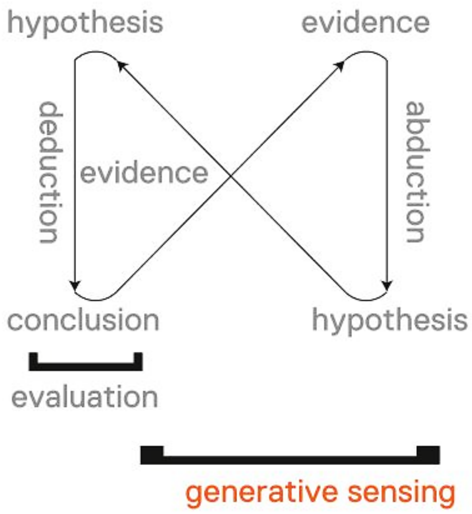


Figure 6.31: Generative sensing as a pattern of design thinking (Dong et al., 2016:83)

Having established which concepts are justifiable, and as a result worth pursuing, these concepts are thus primed for selection. However, the methodology recognises that external social factors are again required to be assessed for reasons of possible change or time-based redundancy. These changes, which could be in the form of regression or improvement, may therefore affect certain sub-systems and constraints and as such must be re-interrogated prior to selection of preferred concept. Upon selection of the preferred concept alternative, the design team is next tasked with typological form giving.

Building typology is comprised in this methodology through the application of geometric and free-form giving. The manner with which this is undertaken is at the discretion of the designer and may be the product of individual or group effort. This is representative of the artistic design process, and this step is intended to accommodate the preference of the methodology user based on their own expertise in design development. This is therefore possible to achieve, for example, through hand sketches, volumetric model building, as well as 3D virtual volumetric modelling facilitated through CAD. It is not the position of this thesis to dictate method in this regard. Interestingly, however, in a study by Jonson (2005:613) it was determined that while hand sketching and digital technology represent the primary conceptual tools in the design process, verbalisation was actually determined to be the major conceptual tool. It was also determined that CAD serves as an ideation tool across design domains. Words are therefore regarded as the most common means of human communication as experienced by many designers during the concept design process (Lawson et al., 1997:182), however the strength of verbalisation in the ideation process and use of CAD for conceptualising still does not side-line the value of hand sketching (Jonson, 2005:622). He further reiterates the importance of allowing the design teams established processes to flourish within this methodology, while rooting them in a sound, holistic approach.

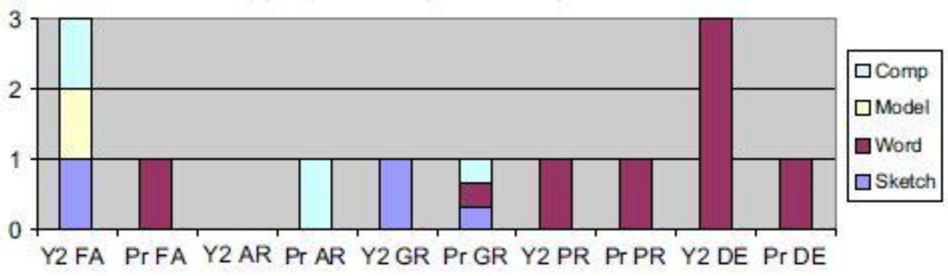
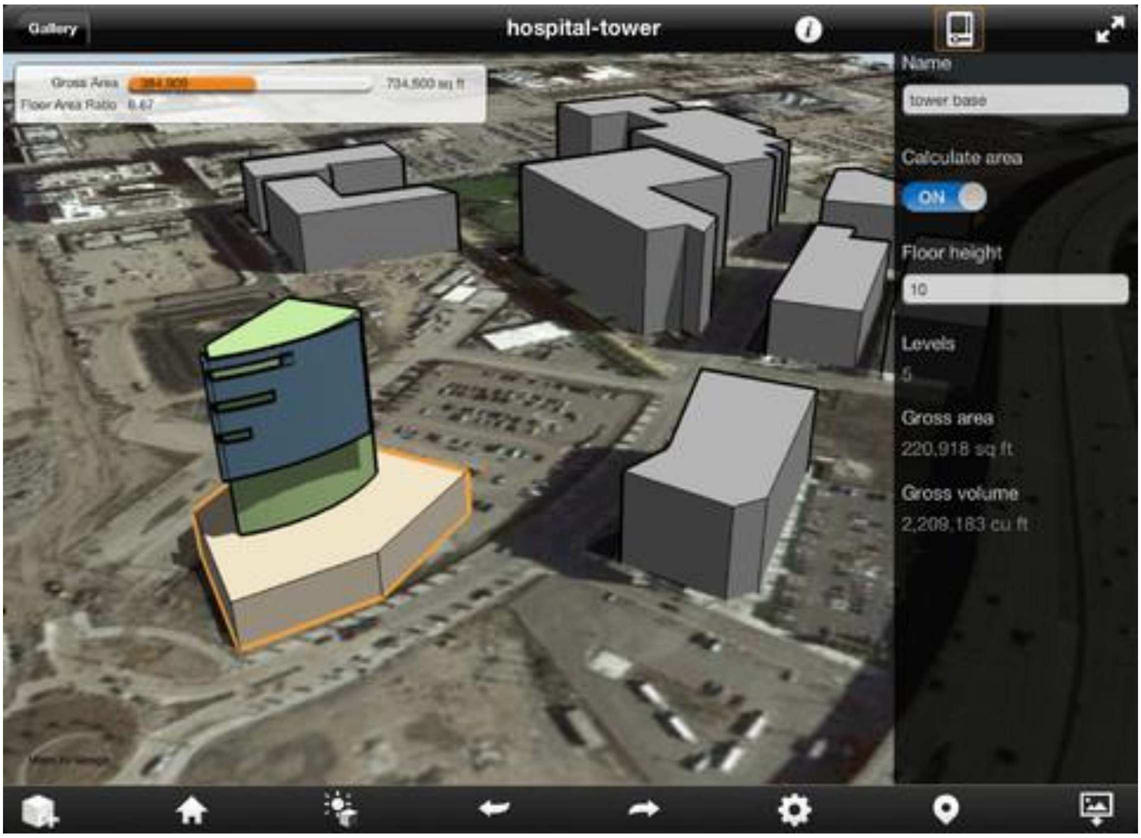


Figure 6.32: Case study of tools used for capturing 'Aha!' moments (Jonson, 2005:621). Y2FA represents an architecture student, PrAR a practising architect, PrFA a fashion designer, Y2FA a fashion design student, PrGr a graphic design practitioner, Y2DE a graphic design student, PrDE a general design practitioner, and Y2DE a general design student

It is important to bear in mind, however, that the researcher has specifically asserted that methodology is benefited by application of BIM in the process. BIM is specifically adept at accommodating the concept design process through many software solutions such as Autodesk Revit® and FormIt®, for example, (used extensively by the researcher in architectural practice) which make use of intuitive and free-form volumetric mass modelling and 3D sketching. These BIM-based conceptual architectural tools make it possible to generate conceptual form and geometry based on the project brief, and also offer the added benefits of integrating quantitative analysis within the process, such as area analysis and accurate geographical placement with embedded satellite imagery. This results in an ability to not only design with a degree of physical contextual awareness, but also to initiate preliminary energy analysis based on accurate representation of solar paths and the effect of direct solar radiation on the building facades. This is also elevated to precise analysis through hypothetical application of variations in percentages of fenestration on the building façade. In addition, changes to building form automatically record adjustments to gross building area over determined levels, yielding an ability to gauge whether statutory and site constraints are being adhered to during early concept design. The benefit of initiating concept design through a BIM-based tool results in the ability to easily translate concept design to the documentation and information-building process with accuracy and without loss of information. This also serves as a collaborative tool facilitating ideas of many into a singular design product through a synchronous and shared design process between team members on a single volumetric model. For this reason it is recommended by the researcher that the paradigm shift towards the design of knowledge buildings requires a technological mind-shift within practitioners towards BIM-based design and documentation for efficient and optimal results.



Name
tower base
Calculate area
ON
Floor height
10
Levels
5
Gross area
220,918 sq ft
Gross volume
2,209,183 cu ft

Figure 6.33. **The user interface within Autodesk Formit ®, representing BIM-based CAD for real-time geometric analysis, and early concept formulation**
Source: https://aec-apps.com/sites/default/files/mzl.pjjgupyi.480x480-75_0.jpg [Viewed 10 June 2016]

Through conceptual tools and processes, the design team develops building typology into a building prototype (see sections 6.1.4.1 and 6.1.4.3). This prototype represents a preliminary model, composed of the results of building typology as well as the concept alternative that was selected. Building prototyping and concepts are also referred to as 'pre-inventive' structures (Christensen, 2000:117). As previously discussed in this chapter (section 6.1.6.3), the selected concept alternative is representative of rigorous justification based on merits of functionality, usability, informational content and desired output. When combined with building typology, the preliminary working model is formed. This preliminary working model comprises factors such as components, attributes and systems. These factors, while necessary in the design prototype, require interpretation and ordering for purposes of optimisation of the relationships between these factors. This is especially important in complex buildings where the relationships between user and building systems significantly affect building usability. User flow diagrams relative to internal functional relationships, for example, would be of critical importance to assess and implement in a building such as a hospital or airport. The ordering of these factors, often through an iterative process, is an important step towards an optimal design resolution and solution, and would benefit from collaborative involvement of the greater design team and systems specialists. Interpretation of these factors is also important relative to the sustainable development criteria as systems requirements for the building product are rationalised. These requirements are now, for the first time, possible to evaluate in physical form relative to contextual social, environmental, spatial and technological, infrastructural and policy-related criteria.

Through BIM-based prototype development, early quantification of building form and function is possible through internalised database analysis, through means such as automated scheduling applicable to building attributes and components. This also makes it possible to preliminarily assess economic constraints and value relative to project budget and feasibility (see Chapter 4 section 4.1.7.6 and section 6.1.6.4), thereby facilitating the decision-making process. In addition, the record of decision making is transferable through building documentation and BIM-based ordering to project stakeholders and users. Knowledge-based criteria are furthermore incorporated through addressing experiential requirements and opportunities through spatial organisation with targeted technological intervention through ICT within the intelligent building solution. By incorporating the building solution decision making and ordering of components, attributes and systems within the project BIM, this is then readily available for interpretation and interrogation throughout the design development process, unlocking continued involvement of project stakeholders and end users (see Chapter 4 section 4.1.7.6 and section 6.1.6.4).

Following ordering of project-defining factors, testing is required. Testing is possible through a number of methods, such as computer-aided digital simulation, virtual construction analysis, case-study analysis, external peer review, project team workshopping and physical mock-ups where possible. The reason behind testing is to determine if the ordering process has successfully met the design intent, as well as justification criteria of the concept. It is therefore a means to ascertain what compromise, if any, has been made through the ordering process, thereby requiring the design to establish if re-ordering is required. The process of ordering and testing is therefore part of an iterative and reiterative design process, also known as design critique. Christensen (2000:117) states that this critique takes the form of an exploratory process that makes use of pre-inventive structures (prototypes and concepts) as its input. Furthermore this exploration process should not be overlooked for its critical role in design problem solving. According to the process of problem-solving co-evolution, as described by Dorst et al. (2001:436) and based on Maher's model in Figure 6.34, processes that alter the problem space, such as contextual shifting and problem re-framing, co-evolve with changes arising in the solution space. This iterative process promotes creative discovery by forming conceptual bridges between the problem and solution space (Dorst et al., 2001:438; Christensen, 2000:117).

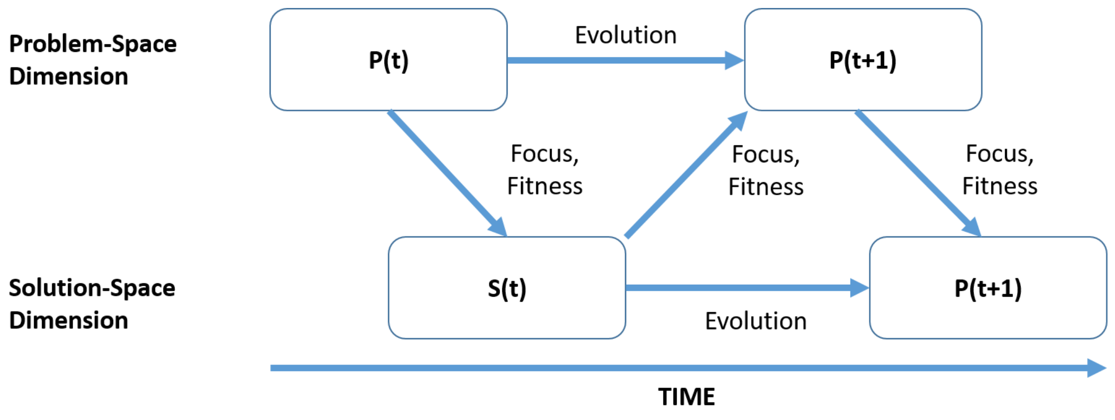


Figure 6.34: The co-evolution model of Maher et al. (1996)
Comprises the initial problem space P(t), partial structuring of the problem space P(t+1), the initial solution space S(t), and the partial structuring of solution space S(t+1) Source: (Dorst et al., 2001:436)

Of potential impact to the ordering and testing process is the identification of aspects of the design at risk of future redundancy and change. The proposed methodology includes the CMEA at the discretion of the design team. As discussed in section 6.1.6.2 the CMEA is representative of the requirement within the design process to incorporate flexibility in the proposed solution, and is investigated based upon following factors: modules, potential causes of change, potential changes, potential effects of change, design flexibility, occurrence, readiness and the change potential indicator. This allows investigations to be undertaken on selected components and systems in order to pre-empt the possibility for a future need for change or adaptability. By doing so, flexibility of approach will be built into the architectural solution to mitigate the impact of threats to sustainable implementation such as technological, functional, and operational redundancies (see section 6.1.6.2) within the project formative process and prior to initial use. These identified modules that are subject to change analysis are furthermore selected and adapted while remaining integral to the outlined ordering process which is based on temporal applicability to the defined constraints and criteria for success. For example, the selection of a certain HVAC or building BMS system might be subject to future technological advancement which would require a re-ordering of components and support infrastructure to adapt to future requirements. Where the basis for the design solution is subject to more radical change based on unforeseen contextual or technological circumstances, design for flexibility is addressed again in this chapter, post-implementation stage. While introduction of the CMEA process seeks to mitigate with accuracy the possibility of redundancy or obsolescence, total identification of riskier components is not always possible at this stage. Robustness is defined by Hoes (2009:2) as the sensitivity of identified performance indicators for errors contained within building design assumptions. Robustness of design is therefore fundamental to the process and must be cognitively pursued by the design team. This is of equal significance to user behaviour and potential changes to that behaviour over time.

Having addressed the steps from identification of alternatives, concept creation, prototype development, ordering and testing, the implementation stage is thus completed prior to initial use. However, the methodology draws specific attention to the fact that the solution is not a finite product, but rather a system in constant development. For this reason, following implementation and delivery of the selected alternative (deployment of the building solution), the success of its deployment will be assessed and measured, thereby identifying key component and system contributors for the need for adaptation and change. The process for assessment and re-introduction of knowledge for design-based decision making will be addressed later in this thesis (section 6.2.5.5).

6.2.3.4. Stage 4: Ramp-up and integration

The ramp-up and integration stage, as indicated within the methodology (Table 6.9), is a departure from planning towards deployment (contract and construction) of the solution and operational monitoring. This stage concerns itself primarily with the actual achievement of satisfactory performance in real-world terms.

Implementation of the selected and tested alternative takes the form of statutory approvals, the regimented documentation process associated with building, and construction conventions. In this step, the building solution is constructed or produced according to applicable contract law in pursuit of end-user beneficial occupation and overall project works completion.

Within this process there are many factors that could yet influence adherence to the defined sustainable development criteria. For example, grassroots involvement in the construction process through training and workforce deployment of local populations could improve social acceptance, knowledge building and economic conditions within the immediate geographical context. In an investigation of the Agenda 21 for sustainable construction in developing countries, Du Plessis (2002:7) states that socio-economic components are viewed to be some of the most challenging, with policy and government strategy seeking to address this by articulating, for example, the provision of housing, job creation, capacity building and gender equality. Thus the challenge of 21st century development within the limits of natural systems is as much a problem of leadership and policy as it is a technological problem (Kibert, 2008:xiii).

Without reducing the importance of ecology to the process, as-built green building principles may also be applied to the physical construction process through strategies such as material recycling, sourcing of locally produced or available materials, recovery or protection of ecology. The Green Star rating system is one such tool that is available to monitor this ecological approach through assessment according to nine defined criteria.[64] The manner in which this is pursued during implementation is also likely to be heavily influenced by policy, hence requiring in-depth analysis of applicable regulations and statutory constraints. Moloney et al. (2014:104) state that addressing the impact of construction processes on the environment and as a factor of resource consumption does not reside solely in making the environment part of decision-making processes, but rests instead on addressing the elements that bind practices together, the ways in which they are enacted, and reproduced. Furthermore, by understanding these interactions the industry can move beyond the ‘behavioural space’ for those attempting to achieve social change. Recognising the multi-indicator importance in project deployment, sustainable strategies in construction require better integration of various actors at the supply side, a shift to innovative and ecological building services, and improvement of user-producer relationships and integration of the consumer into the innovation process.

Following implementation of the alternative, initial use is followed by monitoring of operations through post-occupancy user-product interactions. This is a function of

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[64] Green Star – Design and As Built. https://www.gbca.org.au/green-star/rating-tools/green-star-design-as-built/ [Viewed 30 April 2016].

addressing the role of user experience as discussed in section 6.1.6.3. A pragmatist approach is undertaken in recognition that experiences are temporary constructs that develop from the interaction between people their environment. This interaction between user and product is determined by context of use, as well as social, cultural and knowledge factors. User-product interactions are made of automatic interactions (fluent), knowledge-creating interactions (cognitive), and interactions that forge a relationship between the user and the product (expressive) (see section 6.1.7). The manner with which the built environment or building solution establishes environmental support for human experience and activities as well as incorporating feedback is under scrutiny.

Monitoring of user-product interactions is possible through various means, such as direct survey with building end users for experiential and quantitative understanding, as well as through pervasive technological means for qualitative understanding. This technological monitoring is achieved through building sensors and integrated BMSs which comprise the basis for ‘intelligent buildings’, as discussed in Chapter 4 section 4.1.7.5. The scope of intelligent buildings incudes building management, space management and business management, including the ability to observe, interpret and control building support systems, such as internal microclimate conditions and data network distribution. Therefore intelligent buildings are not just an effective means to exercise limited control and internal flexibility in response to user needs, but also to identify those factors which are beyond control and in need of more holistic systems-design input during the operational phase. The purpose of the ‘monitoring’ step is therefore of a fact-finding nature. The data and knowledge derived therein will then be subject to analysis through measurement processes.

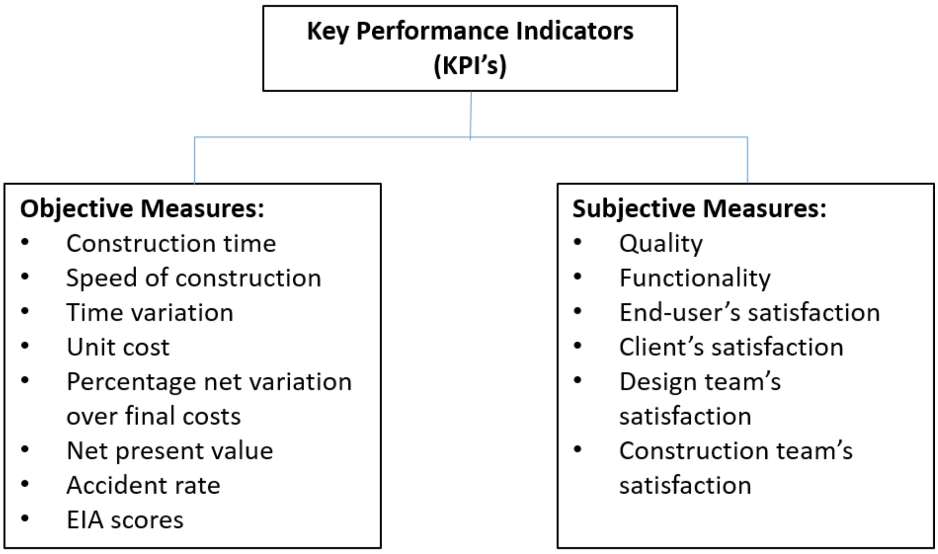

Figure 6.35: KPIs for project success (Chan et al., 2004:210)

This measurement immediately follows evaluation of the user-product relationship. In this way the user experience may be adequately gauged for the purposes of introducing the internalised change control process. Building performance is also associated with the established success criteria, as well as building functionality, usability, informational content and fulfilment of desired output characteristics as set out in concept justification. As indicated in Figure 6.35, key criteria for building performance focus on critical aspects of outcomes or outputs. These performance criteria are representative of combined mathematical quantification, as with the group on the left, and subjective opinion and judgement, as with the group on the right.

On a practical level, building performance also concerns itself with energy efficiency, which is a function of its operational and space utilisation combined with user behaviour (Hoes et al., 2009:295). For this reason, energy efficiency cannot be analysed in isolation without addressing user experience. While building performance has been identified as significant on the scales of user-building experience, and energy and operational efficiency, measurement is also required to include the relationship between the building and context. Context is representative of the building's outdoor environment, as represented by the environmental criterion, but also concerns itself with the role the building is playing in the greater economic and knowledge-societal context. Measurement is thus indicative of assessment processes that represent all sustainable development criteria.

In this aim, and as discussed in section 6.1.7, measurement of success is applied on the basis of a multidimensional approach in order to assess and evaluate performance, provide trends on improvement as well as highlighting declining trends, and providing information to decision-makers to formulate strategies and communicate achievements to stakeholders. The selection of measurement methods remains at the discretion of the design team, but is a requirement for holistically analysing the sustainable development criteria necessary for the proposed methodology. Holistic decision making therefore requires assessment of the relative importance of the various criteria within overall performance options being considered. This approach may lead to a large and complex system, however, which requires large quantities of detailed information to be assembled and compiled. Effort and future work must therefore be undertaken to make the measurement process less complex, and to make the calculation process more flexible and easier to understand, with integration across all stakeholders.

Available methods for assessment are indicated in Table 6.8. This will thus be the product of a combination of assessments or ratings in order to correctly identify whether success criteria are met. Deficiencies according to success criteria of the project thus reveal aspects of the design which require intervention in order to ensure the project's long-term viability, and hence its sustainability characteristics.

Following measurement and assessment of performance, the results of this step must be recorded and documented. While it may appear this step is an obvious one, integrated within this documentation process are the sub-steps: evaluation and validation, and cross-levelling of knowledge. The documentation step is rooted in knowledge building and management (see sections 6.1.4.1, 6.1.4.2, and 6.1.4.3) within the methodology and seeks to actively maintain a knowledge base during the operational life cycle of the building solution for purposes of allowing future projects to benefit from experience gained, as well as the means to simplify the assessment process into tangible results for redistribution into the implementation stage where adaptation of the building solution is deemed to be required. Evaluation and validation of the measurement process and the involved multidisciplinary assessments establishes the means to qualify results based on accuracy and appropriateness. Since a multidisciplinary assessment approach is required, some approaches may weigh certain indicators higher than others, thereby inadvertently affecting accuracy of results. Additionally, performance is also evaluated on a subjective basis which requires validation. The introduction of this step creates a basis for replicable and reliable evaluation since the systematic assessment of measurement results based on predefined performance criteria establishes consistent and regular use between projects. The documentation process therefore contributes to overall effectiveness by facilitating acceptance, understanding and ownership among stakeholders (Chan et al., 2004:209).

Cross-levelling of knowledge is important in an ever-changing and advancing industry. This step encourages learning from other related projects in order that the evaluation process may be shared, thereby contributing to best practice on a greater scale. By cross-levelling knowledge between projects, it is thereby possible to anticipate scenarios that have yet to be encountered, either due to the time that the building has been operational or changing contextual and environmental conditions. Each project is not an island, and exists to contribute to the knowledge landscape of the urban context within which it resides. This is fundamental to the smart-city concept, and the integration of knowledge-based sustainability criteria recognises the active role a knowledge building plays on the larger context. The documentation process is therefore more than just a performance guideline for localised and micro-scale improvement, but an ‘open-source’[65] paradigm contributing to the informational backbone of macro urban development and planning.

Documentation means recording of explicit knowledge, by providing a basis by which it can be transferred and managed between project design professionals and broader built-environment stakeholders (such as municipal authorities and even design professionals on other projects through an open source platform). This is currently possible through traditional methods such as reports, papers and spreadsheets. Yet despite the transition from paper to digital media, provision of data and documented records from construction to operations is still regarded as cumbersome, requiring some manual entry and duplication of effort (Anderson et al., 2012:688). In addition to these methods, the documentation process is also now made possible within the project BIM. As has been discussed in Chapter 4 section 4.1.7.6 and section 6.1.6.4, there is growing interest in how BIM can be leveraged to streamline the operations and maintenance of buildings (Anderson et al., 2012:688), and as such BIM is not restricted to project concept development and planning but is integral to the building operational life cycle. For this reason it remains a digital representation of real-world conditions expressing the physical characteristics of the building solution’s digital form. The benefit of a BIM project is that it provides information about a building, its components,

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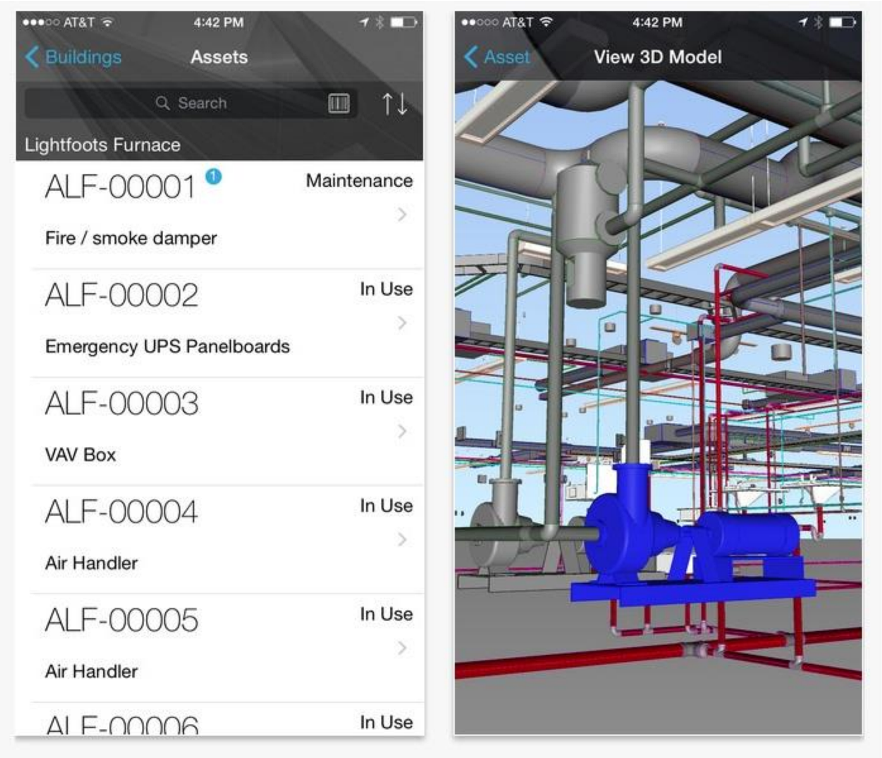
[65] A term adapted for use in this chapter denoting software for which the original source code is made freely available for modification and redistribution.

systems and spaces. The overall goal, as stated by Azhar et al. (2012:21), is to transfer these data into facility management operations whereby information can be accessed by ‘simply clicking on an object in a BIM model’. This digital BIM is therefore primed for collaborative inclusion of the growing information base pertinent to the project. As more information regarding the performance is acquired, this is now possible to ‘build’ BIM asset data into the 4D model, attributing quantifiable information to the relevant systems and components. While the possibility of information integration is made more prevalent, Becerik-Gerber et al. (2011:431) note that BIM still holds undeveloped possibilities for providing and supporting facilities management practices within its functionalities of analysis and control. However, the researcher observes that a distinct line is being drawn between delivery of information between planning and operations phase. The goal is therefore to deliver the project within a systems process by integrating project development stakeholders within the project life cycle. Cross-levelling of information would ultimately benefit from a digital landscape (digital BIM-based library) comprising Building Information Models in a virtual setting equivalent to the physical. In this way, information need not be limited to the single site or building, but overall performance of the precinct could be equally determined and assessed.



Lightfoots Furnace

ALF-00001	Fire / smoke damper	Maintenance
ALF-00002	Emergency UPS Panelboards	In Use
ALF-00003	VAV Box	In Use
ALF-00004	Air Handler	In Use
ALF-00005	Air Handler	In Use
ALF-00006		In Use

Figure 6.36: Autodesk Building Ops® makes it possible to manage BIM asset data during the building operational life cycle
Image source: http://architosh.com/wp-content/uploads/2015/07/autodesk_building_ops2.jpg [Viewed 10 June 2016]

The main goal of digitisation of building information is to make this information more accessible and prevent discrepancy or error. However, the current state of affairs requires an organisational framework that includes training of building end users and facilities managers. It is also currently observed that BIM adoption is falling behind its potential (Ackamete et al., 2010:151) and that there is some resistance to this due to issues of overcoming technology adoption inertia and the perception this will result in additive administrative tasks. However, growth in policy and greater industrial understanding is currently in effect. In a 2004 Construction User's Round Table (CURT)[66] report, for example, the importance of construction operations building information exchange (COBie) was highlighted by stating that digital information created by the collaborative team flows throughout the life cycle of the building project, initiating with the building information model that has virtually constructed the building before construction commences, and supporting its operation throughout its life. Additionally international efforts such as BuildingSMART (2011)[67] are under way to create information exchange standards for design, construction and operations to facilitate creation, exchange and use of this information (Anderson et al., 2012:689). This policy should not be construed as the end of one professional service (architecture) in favour of the next, as this would be contrary to the assertion contained within this thesis that the building solution is the result of an ongoing integrated systems-design process. It is for this reason that this proposed methodology recognises the role of the design team as knowledge-building custodian (see section 6.1.4.5), by instilling an active role in building performance evaluation and knowledge sharing in the professional service offered. However, the researcher observes that this evolved role is not catered for in current definitions of professional services and the fees that are thereby agreed to, which represents an obstacle to adoption since it is the primary concern of any design team and composite organisation to remain profitable enterprises. Hence there is a requirement for continued policy progress in support of the continued role of design teams as well as BIM implementation framework.

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[66] The Construction Users Roundtable (CURT) was founded in the fall of 2000 by construction and engineering executives representing major international corporations. CURT provides a national and international forum for the exchange of information, views, practices and policies of construction users from an array of industries. http://www.curt.org/ [Viewed 1 May 2016].

[67] BuildingSMART: An international authority and policy generator driving transformation of the built asset economy through creation and adoption of open, international standards. http://buildingsmart.org/ [Viewed 1 May 2016].

The building solution's role as an informational database and documentation is therefore of benefit to project life cycle in the following respects (Becerik-Gerber et al., 2011:444):

- Locating building components
- Facilitating real-time data access
- Visualisation and marketing
- Checking maintainability
- Creating and updating digital assets
- Space management
- Planning feasibility studies
- Emergency management
- Energy monitoring and control
- Personnel training and development
- Implications and challenges identification.

These aspects make it possible for the building, in its role as a documented information database, to facilitate the next step in the process: 'processing of aspects for change'. Through previous evaluation and knowledge cross-levelling of performance success measurements, those aspects identified as being detrimental to performance are identified. 'Processing aspects for change' is therefore concerned with isolating those aspects for the purpose of adjusting and adapting the building solution in reaction. However, it is important that this processing of aspects for change not be limited to retrospective interrogation. Aspects for change are represented in the specific reference to performance success criteria, and as such represent broader concepts of building usability and experience, conditions for the justification of concept, and continued adherence to sustainable development criteria.

While it is now possible to address those aspects which are already contributing to unsatisfactory performance, the researcher proposes a second round of change mode and effect analysis as a predictive measure towards components that are not yet detrimental to performance but now carry with them the risk of redundancy or obsolescence. In this way, a predictive process is incorporated with taking retrospective action. This minimises duplication of work and increases efficiency associated with continuous future assessment by specifically targeting and monitoring aspects and components that bear risk of redundancy. This investigation into the need for change is thus linked to building flexibility processes (see section 6.1.6.2) which are a contributor to the building solution's sustainability characteristics. Thus by assessing aspects and components for change, the controllers for change need to be identified. These controllers or actors for change represent the physical intervention required that will impact the initial building solution deployment. An example of this might be systems information indicating that declined occupancy comfort is affecting productivity in an area of the building due to insufficient ventilation rates – initially calculated and designed for a reduced population in the area. Hence mechanical systems intervention is required. Another scenario could be that energy consumption in a retail centre is lower in an area of the building, but due to reduced user occupancy levels since trade is not sufficiently active in this section. An analysis could point to an incorrect tenant mix which would lead to re-organisation of tenant layouts to stimulate consumer interest. For a commercial project, it could be determined that building user interaction is restricted through analysis of occupancy flow patterns, as a result of social spaces being inhibited by lack of wireless data connectivity through high contention ratios. On a knowledge cross-levelling basis, the occupancy rates of a building could be detrimentally affected by the construction of a building in the immediate context that either cannibalises tenants from the precinct, or creates disturbance to the exterior flow of traffic, thereby detrimentally affecting operations. In this case the aspects processed for change might not be limited to the site, but would rather require broader-reaching precinct-level intervention. Hoes et al. (2009:7) state that robustness in design has limitations since, without applying extensive overactive systems, there is no general design concept that can adequately minimise the effect of different user behaviour. However, improved modelling of user behaviour in numerical simulation does contribute positively towards building performance. The premise for each scenario is, however, the same: knowledge is power. If our buildings are to adequately adapt to evolving contextual and user requirements, planning for change is key. The move towards transferring knowledge through increasing databases will inevitably contribute to improving the situation.

Following identification of controllers for change, this information is then made actionable by re-introducing it into the implementation stage. The step that has been identified for this role is positioned intentionally between 'development of a prototype' and 'ordering'. This is due to the fact that this step is concerned with modification, and not a reset on the process altogether. The controller for change is thus incorporated into the step denoted as 'compare'. Where this differs from 'interpret', which shares the same position in process hierarchy, is in the fact that the change controller and initial building solution offering have a basis for comparison according to success criteria.

Comparing new and proposed aspects for change equips the project with the means to gauge the scale of impact and validate the proposal. This does not exclude ’interpretation’ from the process, however, since the change controller might be sufficiently affected beyond the scope of isolated components, thereby affecting the original design intent of the project prototype. Not every building can therefore be adapted to changing conditions if the need is evident. An office block, for example, will find it difficult to adapt to a disappearance of a market for commercial leasing in the area. This would require a larger investigation into regional requirements, potentially resulting in either deconstruction, or complete building redesign for an alternative brief.

This step is yet another reason why it is imperative that change control is maintained with the systems-design methodology, of which the design team is custodian. A holistic understanding of success and systems criteria relative to sustainable development criteria is therefore what is required in the long term.

This methodology of approach makes it apparent that that the integration of sustainable development criteria is not localised to any particular stage or step, but instead has a part to play throughout the project’s life cycle process. While it may not be possible to address each specific criterion at every step, the methodology requires the user to make a conscious acknowledgement that sufficient information has been gathered and interpreted, in order to fulfil ‘achievement’ of that step in order to progress. The role of the integrated systems-design matrix is thus to ensure that the designer remains cognisant of the criteria that define a sustainable solution which will ultimately be incorporated into later assessment in order to measure success. Not addressing all criteria risks undermining future assessment due to ‘lightness’ of information, therefore compromising valid and defensible achievement of satisfactory performance.

6.2.3.5. Summary of methodology

The proposed integrated systems-design methodology is presented in this thesis to achieve the following:

- A replicable process for design stakeholders for use in multiple projects;
- A means to respond to and integrate proposed sustainable development criteria as applicable to the built environment in the Information Age;
- Recognition of the design process as a systems process;
- A staged process, incorporating project inception, initiation, implementation, ramp-up and integration;

- Detailing of steps required in execution of stage requirements, achievement of which allows for informed and responsible progression;
- Cross-referencing of project-specific success criteria and constraints with criteria for sustainable development;
- Recognition of internalised information feedback loops within the process;
- Recognition that design is an iterative process subject to options analysis;
- Integration of subjective and objective feedback and research into project concept formulation;
- Iterative testing of concepts prior to prototype development;
- Recognition that the project does not end at implementation of the selected alternative;
- A means to outline and ensure design stakeholder involvement during project implementation and operations;
- A means to recognise the importance of user-product interactions in design development and measurement of performance;
- A sufficient framework to adequately incorporate the opportunities offered by BIM during design development and operations for purposes of meeting knowledge-based development requirements;
- Project post-implementation requiring evaluation and monitoring to inform change requirements (adaptability);
- Predictive analysis of aspects of the design at risk of redundancy or change in order to introduce flexibility into the proposed solution, design robustness not being sufficient to cater to changing need;
- The recognition that building BIM as building information assets is of significant importance to building operations and reiterative design for flexibility;
- The digital capturing of building information asset data which allows for the possibility of broader scale planning and integration of knowledge into smart-city development; and
- The knowledge criteria of sustainable development are as much a factor in process as it is in product.

Based on, but not limited to, the above conditions and reasons, the proposed integrated systems-design methodology provides design stakeholders in AEC the ability to address sustainability criteria with specificity, removing vagueness of approach. By attaching sustainable criteria analysis to the step-by-step framework as proposed by this methodology, the quantifiable approach that has become a readily accepted feature of green building design tools, for example, is thus comfortably assimilated into a similar linear approach, thereby removing perceived obstacles to industry acceptance and adoption. Furthermore, the methodology is geared towards a systems process that recognises the path from project inception to product is not a finite one. The pursuit is therefore both of a product, but also a building solution representative of a systems process. This therefore integrates itself with the design process in a closed system resulting in the establishment of clear information feedback loops which serve to re-inform steps for future adaptability and re-evaluation to establish project longevity and flexibility. By building into the methodology the capacity to self-regulate, assess and adapt to changing contextual as well as user-based requirements, while ensuring consideration of sustainable development criteria, the building solution is therefore equipped to serve its role as an enabler of equal opportunity and value to future generations. In pursuit of this, the design team concerns itself with the creation of knowledge buildings as systems-based solutions, acting as custodians of the information over the project life cycle to actively pursue and facilitate achievement of satisfactory and sustainable performance.

6.2.4. Applications and future potential

At the time of writing this thesis, we find ourselves in the age of technologies such as Google Glass and Microsoft HoloLense where it is proposed to mainstream consumer society that we are able to function better than ever in spite of our physical environments rather than because of them (Macagnano, 2015:7). These devices represent a segment of the information and technology sector that recognises the importance of integration and overlay of information on our daily lives as an enabler of progress and a facilitator of a new age of social interaction. To ignore this, places architecture and the built environment in the ‘background’, and with it a missed opportunity to create physical environments rich in digital immersion (Macagnano, 2015:7).

One of the greatest challenges to architects and built-environment designers is the manner with which new projects are undertaken (Macagnano, 2015:8). New projects are bound by physical limitation. The mandate to design and build requires confinement to a singular site due to legalities of proprietorship, a perceived unimportance of larger planning frameworks, and budgetary restrictions. In an Information Age, where knowledge is passed freely without limitation irrespective of locality or other constraints of the physical dimension, buildings remain relics to a fixed point in time the minute the planning process begins to exclude the greater context.

The fact of the matter is that no client should be expected to pay for the design of a greater urban framework within which the building resides if there is to be no economic benefit, guarantee of successful implementation or buy-in from the surrounding sites and buildings. This mandate cannot be taken singularly, but instead a greater system of inter-site collaboration is required.

Architecture in its primary sense is concerned with space, statics, resistance of materials, equilibrium and gravity. Architects are trained to work with the mass and energy of a building and its structure. However, in terms of information, the researcher reaffirms the opinion that architecture consistently remains behind the present development. Architects need to recognise that the digital footprint is as integral to successful implementation and operation as the physical footprint.

Figure 6.37: The architect's scope, and the building's influence rarely escape the confines of the site boundary
Image source: http://thumbs.dreamstime.com/x/cityscape-model-3d-red-skyscraper-10876651.jpg [Viewed 10 June 2016]

Currently the building and urban design process is benefited by BIM, the means of creating 3D virtual representation of buildings prior to actual construction. BIM runs deeper than 3D representation however, as it also provides a digital representation of a building in an accessible database of quantifiable data. This can be in the form of construction area, materiality quantities, spatial volumes, energy efficiency among others. What is effectively created is a digital avatar of a building, yet following the planning stages this virtual representation and all the information it contains is consigned to the hard drives of the design practitioners. Globally the construction industry is taking firm steps to recognise the importance of this role, as can be currently observed in Dubai whereby its municipality has legislated that all new large-scale buildings must be designed using BIM.[68] This new chapter in design, and the possible beginning of a new global trend, opens up some interesting possibilities.

Intelligent buildings represent an era of architecture whereby built environments are provided with the means to self-regulate, monitor and adapt (to limited degree). An intelligent building, with a BMS as its brain, is able to evaluate how different internal spaces are being utilised and control the artificial intervention to supplement or adapt to conditions. This can be in the form of lighting and HVAC control, the positioning of external shading devices, and CO_2 regulation, to name a few. Intelligent buildings, however, are limited to regulating operations for the function for which the building was originally designed. An intelligent building does not guarantee a successful or sustainable building, as building performance is currently inadequate to properly integrate concepts of economics, society, environment, knowledge and user experience.

Smart Cities are currently being realised in varying manners in municipalities around the world. These cities will make use of ubiquitous communication networks, highly distributed wireless sensor technology and intelligent management systems in order to solve challenges and create new services (Clarke, 2013:1). Smart Cities provide an opportunity for buildings, city-wide users and infrastructure to participate in a dialogue for constant growth and renewal. However, the researcher proposes that since buildings are implemented as ‘islands’ in the greater context, by being limited to their singular sites, this dialogue often excludes the building and the architect. At present, when municipal approval is sought to initiate construction, the potential for inner-city participation is never interrogated. Instead, compliance to outdated zoning restrictions is applied, providing a static evaluation of context at a past point in time (sometimes decades old) within which development is required to occur. This not conducive to sustainable environments, but instead slows the process for growth and development which at their core require agile and flexible approaches to the evolving needs of their populace. The municipal bodies will need to develop and provide access to usable information as fast as the Smart City requires them to, not only to inform appropriate

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[68] As featured in online news article ‘Dubai to make BIM software mandatory for major projects’, source: http://www.arabianindustry.com/construction/features/2014/may/25/a-model-approach-4708613/#.VbOyQ_mqqkq [Viewed 10 June 2016].

design, but to assess and evaluate it as well. In order to do this, however, on-the-ground and up-to-date information is required.

Buildings need to ‘plug in’ to the digital context in order to feed the information databases that describe our urban contexts to the benefit of institutions and design professionals. For this to happen, digital oversight is required. The future sustainable environment requires recognition that the physical world is complemented by the digital world. In lieu of this, the role of municipalities should therefore evolve from that of a fixed-point approval of design, to that of constant oversight to include the digital landscape as a means to interrogate and better our physical environments (Macagnano, 2015:9).

Imagine, therefore, a digital city built of BIM-based avatars (provided by the architect or engineer) that are able to communicate in real time with a smart-city central management system (municipal governing body) creating the means to make informed real-world decisions. Through this communication quantifiable data such as building occupancy levels, user comfort and happiness, economic activity, traffic and pedestrian intensity, electrical consumption, could all be received and interpreted. Neighbourhoods could be identified to be dwindling in economic prosperity, for example, prompting a broader scale recognition in demand for amenities of a certain nature that could cater to the particular social requirements of the area. Buildings in an area that are deemed to be decreasing in popularity and population can be re-evaluated in their function and re-use suggested. This would be of benefit to building owners, users, as well as the continued involvement of the construction industry. This actionable data could also even be extended to design practitioners currently designing buildings in the area – on the assumption that the project is registered as being developed with BIM data provided to the central oversight system during development – so that real-time adjustments can be made prior to finalising the design. In the realm of software and simulations where it is possible to artificially reconcile contributing factors to change within one ecosystem of information availability, developers have for many years recognised that the most effective means for sustaining effective city-scale functionality and operations is to use all available data from macro and micro scales to affect decision making (Macagnano, 2015:10). This same ideology logically applies to an era of information availability that knowledge societies are currently experiencing, yet what is required is overall legislative support and on-the-ground implementation strategies to make for contributing information feedback loops.

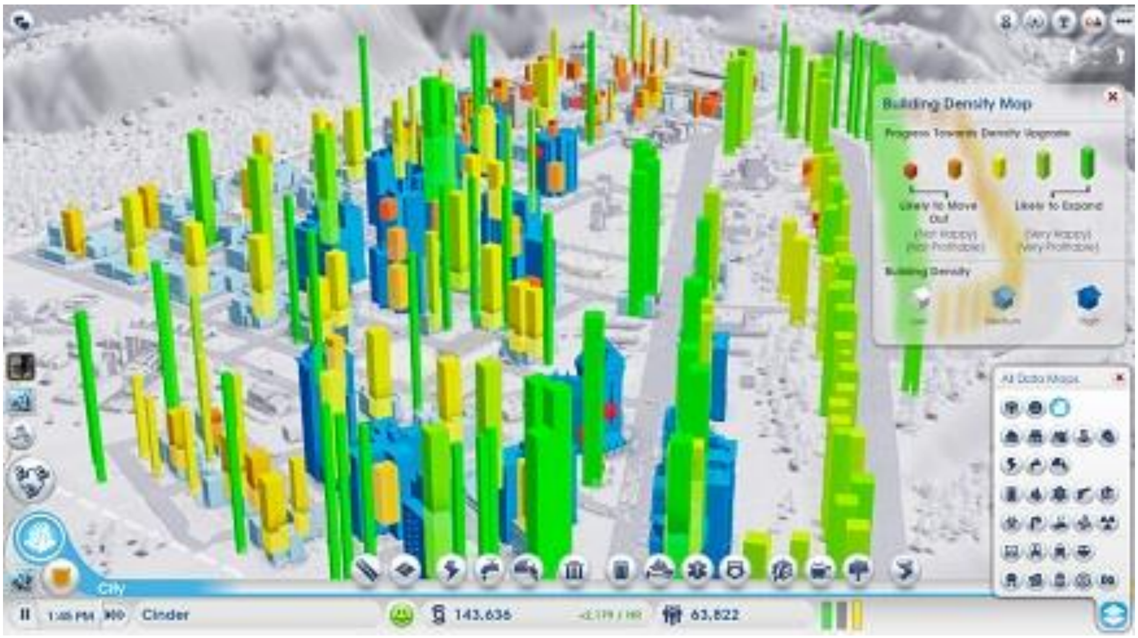

Figure 6.38: **The city-management simulator 'SimCity 5'**
It provides the ability to evaluate and adapt planning to the evolving dynamics of a city and its occupants. Population happiness is related to provision of infrastructure, services and amenities. Source: http://www.primagames.com/games/simcity/strategy/simcity-road-happiness [Viewed 10 June 2016]

The future of sustainable built environments is therefore not achieved through isolation of approach. It requires an integrated systems approach. This approach is therefore inclusive of the architect, the client, the single site, the greater urban and environmental context and the urban overseer (municipality). It is required to recognise that the job is not done when construction is complete, but rather that a building remains as a contributor to the greater sustainable context. Inclusion of these stakeholders therefore importantly requires the framework for inclusion of a feedback loop and integration of ICT and processes that allow for real-time simulation and evaluation of the physical world in a digital realm (Macagnano: 2015:10). For the first time in our existence, this technology is available to make this a reality. All that is required is the impetus and know-how to implement it. Sustainable development in the Information Age is therefore possible to achieve in recognition of the needs and opportunities that our knowledge societies present.

6.2.5. A theoretical application of the integrated systems-design methodology

The supporting case study analysis for this methodology resides in the realm of the theoretical. In order to place the methodology into a context of potential application, however, it is possible to make reference to existing architectural processes that support certain links and process paths within the methodology framework. These include aspects such as site and context analysis, typological design and free-form giving, and BIM for integration of information into design options. This section seeks to expand upon this, while attempting to minimise speculative discourse by aligning parts of the methodology to current technologies that are already pervasive in traditional architectural practice.

In this theoretical application (hypothetical case study) of the proposed integrated systems-design methodology, the researcher will illustrate how this can be practically implemented. This theoretical application is intended to be high-level and hypothetical. The reasons for this, and assumptions for the case study are as follows:

a) The methodology assumes that the design professional (architect) will be afforded the opportunity to remain integral to a building solution during and within its operational life cycle. This is currently not a prevalent condition in the industry, nor is it specifically covered in all global professional fee structures and ‘identification of work’.

b) By virtue of maintaining an active role in operational life cycles, reporting on an existing project would only be possible following interpretation and analysis of operations-related data for a period of time to adequately measure user experience.

c) Tools for measurement and assessment of sustainable development criteria are abundant, but are required to be used in a multi-dimensional approach in order to adequately cover all criteria based on weighting. These tools are in constant flux, with new tools being developed constantly. This hypothetical case study does not delve into the detailed use of each assessment tool (since project details are high level) and therefore would not simulate the success or failure of any particular chosen measurement method(s). Instead it assumes success or failure, and recommends action accordingly.

d) Methods for change mode and effect analysis (CMEA) are referred to in this thesis, but processes of execution are not strictly defined. This hypothetical case study does not delve into the detail of use (since project details are high level), and therefore would not simulate the success or failure of CMEA. It would instead assume success or failure and recommend action accordingly.

e) The success of this proposed methodology relies on the premise that cross-levelling of knowledge is to occur. This requires an ‘open source’ philosophy of approach in the industry whereby lessons learnt are documented and shared for use by stakeholders both to the project as well as external to it, while operating within the same context.

f) This proposed methodology assumes that all contributing design professionals are adequately proficient with software and information-based technology to facilitate collaborative working and knowledge management.

g) The actual period of implementation or execution of this methodology may run for many years which, since this methodology is a new proposal, does not afford the researcher the opportunity to retrospectively report on a real-world project. This will instead form the basis for future potential research.

It is furthermore assumed that this hypothetical project occurs within the development context of South Africa, according to which the Identification of Work of Architectural Professionals as governed by the South African Council for the Architectural Profession (SACAP), and defined by the Architectural Profession Act, No. 44 of 2000, board notice 121 of 2015.[69] This example makes reference to these work stages during its progression as represented in Figure 6.39 below, in order to familiarise the reader with their integration into an example of standard professional practice. These work stages are summarised as follows:

- Stage 1: Inception – Receive, appraise, and report on the clients requirements
- Stage 2: Concept and viability (concept design) – Prepare an initial design
- Stage 3: Design development
- Stage 4: Documentation and procurement
    - 4.1 Prepare documentation for the local authority submission
    - 4.2 Complete construction documentation and proceed to call for tenders
- Stage 5: Construction
- Stage 6: Close-out.

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[69] ‘Board notice 121 of 2015’. http://c.ymcdn.com/sites/www.sacapsa.com/resource/collection/7E4759E1-870D-4483-A3F9-8020ADDFFD2A/Board_Notice_121_of_2015.Scanned_version.pdf [Viewed on 2016-09-15]

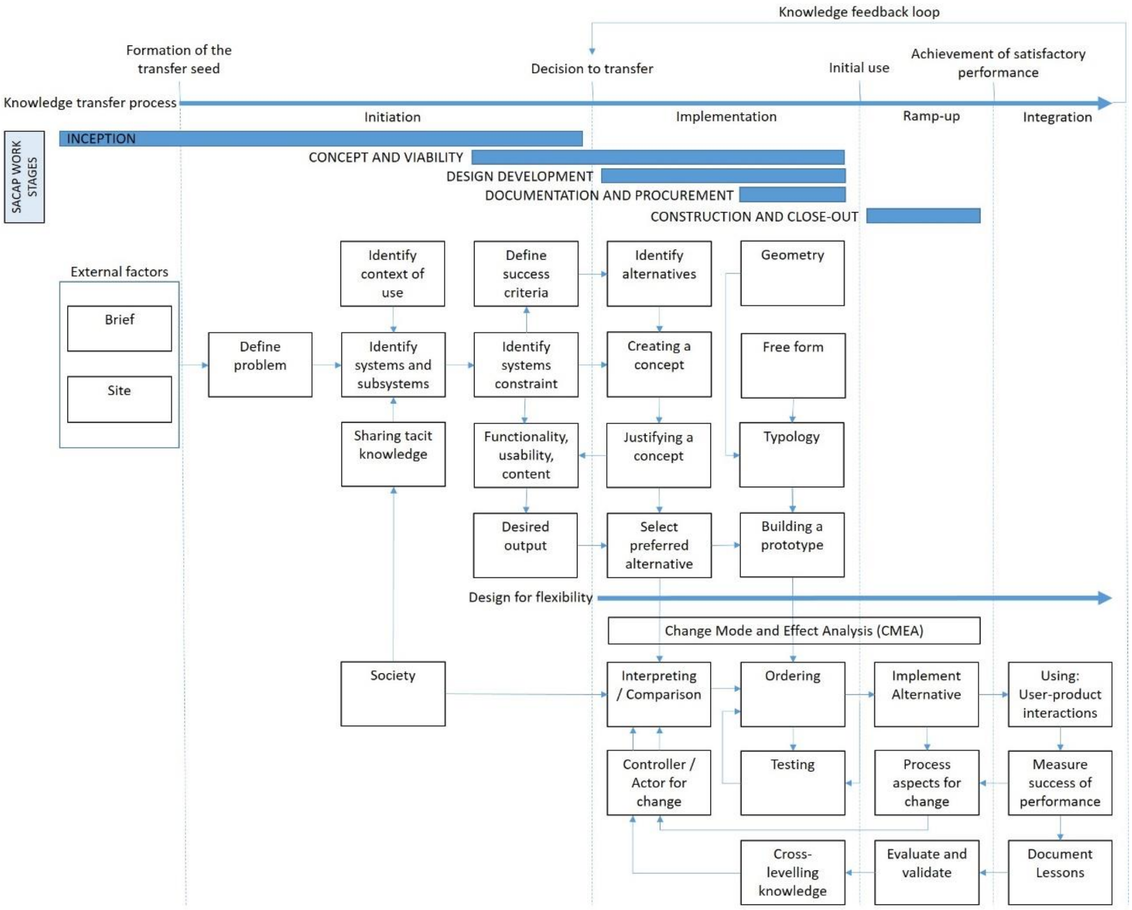

Figure 6.39: An overlay of SACAP work stages on the integrated systems-design stages of project execution.

While the SACAP work stages are referred to, the researcher notes that other global work stages, such as those defined by RIBA,[70] make specific inclusion of building operations in the works stage process, which SACAP does not.

The theoretical scenario is defined as follows:

Client A has approached the architect with the intention of designing a new building within the context of a metropolitan city. In this scenario, the city is in the process of increasing its infrastructural offering to offer high quality data services to the area, although not all areas are sufficiently covered at this stage. The architect is part of a

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[70] The Royal Institute of Architects (RIBA) refers to eight stages in the plan of work, namely: 0) strategic definition, 1) preparation and brief, 2) concept design, 3) developed design, 4) technical design, 5) construction, 6) handover and close out, and 7) in use. https://www.architecture.com/files/ribaprofessionalservices/practice/ribaplanofwork2013template.pdf [Viewed 2016-09-08].

medium-sized company that has access to, and capabilities in BIM, and is proficient in achieving work of a standard of BIM Level of Detail (LOD) 3 (UK), while being contracted at this stage to undertake work to a LOD 2 (UK). Client A is willing to appoint the architect for a full scope of professional services, without work 'on risk'. This enables the architect to engage a full project team from the onset, representing responsibilities in the design of the concept, design development and project documentation, contract administration and site supervision, and BIM Execution Plan management. In addition, Client A has agreed to appoint engineering services (structural, civil, and MEPF), who are of a complementary level of technical proficiency and capable of operating on a cloud-based collaboration platform for shared execution and real-time coordination of work. In addition, full geotechnical and topographical surveys of the site are agreed to be undertaken before design begins. Inclusion of facilities management consultants is not agreed to at this stage, but future consultation is intended to occur during later stages of execution of work once the project costing and feasibility study is concluded. Budget allowance has been preliminarily made for professional fees for facilities management, interior design, and landscape architecture, taking into account project cost escalations during the time period allowed for design development, project financing and regulatory approvals.

It is furthermore noted by the researcher that the proposed table-format methodology, as indicated in Table 6.9, is not intended to serve as a database of decisions-taken, but instead as a roadmap of the investigations and steps required to achieve the goal of sustainable implementation and integration of a holistic building solution consisting of processes, systems, components, and users. This record of information and design decisions will be at the discretion of the design team to maintain, and may be undertaken using processes such as collaborative BIM, for example.

This theoretical case study is intended to provide a context of application to the proposed methodology of this thesis. However, this has limitations since the scientific validation of this methodology will benefit from future research, such as case studies in the context of real world application, as well as participant survey. At present, the conditions do not exist for this additional research to be conducted, due to factors previously mentioned in this section; therefore, the case study is undertaken in the realm of the theoretical.

6.2.5.1. Inception Stage (1):

Inception		External factors	Brief
			Site / Place

Figure 6.40: Stage 1 excerpt from the integrated systems-design methodology.

Client A offers the following details pertaining to the site, its land use, and development potential:

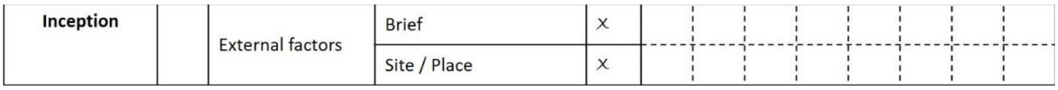
- The stand is 8,000 square metres in size, is assigned by the municipality with a maximum Floor Area Ratio (FAR) of 5,5 allowing for a potential development of 44,000 square metres (excluding parking areas, service spaces, vertical penetrations, and mechanical rooms) over a maximum of 10 storeys (excluding basement).
- The stand, as a brownfield site, has existing three-storey structures with a single storey basement which cannot accommodate the project brief, requiring integration or demolition.
- The site is accessible on two sides via adjacent roadways with a public transport node in close proximity.
- The site has electrical and water supply, and municipal bulk contributions are paid for.
- The site has no registered servitudes over its extents.
- The site has a topographical slope of 4 metres from the Northern property line to the southern edge.

Client A offers the following details of the project brief, describing the development intentions for the development:

- A commercial A-grade office space offering.
- A design for a single tenant with a view to a 10-year lease. This building must therefore provide for corporate amenities.
- Principles of green building design to be applied, with a view to obtain an internationally accredited rating.
- On-site parking to be provided on a commercial ratio of bays to office area of 5:100.
- An iconic and aesthetically pleasing design that provides market value for the corporate tenant.

- A design that facilitates future business flexibility in the event that the lease expires and this building must be reconfigured to allow for multiple tenants of varying sizes.

The architect is thus in a position to investigate these parameters towards definition of the design problem, and by doing so establish the relative weighting of affected sustainable development criteria. The architect does not have influence over matters of site selection, but will contribute to determination of project feasibility. The investigation and assimilation of information pertaining to external factors is thus addressed to a level sufficient to progress.

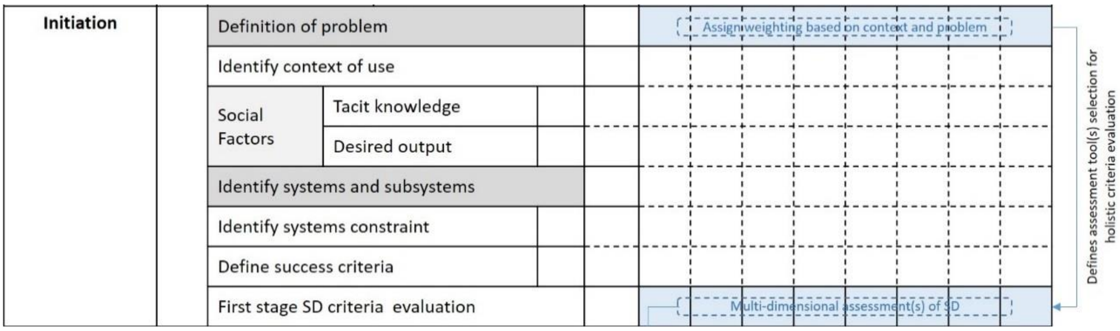


Inception		External factors	Brief	x
			Site / Place	x

Figure 6.41: Stage 1 ‘completed’ by methodology user.

6.2.5.2. Initiation Stage (2):

The initiation stage concerns itself with progressive analysis and information assimilation.



Initiation		Definition of problem		Assign weighting based on context and problem
		Identify context of use		
		Social Factors	Tacit knowledge	
			Desired output	
		Identify systems and subsystems		
		Identify systems constraint		
		Define success criteria		
		First stage SD criteria evaluation		Multi-dimensional assessment(s) of SD

Figure 6.42: Stage 2 excerpt from the integrated systems-design methodology.

The architect defines the problem accordingly:

The creation of a sustainable building solution, highly adaptive to market conditions to ensure long-term project feasibility and sustained usefulness. This building, comprising multiple integrated systems, will have a contributory relationship to its immediate physical context, state of the environment, place, technology, infrastructure (where appropriate), and knowledge transfer. Aspects of the work environment will be evaluated to understand the implication of cyber activity, and validate the provision of formalised spaces on the basis of cultivating digital connection to remote stakeholders.

This could result in a fluctuation of required space for work and recreation-related activities, to which the building must adapt in the interests of continued economic feasibility.

Definition of the problem thus proceeds by interpretation of contextual circumstances towards defining the project systems and subsystems, as indicated in Figure 6.43 below (derived from the design framework of Figure 6.29).

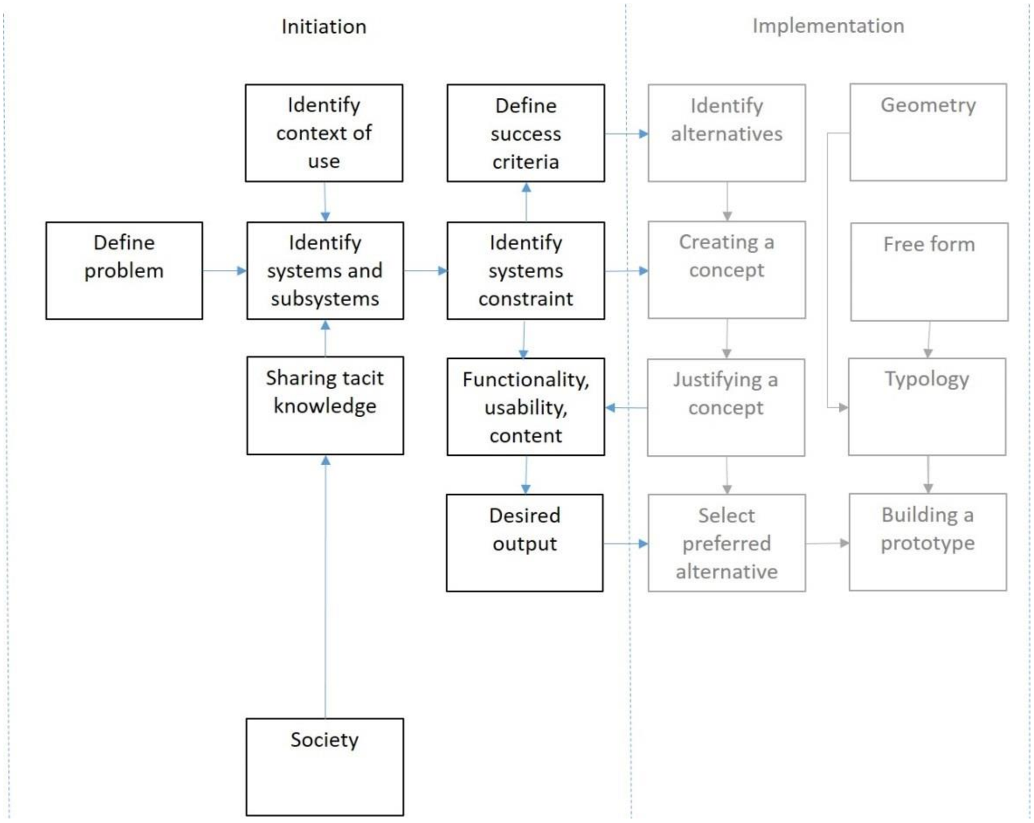


Figure 6.43: Inception and implementation stages. An excerpt from the integrated systems-design framework.

The architect is thus in a position to make use of existing assessment tools, as well as possible future GIS-linked municipal databases that draw real-time data from the city in order to obtain a scientifically determined assessment of applicable sustainability criteria weightings. For the purposes of this theoretical assessment, the values have been assumed in Table 6.1 below (the nature of each criterion may be referred to in Chapter 5, section 5.2.2):

Table 6.10: Example of SD Criteria weighting allocations.

Sustainable Development criteria schedule of weighting (values totalling 100%)							
Core criteria (must have weighting)				Ancillary criteria			
Environment	Society	Knowledge	Economy	Policy	Culture	Space and technology	Physical infrastructure
20	10	15	15	5	10	15	10

It should be noted that while the table has been used for the purposes of maintaining similarity to the proposed methodology as per Table 6.9 of this thesis, additional graphical representations can describe this analysis, for example, 'spider graph' format, resultant from the assessment method(s) used.

This weighting is used by the architect as an informed basis for holistic decision-making, in order to adequately respond to criteria of importance at this concept stage, thereby assisting in a responsible and focused approach.

In 'identifying the context of use', the architect is required to address the broader circumstances affecting the development. Some of these would have been identified in the interrogation of the site; however the implications of the macro-scale context must be taken into consideration. In this instance, and assimilating the previous weighting of sustainability criteria, this data gathering will affect aspects such as, but not limited to:

- Physicality – surrounding buildings, effects of direct solar incidence and shading, wind simulation, weather studies, storm water flow.
- Population demographics – levels of economic activity, levels of education and training, general social wellbeing and quality of life, trends of habitation, duration of sustained presence and movement patterns.
- Ecology – balance of the ecosystem under direct influence, shortfalls in provision or preservation of available resources, the need for generation of new resources and what role this project could have, ecological footprint of the macro and micro-level contexts.

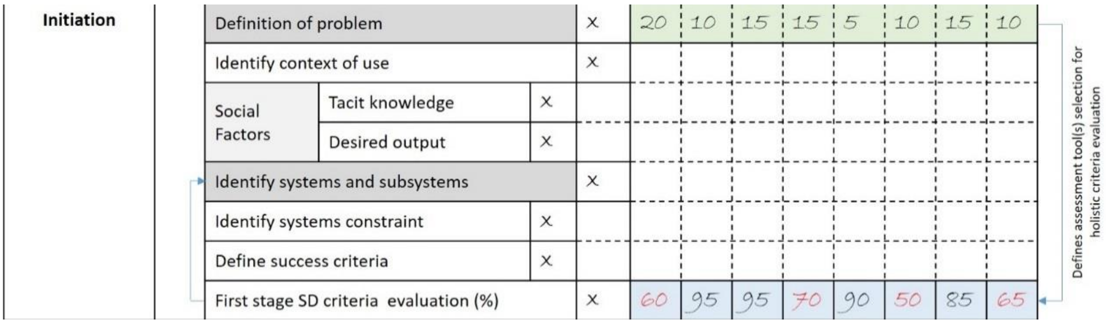
In the next step, the architect addresses the 'social factors' of influence. This is affected by the weighted importance of society, knowledge, policy, and cultural criteria. On the basis of 'tacit knowledge' as a sub-component of 'social factors' in this theoretical case, the question is asked: will this development leverage off of available skills and as a result contribute to economic well-being, or will it attract newer talent to fill the skills gap, and where will they stay? This information is furthermore complementary to the role of the smart city municipality which informs continued flexibility in regulatory zoning and infrastructural improvements for the area base on actionable intelligence. The 'desired output' is considered within this stage as providing a sound solution to contribute to the economic wellbeing of the client, the sustained feasibility of the building, as well as the sustained opportunity afforded to current and future city inhabitants that would seek to form a part of this project's eventual enterprise.

It is important to note that the characteristics of these 'social factors' have been devised in this methodology to incorporate changes to the social landscape and therefore this step is inclusive of the first instance of a repeating knowledge feedback loop attached to the project life cycle, prompting future re-interrogation and investigation.

The identification of systems and subsystems concerns itself with preparing design development for proactive inclusion, rather than reactive retrofit. This process will involve the larger project team to define all components and the working relationships between them required to address the design problem, the contextual circumstances, social factors, and knowledge factors applicable to the project. This therefore places the design team in a position of responsibility by stimulating holistic discourse and project parameters for intelligent building modelling. For example, fenestration of the building is not strategised for in isolation due to preferential pre-concept ideals, but done so on the basis of contextual appropriateness (climate), technological development of materials, budget, energy efficiency, space cooling and glare. The building operations manual is addressed on the basis of facilities management and staff training. Building wireless networking is intended to incorporate software to record user movement patterns through their smart devices, and zonal lighting layouts are calculated to complement natural daylighting levels for integration into a building information management system (BMS). Furthermore the building BMS is planned for integration into the larger urban digital infrastructure to actively report building usage statistics that relate to continued economic feasibility report and data infrastructural loads. By defining these examples of available systems at this stage, quantifiable information is introduced into the design process according to which the concept may be holistically developed. This quantifiable information is represented in the steps defined as 'systems constraint' and 'success criteria'. This has been devised accordingly in order to list the applicable opportunities and challenges, and establish those parameters which contribute directly to the success and failure of the yet-to-be-developed concept(s).

It is at this stage that the project now has defined parameters and a strategy for execution. This is a sufficient basis to begin testing whether the sustainable development criteria are being adequately addressed. Multi-dimensional assessment may thus occur on the same basis of preferential selection influencing the weighting of criteria as defined at the beginning of this stage. In this example, and based upon the assessment potential for sustainable development criteria, as described in Table 6.7, the collective application of assessment tools for the project are proposed to be inclusive of SBAT (environmental, social, economic), BEPAC (space and technology), DQI (knowledge, and culture), and SPeAR (policy, and infrastructure). It should be noted that these assessments are not necessarily aligned with, or suited to the actual project parameters, and that some development and interpretation of each assessment tool will be required.

These criteria are individually assessed and given a respective score as a percentage out of 100. It is at the discretion of the team to decide a minimum score deemed to represent a ‘pass’. For the purposes of this exercise, a hypothetical minimum score of 70% for each criterion is satisfactory (results of these assessments are hereby assumed for the purposes of theoretical simulation of the process). Deficiencies are thus identified, and then decided upon as being solvable in this current stage, thereby prompting a revision of systems and subsystems, or whether to be addressed at a later point if, for example, technology to achieve a particular result is not available at that time.



Initiation	Definition of problem			X	20	10	15	15	5	10	15	10
	Identify context of use			X								
	Social Factors	Tacit knowledge	X									
		Desired output	X									
	Identify systems and subsystems			X								
	Identify systems constraint		X									
	Define success criteria		X									
	First stage SD criteria evaluation (%)			X	60	95	95	70	90	50	85	65

Figure 6.44: Example of stage 2 as 'completed' by the methodology user.

In this scenario, it is determined that while not all criteria are suitably achieved, these are of sufficiently low risk to the project to warrant being addressed at later stages. These deficiencies can be achieved through additional research into possible technologies to assist in recovery of ecological value to the project (environmental criterion), improving internet infrastructure to the area (knowledge, and space and technology criteria), a better collaborative relationship with the municipality (policy criterion), and the introduction of pending amendments to regulatory frameworks to better integrate performance data of this project into a larger digital database (knowledge and policy criteria). Having addressed all steps, and assessed the suitability of decision-making to meet the success criteria through definition of requisite systems for design consideration, the implementation stage is entered into.

6.2.5.3. Implementation Stage (3):

The implementation stage concerns itself with developing concept and prototype proposals, forming the basis for technical development.

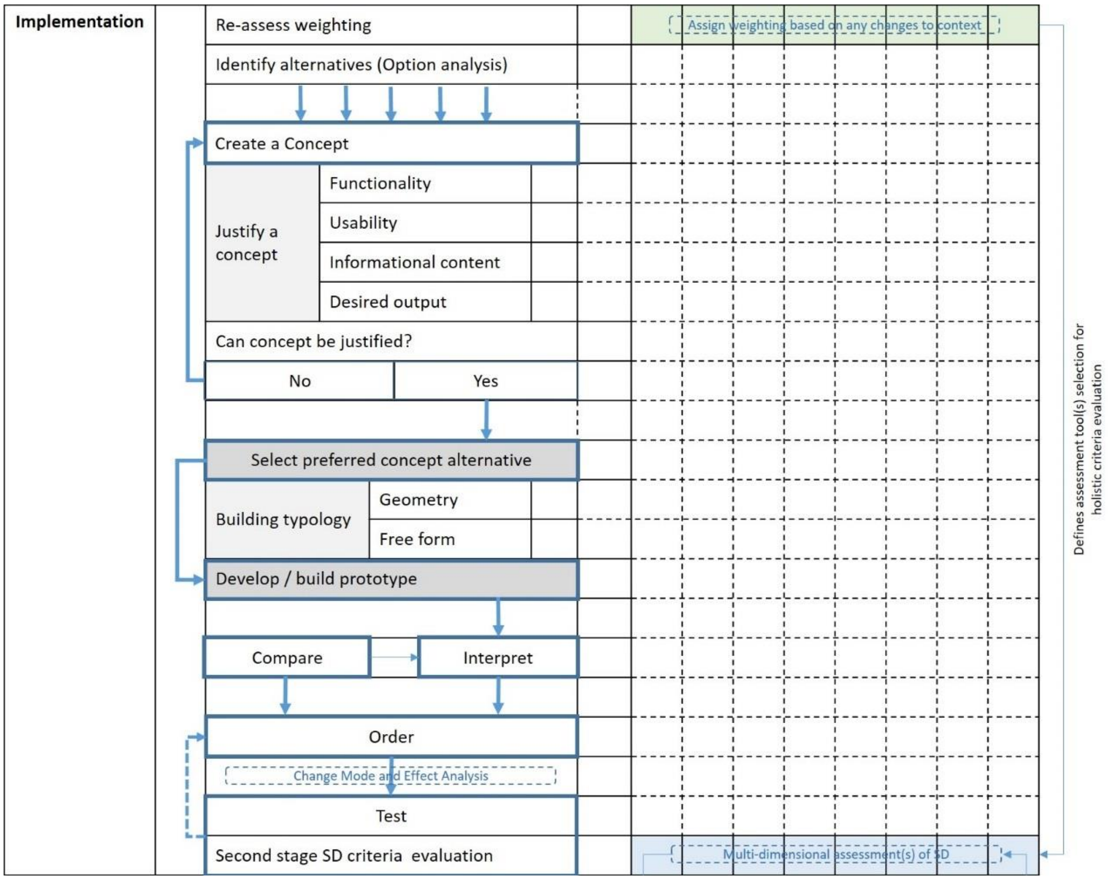
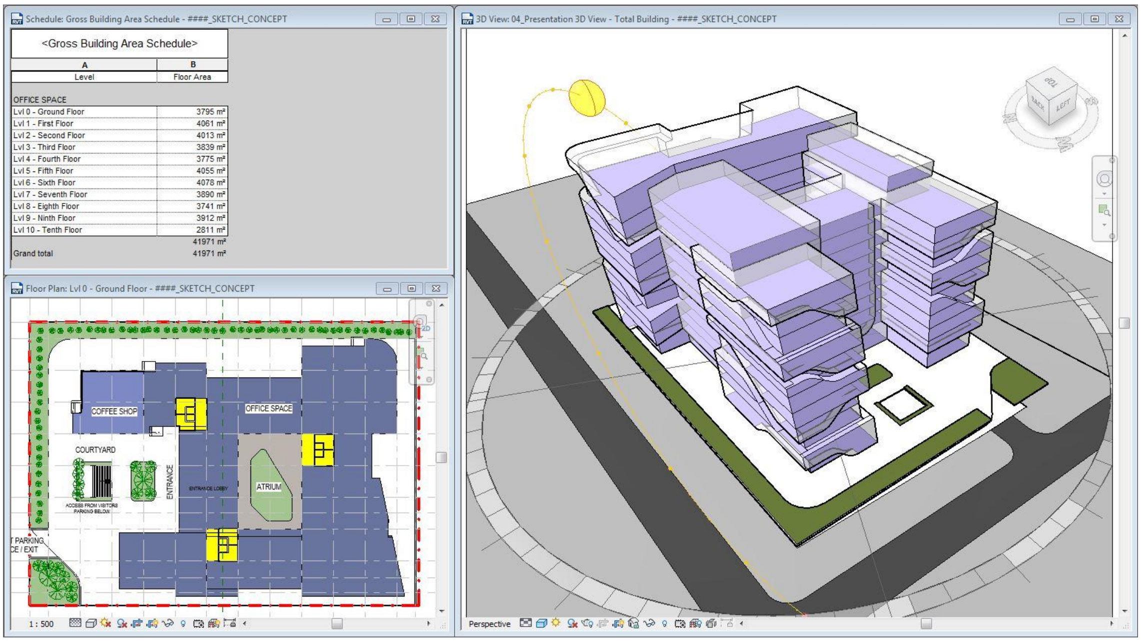


Figure 6.45: Stage 3 excerpt of integrated systems-design methodology.

At the beginning of this stage, the methodology invites the design team to re-assess and revise the allocated weightings to sustainable development criteria. This is on the basis of a prolonged period of time having potentially passed to reach this point which may have resulted in changes to contextual circumstances. Should weighting be revised, this would cyclically affect the previous stage results of the assessment of criteria, which would again require revisiting the project systems and subsystems. For the purposes of this theoretical example, it is assumed that no significant changes to the project context have occurred that neither affect the first round assessment, nor hinder progress.

Having identified the applicable systems and subsystems in response to the project brief, and an understanding of site constraints, the design team is now concerned with identifying alternatives as a form of high level option analysis. In the case of this example, this is proposed to be undertaken utilising spatial relationship and flow analysis diagrams to plot volumetric mass modelling upon a 3D representation of the stand. The concept design is developed using principles of, but not limited to, FAR capacity as a function of gross building area (which, if captured parametrically, allows for real-time assessment and even automated computational guidance); space diagrams and generic floor plate assemblage on the basis of internal office area sub-divisibility (parametrically linked to FSR constraints while measuring increases in building area and volume through building information modelling); the relationship of office spaces to structural column grids and vertical circulation and service cores (parametrically linked to structural design and real-time automated assessment of design loads); access to the stand and vehicular basement access to topographical conditions (deriving and assessing input from municipal traffic impact information); and building orientation and relationship to externally positioned existing buildings (parametric energy modelling linked to the base building volumetric model analysis and real-world simulation according to geographical coordinates).



<Gross Building Area Schedule>

A	B
Level	Floor Area
OFFICE SPACE	
Lvl 0 - Ground Floor	3795 m²
Lvl 1 - First Floor	4061 m²
Lvl 2 - Second Floor	4013 m²
Lvl 3 - Third Floor	3839 m²
Lvl 4 - Fourth Floor	3775 m²
Lvl 5 - Fifth Floor	4055 m²
Lvl 6 - Sixth Floor	4078 m²
Lvl 7 - Seventh Floor	3890 m²
Lvl 8 - Eighth Floor	3741 m²
Lvl 9 - Ninth Floor	3912 m²
Lvl 10 - Tenth Floor	2811 m²
	41971 m²
Grand total	41971 m²

Figure 6.46: Project concept design development through BIM-based parametric and computational design. Image copyrighted to, and courtesy of Bentel Associates International.

Once these concepts have been produced at sufficient detail to warrant interrogation, these are tested against specific criteria for 'concept justification'. This justification is intended to assist with concept proposal 'checks and balances'. As a team collective, which at this stage would preferably involve the input of facilities management, the 'concept justification' sub-categories (functionality, usability, informational content and desired output) are evaluated and critiqued on the merits of the design concept complying to the brief and building system intentions.

Firstly, in this example, an investigation of the sub-category of design, 'functionality', asks the following questions:

- Does the space meet optimised requirements for ease of office layout based on depth of space, possibilities of partitioning, and circulation routes?
- Are minimum requirements based on universal accessibility, provision of services, and amenities satisfied?
- Are office areas correctly grouped around vertical circulation cores to allow for multiple points of access from lobbies to allow for options of internal subdivision and ease of letting?
- Are security, public, and private zones correctly apportioned and efficiently located?
- Are services cores and reticulation routes sufficiently provided for?

Secondly, on the basis of 'usability', the design options are interrogated through the critique of issues, such as:

- Do spaces facilitate ease of navigation and way finding?
- Are networks designed for maximum plug and play?
- Is user experience recorded and monitored adequately?
- Is the design conducive to efficiency of operations?
- Is the design flexible enough to accommodate shifts in trends of user needs?

On the basis of 'informational content', the design concept operational strategy with the user at its centre is interrogated. This asks questions of the design such as: a) how user experience is recorded and relayed to operations and facilities management; b) how the concept interacts with users on a direct and pervasive level and whether the experience of the design is enhanced by doing so; and c) how the concept interacts with its context and utilises derived information to the benefit of operations. Finally, the concept is interrogated on the basis of achieving its 'desired output'. This step concerns itself with comparing the desired output, as previously formulated in addressing the social factors and identification of context of use, with success criteria and systems constraints, and revelations of user experience in the previous three steps. Should the concept seek adequate reconciliation between these factors, the desired output is deemed to be achievable. Successful resolution of these four steps will result in the concept achieving the status of being 'justified'. On the basis of multiple concept creations, this same justification process will be undertaken for each. Concluding this the design team is tasked with selecting the preferred alternative. As stated within Chapter 6 section 6.2.3 there is no prescribed method for achieving this. However, a scientific method based on SWOT analysis, for example, is an option to resolve the selection process.

Upon selection, the concept design then undergoes design development to refine it from an abstract proposal comprising quantifiable design interventions based upon success criteria and systems constraints, to a tangible building solution. This step caters to the creative preferences of design professionals to sculpt the form using scientific geometric addition and subtraction, of free form and intuitive design. It is important, however, that the constraints of the design problem not be side-lined in this process, but instead inform the creative process. For example, while the building typology might morph the concept into a highly glazed envelope of sweeping shapes and deep overhangs, the building orientation will dictate proportionate application of solar shading, or require high-performance of glazing material. This would also require that the building BMS be 'designed' in unison to control automated mechanisation of these shading devices, for example. This stage is therefore a measured exercise in creativity, subject to integrated simulation and analysis based on the pre-established criteria for success.

Figure 6.47: Project prototype developed to greater detail. Envelope, interior space spatial relationships and functionality refined. Image courtesy of, and copyrighted to Bentel Associates International.

The building typology now represents a final building form, as per the example in Figure 6.47 above. However, the building form is not yet representative of an integrated systems approach. This requires further technical development, which is represented in the design or building of a prototype. This prototype is a technical representation of building performance, and serves as the basis for construction documentation. The building prototype thus assimilates all architectural and engineering information, coordinates, collaborates and integrates into the building systems (relationships between components and processes). This is undertaken through the process of systems and process interpretation, and ordering.

In the case of this hypothetical office block, the design requirements to meet the needs of an internal accommodation schedule, relative to the services that are required to support those functions, is used as an example.

It is determined that four consecutive floors will be dedicated to a single department within the organisation. This department is responsible for its own reprographics, archiving, server rooms, and meeting facilities. In this department, a combination of compartmentalised office space and open plan space supportive of hot-desking is required. In addition, tacit knowledge transfer through social interaction is encouraged through break-away areas. The prototype design challenge is therefore to reconcile these functions, taking into consideration physical building services such as data infrastructure, wet services, HVAC, and lighting. This will also be required to accommodate fluctuating user presence in areas that are not formally occupied without causing loss of efficiency to all systems. Reprographics is determined to be a fixed 'station' and for this reason is planned for first as a constraint to the space design, particularly since size is largely modular, and targeted extraction of potentially toxic fumes requires a direct access to internalised vertical ducting. However, the design team must recognise, for example, that changing trends in business operations are moving towards a paperless environment, and the need for photocopying might soon become redundant, therefore causing disruption to future internal layouts. The decision is thus taken to position this station adjacent to the ablution core where continuous vertical shafts are a fixed requirement to the longevity of the building, into which the extract ducting can interface. This space is furthermore positioned upon access flooring to accommodate a change in function in the future. While the interpretation and ordering of systems and components are many, and it is not necessary to discuss them at length within this example, the equivalent process is applied.

In order to correctly assess and predict further risk to the prototype, it is advised at the proposed methodology introduces, at the stage of overall resolution to the 'ordering' process, the first instance of Change Mode and Effect Analysis. This analysis predicts risk of parts, components and sub-systems to prototype longevity and redundancy. This assists the design team to identify those aspects of the prototype that, while necessary at the stage of implementation, have a high probability of requiring replacement or removal. Following analysis of components and sub-systems, the overall design as an integrated system is tested. This is achieved through the technical development of the prototype through BIM, and tested through pre-emptive simulation. Successes and failures are noted and, where necessary, a return to the ordering process is required.

It is then at this stage that the second evaluation of sustainable development criteria is undertaken to accommodate adjustments to the criteria weighting and assess any changes to the context as well as user needs. This weighting will later be used as a basis to better facilitate the measurement of actual operational performance of the building solution.

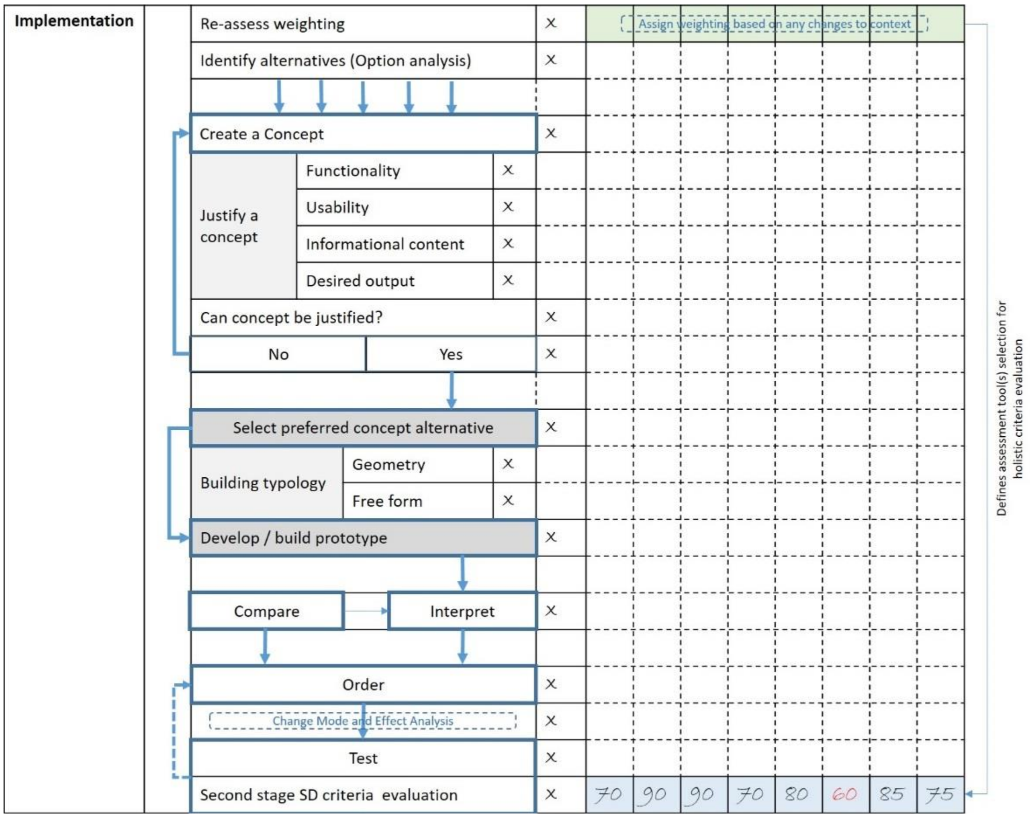


Figure 6.48: Example of stage 3 as 'completed' by methodology user.

In the case of this example, the project design team will decide if the same multi-dimensional tools for assessment will be utilised as within stage two. This is up to the discretion of the team based upon available assessment tool of the time. In order to forward the example, values have been assumed (since rigorous assessment requires a specific spatial and temporal context). It has been determined through the necessary steps of option analysis, risk management through change mode analysis, testing, and technical design development that all criteria of sustainable development are adequately adhered to. It was furthermore ascertained that policy to support the development is still somewhat underdeveloped, but this can be overcome through further municipal engagement and knowledge transfer.

This flexibility of approach, taking into consideration the preferences and capabilities of design teams by allowing for multiple and evolving evaluation processes, reinforces the principle that the methodology is an ‘open’ platform into which project-specific and preferred assessments may be integrated, allowing the user to maintain a holistic goal-orientated purpose.

6.2.5.4. Ramp up and Integration (4):

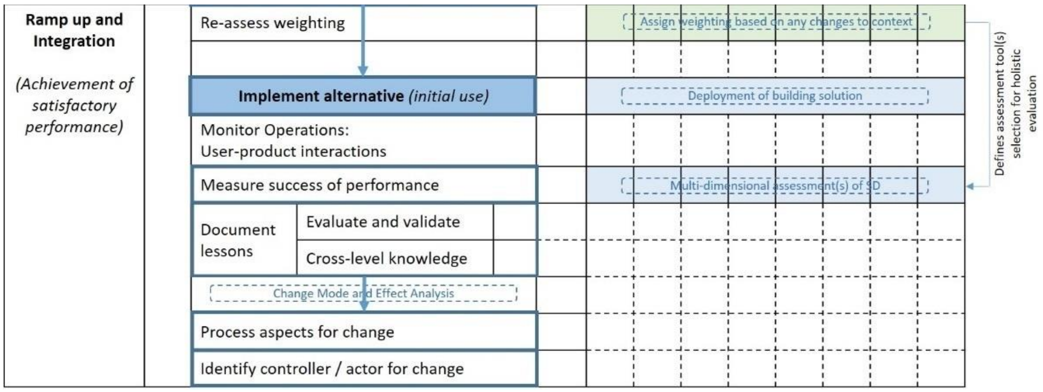


Figure 6.49: Stage 4 excerpt from the integrated systems-design methodology.

The final stage of the proposed methodology concerns itself with the construction, operations, and integration stage of the project (deployment) within its context.

It is at the completion of stage three, and the inception of stage four that the second evaluation of sustainable development criteria is undertaken to accommodate adjustments to the criteria weighting, and assess any changes to the context and user needs. This weighting will later be used as a basis to better facilitate a measurement of actual performance of the building solution. For the purposes of this example, it is assumed that the relative weightings remain unchanged on the basis that contextual factors and new technologies have not caused notable disruption.

This step, termed ‘implementation of alternative’, is concerned with the physical deployment of the chosen prototype representing the intended building solution. It is at this stage that the building becomes tangible on a physical dimension, and is integrated to the practices of its users as well as the context within which it exists. The building solution now also becomes a mechanism through which a particular use is pursued and, in doing so, is required to go ‘online’ in terms of operations, its information systems, and communications network.

Project construction and deployment, while complex in nature, often taking as long to complete as the preceding design process, and accounting for two work stages within the SACAP Identification of Work for Architectural Professionals (stages 5 and 6), is summarised within one step of this design-orientated methodology. This methodology recognises this step as an important milestone in the role of the architect for project delivery, but assumes that all necessary design and technical development to facilitate construction has already responsibly occurred through rigorous adherence to the previous steps in this proposed methodology. In the event that the scope of the project is changed during construction, it will be required of the design team to retrace their steps within the methodology on the basis of the severity of disruption. A substantial change to the brief would require a reinvestigation of the principles of stages one and two. A change to components of the design would require a reinvestigation of the principles of stage three.

Following project deployment, the design team becomes involved with interpreting results from monitoring building operations. In the case of this theoretical example, this is possible through the use of BIM, combined with an intelligent building management system and facilities management operational guidelines. Through combination of these technologies (as has been discussed in Chapter 6 sections 6.1.6 and 6.1.7) the design team maintains an important role in accumulating information and interpreting it. This allows the building operator to evaluate a number of aspects, such as:

- Is the building solution meeting design expectations on the basis of energy efficiency?
- Are users reporting optimum quality of life and user experience?
- Is the building solution operating successfully on the basis of functionality and usability?
- Are there shortfalls in design?
- Are any components or systems underperforming?
- Has any functional or technical redundancy affected the system and subsystems?
- Are users sufficiently ‘enabled’ on through access to information and communication?
- Is the building solution integrating sufficiently into external context data and services infrastructure?
- What are the effects of the building solution on contextual sustainable development criteria, and social demographics?

Supporting the above aspects, the third instance of formal sustainable development criteria assessment is introduced at this stage. As with previous instances, the use and combination of quantifiable assessment tools is left to the discretion of the design team on the basis of availability and suitability. The results of this assessment are then formally documented, to be made available to a larger body of knowledge. Before being made broadly available, and in the interests of ensuring quality of information, it is important that measurements and conclusions be evaluated and validated. This is possible through specialised auditing as well as peer-review. Once validated, it is proposed by the researcher that the optimum custodian of this knowledge would be the responsible municipality which may use this information to the benefit of more responsive planning and statutory direction. This would effectively address the important step of 'cross-levelling of knowledge' by making lessons learnt an open source database to the benefit of future design and management of the context within which this project interacts. This is important since, as the integrated feedback loop at this step indicates (linking 'document lessons' back to the 'social factors' step within the initiation stage), successes and failures of this project may need re-assessment based on changing social factors, or may have had an effect on the contextual social factors (desired output, and tacit knowledge) prompting a re-evaluation of the project's continued sustainability.

In the event that a change to social aspects is easily mitigated, the building solution, its systems, and its components are furthermore interrogated on a cyclical basis during this second instance of CMEA. This furthermore assesses risks to the building solution, identifying components, systems, and the relationships between them that risk redundancy based on technological advancement and changing usability of the project. Aspects for change are categorised, processed, and cycled back within the earlier prototype management steps. In these steps, components and systems that are identified to be at risk are compared to scenarios for retention, replacement, or upgrade to determine the potential disruption to the project. Once necessary interventions for change are identified, these are ordered and implemented, restoring the methodology user (design team) to the integration stage associated with project operations. In terms of this example, it could be assessed that the building's internal wireless data network is within two years of reaching a reduction in capacity through high contention ratios and technological trends indicating an increase in data appetite of mobile devices every few months. The systems and components of this network (controllers or actors for change) are therefore identified precisely through CMEA and categorised into a hierarchy of importance, robustness, and challenge for upgrade. A roll-out plan for this upgrade is proactively strategised for based on the needs of the users (identifying when ideal timeframe for minimum disruption might be due to network usage statistics) and compared to building operational requirements and profitability.

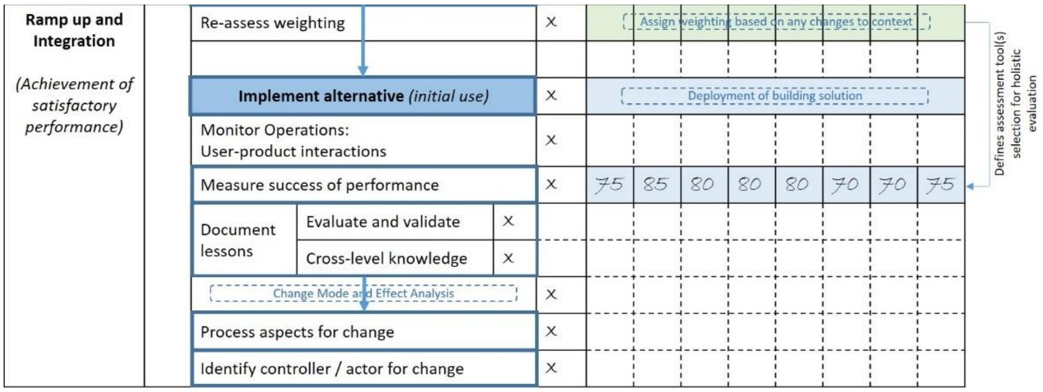
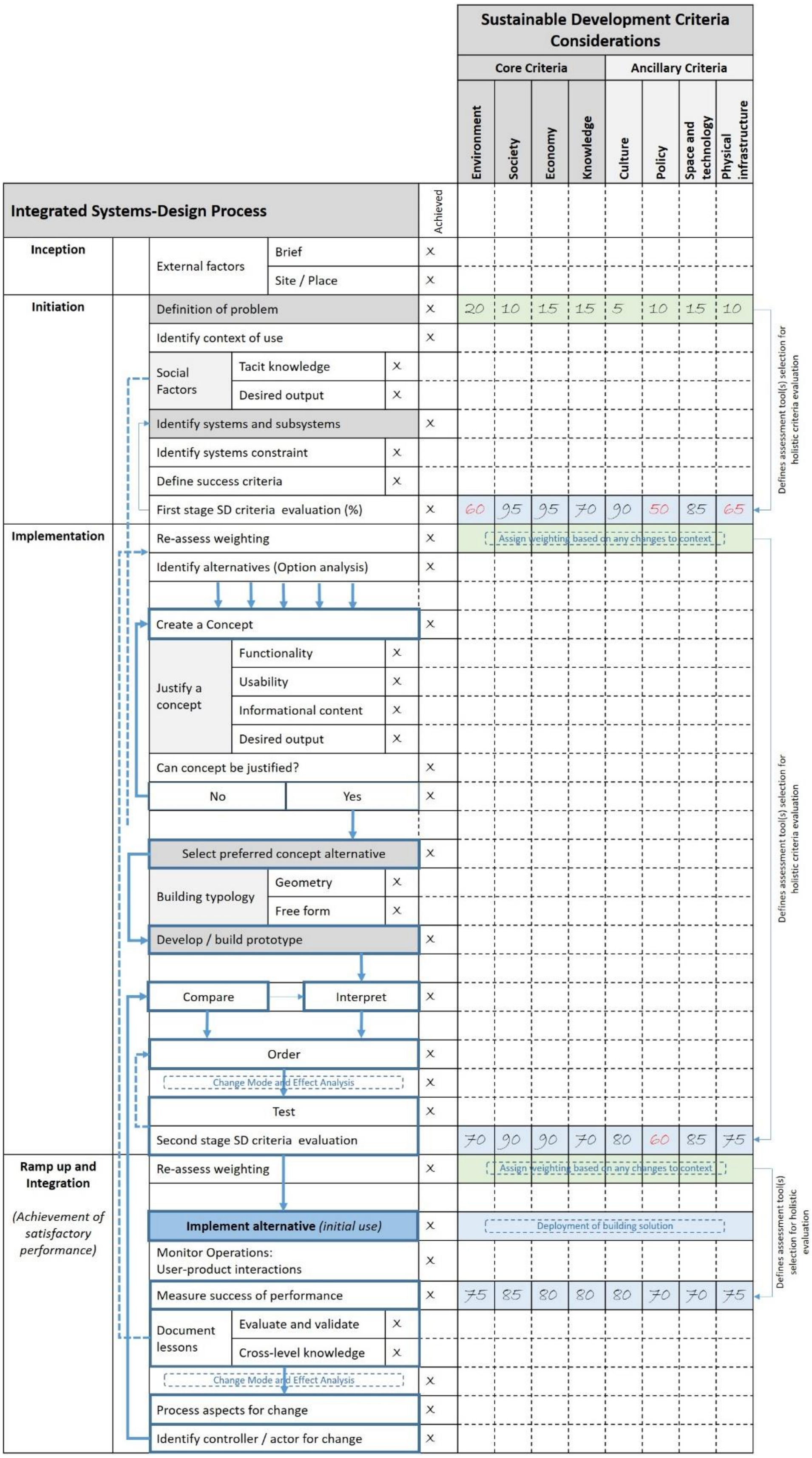


Figure 6.50: Example of 'completed' stage 4 of the proposed intergated systems design methodology. Inter-stage feedbackloops not indicated.

This last step in the final stage therefore does not represent the end of the methodology, nor of the design team's involvement. Instead this lays the foundation for project teams to remain custodians of the project's sustainable future through a continuous and cyclical feedback loop, as indicated in Figure 6.51 below. This empowers the most knowledgeable team associated with defining the project success parameters and conceptual prototype to remain active in ensuring the project is led into the future as an actively self-regulating and externally assessed building solution. Additionally, the availability of project-based knowledge empowers the community at large to learn from the project's development, to devise their own interventions for improvement, as well interpret changing contextual conditions that could affect other local projects, the environmental status quo, social dynamics and demographics, economic conditions and prosperity, and knowledge base for continual learning and development.



Integrated Systems-Design Process				Achieved	Sustainable Development Criteria Considerations							
					Core Criteria				Ancillary Criteria			
					Environment	Society	Economy	Knowledge	Culture	Policy	Space and technology	Physical infrastructure
Inception		External factors	Brief	X								
			Site / Place	X								
Initiation		Definition of problem		X	20	10	15	15	5	10	15	10
		Identify context of use		X								
		Social Factors	Tacit knowledge	X								
			Desired output	X								
		Identify systems and subsystems		X								
		Identify systems constraint		X								
		Define success criteria		X								
		First stage SD criteria evaluation (%)		X	60	95	95	70	90	50	85	65
Implementation		Re-assess weighting		X	Assign weighting based on any changes to context							
		Identify alternatives (Option analysis)		X								
		Create a Concept		X								
		Justify a concept	Functionality	X								
			Usability	X								
			Informational content	X								
			Desired output	X								
		Can concept be justified?		X								
		No	Yes	X								
		Select preferred concept alternative		X								
		Building typology	Geometry	X								
			Free form	X								
		Develop / build prototype		X								
		Compare	Interpret	X								
		Order		X								
		Change Mode and Effect Analysis		X								
		Test		X								
		Second stage SD criteria evaluation			70	90	90	70	80	60	85	75
Ramp up and Integration *(Achievement of satisfactory performance)*		Re-assess weighting		X	Assign weighting based on any changes to context							
		Implement alternative *(initial use)*		X	Deployment of building solution							
		Monitor Operations: User-product interactions		X								
		Measure success of performance		X	75	85	80	80	80	70	70	75
		Document lessons	Evaluate and validate	X								
			Cross-level knowledge	X								
		Change Mode and Effect Analysis		X								
		Process aspects for change		X								
		Identify controller / actor for change		X								

Figure 6.51: Example of methodology, preliminarily 'completed' with reference to internal feedback loops for future assessment during project life cycle that may require future design intervention.

6.2.6. Summary and resolution of final hypothesis

The goal of this chapter is to propose an actionable methodology for the purposes of practical application by built-environment design practitioners, by providing the means to develop architectural process in the pursuit of creating sustainable architectural solutions. These solutions are representative of a) the effect of the progressive Information Age on society; b) the development and needs of knowledge-based societies; c) a proposed new model for sustainable development; d) the formulation of an integrated systems-design process; and e) the understanding that the solution is not temporally based but an adaptive manifestation of a life cycle process.

This chapter begins by addressing previous research relating to the impact of the Information Age on evolving knowledge-based requirements of humankind and the proposal of revised sustainable development criteria. These criteria are proposed as an iterative re-evaluation of pertinent issues associated with sustainable human-centric development. Criteria are then associated with a revised model for sustainable development, identifying core criteria and the ancillary criteria that reside within relational middle-grounds of these core criteria. This model therefore represents a four-pillar approach to sustainable development, with ancillary criteria providing focus to industry-specific applicability for the built environment. This model therefore addresses previous concerns, as highlighted in Chapter 3, that sustainable development models are ambiguous in nature and therefore present challenges of implementation.

As the world progresses through the digital age, the question of applicability of architectural solutions relative to the virtual landscape is addressed. The manner with which our physical environments are required to adopt principles of the paradigm of integration and respond to the needs for establishing informational, spatial, temporal and material relationships is not as a product but as a process. Our realities are shaped by augmentation and amplification, resulting in a sharing of interactive space between the digital and the physical. The built environment therefore acts as a physical manifestation of space, while the digital realm serves as ambient information-based infrastructure affecting the usability and experience of place. The proposed built environments of the future are therefore required to cater to this information and knowledge-based need of society, by integrating process with product during the operational life cycle. This reflects the importance of the concepts of user experience and quality of life on sustainable development principles.

Following investigation of the common ground between the Information Age, knowledge-based development, sustainable development and applications in architectural approach, a framework for implementation of an integrated systems-design process was proposed. This framework takes into consideration the understanding that the goal is not to exclusively develop a product (building), but instead a systems process represented as an 'architectural solution'. This architectural solution is therefore developed as being a closed system, inclusive of information feedback and sustainable in its ability to incorporate informational feedback loops, thereby incorporating flexibility and adaptability, human-product interactions and user experience into steps for continued process evaluation. Sustainable development is furthermore characterised in this way through a prolonged project life cycle, characterised by project responsiveness and usability.

The integrated systems-design methodology was divided into four stages for undertaking on a linear format and progression of steps, summarised as:

1. **Inception:** concerned with determining and identifying external factors imposed on the project: a) the site or place and b) the project brief.
2. **Initiation:** concerned with defining the problem, identification of applicable systems and sub-systems, identification of the systems constraint, and definition of the criteria for success.
3. **Implementation:** concerned with the development of options, creation and justification of a concept, selection of a preferred alternative, development of a prototype and the ordering and testing of systems, components and attributes and relationships between them. Included in this stage is the formative creative process of architectural geometric and typological design process for the purposes of prototype development. This stage also includes specific interrogation and testing of components and systems for possible project redundancy and risk of change.
4. **Ramp-up and integration:** concerned with the deployment of the building solution, and achievement of satisfactory performance. It includes processes of operational monitoring, measurement of success, documentation and cross-levelling of knowledge, as well as change mode analysis for re-implementation into the project during operations for future flexibility and adaptability.

These four stages are therefore characterised not by a start-to-end philosophy of approach, but instead a recurring and internalised feedback loop in pursuit of continued achievement of satisfactory performance according to the identified goals of the project, and responding with focus to the identified criteria for sustainable development. By applying this methodology, the design practitioner, team, architect and others are therefore equipped to develop responsive building solutions that are capable of reacting to global social trends, building-specific functional adaptation and change of requirement, and technological advancement of systems and components. This methodology also provides the basis to integrate information-based design practices with a broader context, allowing for city-wide intervention at an institutional level through policy-requisite BIM-based design. This encourages a broader dialogue and urban scale intervention, by opening the door for knowledge-based decision making for all built environment stakeholders through high-level database accessibility. This accessibility will in future allow for cross-communication of built environment information assets on an unprecedented level, providing the means for holistic planning and intervention in both new and existing projects.

The researcher recognises that the methodology is reliant on the incorporation of a variety of externally sourced tools and evaluation methods. This is due to the fact that these assessment tools, in seeking to provide focus to the concept of sustainable development (as discussed in Chapter 3), emphasise and isolate only parts of the problem. To allow for a holistic focus, inclusive of all necessary criteria defined as appropriate to the built environment (Chapter 5, section 5.2.2), the use of multiple assessment tools and methods is likely to be required. The development of additional tools of assessment that cater to the evolving needs will be continually required. This has been specifically provided for in this methodology in order to ensure that is not reliant on any given tool, but is a suitable basis to accommodate preferences of the user. Future tools, assessment methods, and increases in computational analysis will occur after the writing of this thesis, and hence it is important to allow this methodology to suitably accommodate these changes and advances in order to remain robust and usable for the future. The methodology is therefore not intended to be prescriptive to a detail level, but a guiding framework to ensure a holistic systems approach. Future research will be necessary in order to develop assessment methods that are representative of the proposed core and ancillary criteria of sustainable development, to integrate capabilities of CMEA into architectural design and BIM, to increase the computational logic of BIM to accommodate operational analysis from the perspective of user experience, as well as development of a more complementary municipal policy that facilitates knowledge sharing between industry stakeholders for more proactive decision-making in the urban context.

7. Conclusions and recommendations

7.1. Summary of findings

This thesis firstly concerned itself with an understanding of the history and evolution of sustainable development as a concept. It investigated whether the definition of sustainable development as development that 'meets the needs of the present without compromising the ability of future generations to meet their own needs' is still appropriate. The concept of 'human need' was re-established as of fundamental importance, recognising that without humankind, development would not exist as a concept. Furthermore, various models of sustainability were investigated in order to establish if there were sufficient grounds to implement sustainable development without ambiguity and with sufficient industry-specific focus. The various methods and models on offer sought to reiterate the assertion that sustainable development has, as a concept, been characteristically generic since its inception, making implementation a challenge. It was, however, accepted by the researcher that the triple bottom line, and core principles of sustainable development were a sufficient basis to explore evolution of the concept to a) provide greater focus for implementation, and b) react to the current needs of humankind.

In order to investigate the required evolution of the model for sustainable development, the researcher investigated how current characteristics of human need might differ from the world of the 1980s, during which triple bottom line theory was developed. It was determined that humankind has shifted into the midst of a digital revolution, termed the Information Age. This has resulted in significant advancements in ICTs, and established a new era of knowledge-based societies. The Information Age furthermore gave rise to knowledge-based development. With this, the needs of current generations are firmly linked to access to information, and knowledge creation, transfer and management. This new age was also investigated on the basis of its compatibility with sustainable development principles. It was established that a congruency of goals was possible through specific alignment of the criteria of sustainable development to knowledge-based development. This would, however, require that a criterion of knowledge, as a contributor to sustainable development, be included into a revised definition of the sustainable development model.

Additionally, the impact of the Information Age on the built environment was investigated. This was with the aim of establishing how the role of the architect might evolve in a world that is becoming increasingly digital. It was established that the world is currently experiencing a duality of approach, defined by real-world and digital-world scenarios. These aspects were investigated on the basis that architectural process should not resist this revolution but should embrace it at the risk of being left on the fringes of development. It was investigated that significant progress is being made in the realm of ICT to define and shape the ways our (intelligent) buildings and (smart) cities work. It was also determined that these advances are often peripheral and retroactively additive on built-environment infrastructure and backbone. The architect is being left out of the equation. It was determined at this stage that not only is the concept of sustainable development in need of industry focus for implementation in the built environment while responding to the evolved needs of man, but also that the architectural design process requires an evolution of approach in order to facilitate responsible and necessary involvement in this new era of mixed realities.

The revised model of sustainable development was addressed on two fronts: a) the investigation and alignment to the Information Age, and the goals and concepts of ICT and knowledge-based development; and b) providing focus for the built-environment to create a suitable version of sustainable development for the built environment that removes vagueness and ambiguity, thereby facilitating ease of implementation. In doing so, eight criteria of sustainable development were identified. In addressing the first issue of alignment to the Information Age, four ‘core’ criteria were identified, incorporating the traditional triple bottom line with the inclusion of knowledge as the fourth important criterion. These core criteria are supported by four ‘ancillary’ criteria which provide the necessary industry focus towards implementation in the built environment. This creates an overview for sustainable development that is particular to the needs of the Information Age, remembering that human need lies at the centre of development.

These criteria therefore provide the basis to address issues of physical and ecological constraints, the concept of culture and policy, socio-economic issues, and knowledge creation and transfer. These criteria were furthermore determined to be fundamental in responding to the new world of the Information Age, as well as an appropriate investigative basis for a responsible architectural approach in design and practice.

Having established the research basis of approach for sustainable development in the built environment, the matter of implementation was then addressed. This was important since the main contributor to the difficulty of implementation is not a lack of knowledge in the ‘what’ or the ‘why’, but specifically the ‘how’. The model therefore allows the design practitioner and industry professional the ability to interrogate a design problem based on the eight criteria prompting a responsive design methodology for architecture that does not simply focus on the creation of a finite building ‘product’, but a building ‘solution’ that continually contributes to the knowledge landscape throughout its life cycle.

As outlined earlier in this thesis, the problem of implementation of sustainable development principles is widely documented and accepted. It was observed that in the time of intelligent buildings and smart cities, the issue of knowledge creation and management is as pervasive in the process as it is in the environments we are creating. For this reason, the architectural design process was found to be inadequate since the role of the architect is required to evolve towards the creation of systems processes as opposed to products. The product is finite, and developed for a fixed temporal and spatial scale. This leads to redundancy and poor long-term usability, thereby not adhering to principles of sustainable development by compromising the needs of future generations. A systems process, however, is agile and flexible. A process is the result of relationships between end users, products and their attributes and systems. The architectural solution therefore resides in the application of not only a design process, but also a systems process.

The integrated systems-design process establishes the means for creation of architectural buildings infused with the means to satisfy criteria for success through identification of core systems and sub-systems within defined project constraints. This is inclusive of knowledge management in the process as well as the solution (product). In doing so, feedback loops in the process are developed on the basis that the role of the design team and project stakeholders does not end at the initial project delivery, but is prolonged into the operational life cycle. This allows the process to be inclusive of change mode analysis, flexibility and adaptability, and the means to continually gauge project usability through end-user involvement and analysis.

All of these factors make it possible to measure the success of the approach and effect ‘course-corrections’ during operations in order to ensure that the needs of current and future generations are equitably prepared-for. By recognising the project as a systems process, the issue of life cycle and sustained usability is brought to the fore and made a fundamental feature of project success. This places new emphasis on the role of the design team and project stakeholders not as project executors, but as custodians. By incorporating knowledge management into the process as well as the solution, a basis for sustainable decision-making is established.

Having translated this integrated systems-design process into a formative framework and theoretical design methodology for architects, this thesis equips industry practitioners and architects with the structure to holistically implement sustainable development principles. These principles are conducive to the creation of sustainable process solutions and inclusive of knowledge feedback loops. What is furthermore understood by the researcher is that this methodology expects the design practitioner to apply multi-dimensional evaluation and assessment tools at their discretion, based on weighting of the SD criteria that are applicable to the project. This methodology is designed to accommodate personal (substantiated) interpretation and changing project dynamics over its life cycle, recognising that the application of multi-dimensional assessments and tools will enable validation of results, as well as the development of future tools for assessing project success. It is intended to serve as a 'blank canvas' onto which the designer's personal preference for design 'type' (see Chapter 6 section 6.1.3) may be accommodated. Similarly, this methodology is developed to accommodate advances in technologies (including artificial intelligence in design) and related systems without being prescriptive. In doing so, this prolongs the period for which this methodology will be useful to the industry without becoming reliant on specific processes or technologies that are prone to redundancy

7.2. Conclusions

This thesis effectively proposes a revised model for sustainable development and an integrated systems-design methodology for the built environment in the Information Age. The sub-problems investigated aspects that are necessary to compile and theorise the model and methodology respectively.

The first sub-problem: *"Are current theories of sustainable development adequately focused for industry-based implementation?"* investigated international concepts in sustainable development. This chapter identifies characteristics of sustainable development based upon the 1972 UN definition and the three pillars of sustainable development, indicating that existing models are varied and generic. It also indicates that future models would benefit from industry-specific focus based on scale of implementation.

Hypothesis One: *"Industry-specific interpretation of sustainable development is required for appropriate implementation in the built environment"* is substantiated through literature review and investigation of progressive international models of sustainable development and the associated challenges of implementation in architecture.

The second sub-problem: *"How have the needs of 21st century societies changed in the midst of the Information Age and how is this applicable for future sustainable development?"* investigated how the world has evolved in the Information Age and the impact this has on the concept of sustainable development. This chapter indicates that, since sustainable development is aligned to human need and the Information Age has brought about knowledge-based development, there is scope for alignment of these two concepts. These findings are valuable as they help to define the goal of a revised model for sustainable development with a human-centric focus.

Hypothesis Two: *"Sustainable development and its criteria require alignment and redefinition according to the needs of the Information Age and knowledge-based societies"* is substantiated through investigation by literature review on knowledge-based development and identification of the gaps in the three pillars (criteria) of sustainable development.

The third sub-problem: *"What are the aspects of ICT that align it with the goals of sustainable development in the context of the built environment?"* investigated the common goals between ICT and sustainable development. It also identified the characteristics of knowledge-based societies, knowledge-based development, and the challenges posed to architectural product and process. The findings are valuable as they establish that there is scope for a new architectural design process.

Hypothesis Three: *"Alignment of the goals of sustainable development and ICT provides a basis for advancement of sustainable development principles in architectural design process and product within the Information Age"* is substantiated through literature review on sustainable development in the Information Age, including the European Commission's Digital Agenda. New criteria for sustainable development are developed with a specific focus on architectural application. It also identifies aspects of ICT integration in architecture and the design process towards meeting these goals.

The fourth sub-problem: "*How can architectural approach in design and implementation towards sustainable development in the built environment be improved to meet the needs of the Information Age and knowledge-based development"* investigated a revised model for sustainable development applicable to the building environment. It also identified an integrated systems-design process as the means to achieve this revised model. This incorporates research in chapters three, four and five in order to substantiate the objectives of the model and methodology.

Hypothesis Four: *"A new integrated systems-design methodology for architectural design is required, implementing the integrated systems-design process and the proposed new model of sustainable development"* is substantiated through the development of an integrated systems-design methodology for architects and its theoretical application.

7.3. Implications for existing theory

This thesis introduces a revised model for sustainable development as a basis for future architectural process. This model requires that architectural design evolves to integrate concepts of ICT and knowledge-based development for sustainable development in the Information Age. Existing sustainable development theory is provided with new criteria aligned to knowledge-based development and the built environment, for which existing architectural design processes are currently inadequate. The implication is a new architectural paradigm that caters to the needs of sustainable development in the 21st century Information Age. The larger significance of findings in this thesis will be a basis for improved sustainable architecture through the proposed new architectural integrated systems-design methodology, creating a flexibility for the integration of future technologies in process and product.

It is still unknown what the impact of continually evolving ICTs might ultimately have on society, economics, governance, policy, and infrastructure. This would affect how architectural projects might share information with other projects within a broader geographical context for the benefit of user needs analysis, integrated design, and macro-scale planning. It will be important to periodically test the full implementation of this methodology over the total life-cycle of projects over periods that will be prone to changing technology and policy. A project lifecycle will account for many years, and for this reason a staged approach to implementation is recommended. Measurement of projects and process through future survey and collection of building performance and feasibility data is recommended, as this will have influence on the long-term utilisation and customisation of this methodology.

7.4. Recommendations

This thesis makes the following recommendations:

Revised model for sustainable development: it recommends that the revised model for sustainable development address the shortcomings of existing theory as identified by research contained within Chapters Three, Four and Five. Individual recommendations stemming from the research as discussed in this thesis are combined into the revised model for sustainable development in Chapter Six.

Integrated systems-design methodology: it recommends that an integrated systems-design methodology address the shortcomings in architectural paradigm and process, contained in research in Chapters Four and Five, in pursuit of sustainable development as defined by the revised model contained within Chapter Six. Detailed recommendations for the methodology are made in Chapter Six.

7.5. Suggestions for future research

The researcher recognises that it will be necessary to periodically re-evaluate the proposed methodology, and propose future studies based on the following aspects:

1. The development of future technologies that seek to develop, or replace BIM as a platform for collaborative knowledge-sharing among design professionals.
2. The continued emergence and significance of computational and generative design, and artificial intelligence on the methodological process as computing assumes a greater role in design decision-making and iterative testing of success criteria during building operations.
3. The development of a more holistic evaluation tool, aligned to the proposed model of sustainable development, which incorporates the identified core and ancillary criteria of sustainable development for use in the built environment.
4. Proposals for changes to current policy that will affect the continued role of institutions and municipalities, the means in which their input is formative towards product and process, as well as the active evaluation of the urban environment towards understanding and adapting to changing contextual constraints.
5. Changes to current operations through new policy that make integration of municipal (regulatory) input a fluid and informative factor in design.
6. Evolution of architectural paradigm to adopt an ‘open source’, collective approach to knowledge-sharing for the benefit of sustainable development.

7. The formation of a digital city database as an accessible and real-time record of building and city performance, promoting oversight and the capacity for predictive simulation, and the advancement of building design documentation through 5-Dimensional information modelling to facilitate this.
8. Evolving broad-based computing and networks that contribute to decentralised autonomous information-sharing and record-keeping processes (digital ledgers), such as the blockchain. This could have a profound effect on macro and micro socio-economics, and the way in which smart contracts might affect our user experience in a physical world supported by ubiquitous computing.

Therefore, while conclusively structured, the methodology remains partially limited in its possible implementation. Limitations will rely on aspects such as, but not limited to, the suitable use of ratings tools by its user, the evolution of assistive computing processes in design, as well as knowledge management and transfer between one or more projects and their stakeholders. This methodology is therefore developed with a long-term view, anticipating a future where technology and policy align to facilitate its unhindered usage. In the same way that BIM has taken many years to become an industry standard, this methodology will therefore require some industry acclimatisation. Without increases in the capacity and availability of computational design and artificial intelligence for problem-solving, the processes of scenario simulations, CMEA, and iterative prototypes analysis will be limited. However, the era of computing capabilities to facilitate this is fast approaching, and this methodology will prime the industry practitioner for these technological advances.

7.6. Closing statement

At this stage the researcher acknowledges certain successes in theoretical advancement, as well as opportunities for future development and supporting research. Sustainable development has proven to be a malleable theory that, while based on certain persisting principles, allows itself to be shaped to a specific intention and context of application. Through interrogation of the evolution of human need in a 21st century Information Age, it is possible to align the concept of sustainable development to knowledge-based development. Current global difficulties experienced in the realms of the traditional triple bottom line entrench the sense that these are still being treated in isolation. Global warming and climate change, social strife and Brexit-era anti-globalist sentiment,[71] and the public discontent of Occupy Wall Street[72] all demonstrate continuing rifts in the ecological, social and economic realms. What is prevalent is that the ability of humankind to empower themselves to participate in the solution is hampered by a shortfall in contributory capacity. Knowledge stands on the precipice of replicating entrenched economic inequality as a commodity of the 'haves' and 'have-nots'. This is the reality of the digital divide, the mere existence of which validates the importance of equal access to information. By neglecting knowledge as an important criterion for equitable development in the Information Age, the pursuit of sustainable development for the benefit of future generations is compromised. This thesis has undertaken to contribute to developing that model, and in doing so provides the means to attribute greater specificity to the spatial and temporal scale of intervention in the built environment. Furthermore, the revised model of sustainable development creates the conditions to interrogate a design problem holistically, as well as integrate knowledge management in the process. In this way, a logical and (partially) linear methodology is developed. This integrated systems-design methodology provides the basis to implement this a theoretical model. However, this thesis also reveals that the methodology will benefit from future testing whereby its intentions can be validated through additional case study and participant survey. This will only be possible, however, once building operations have persisted over time, change mode effect and analysis has been implemented and evaluated, and certain technological and statutory conditions in the industry are further developed.

In concluding this thesis, and considering the possibilities of a theoretical future built on a foundation of possibility, the researcher recalls the work of Jacques Fresco and "The Venus Project". While it is not possible to empirically validate the certainty or feasibility of this proposed future, based on constructive research and deductive logic a new reality is devised with the potential to change paradigms, and give rise to future research. In this particular future cities concept, Fresco 'proposes an alternate vision of what the future can be if we were to apply our current knowledge to a "clean slate"

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[71] 'Brexit is a rejection of globalisation', by Larry Elliot. 2010. https://www.theguardian.com/business/2016/jun/26/brexit-is-the-rejection-of-globalisation [Viewed on 07 March 2017].

[72] 'Occupy wall street – we are the 99%'. A protest movement against global economic inequality. http://occupywallst.org/ [Viewed on 09 March 2017].

scenario in order to achieve a sustainable new world civilisation.'[73] In other words, if we could start over and build the world again from the ground up, knowing what we know now, what would we do differently? One of the key aspects of this 'alternative future world' that is of interest to the researcher in the context of this thesis, is the intention for processes of production, manufacturing, and analytics to be comprehensively reformed through automation and computation. By establishing protocols according to which a scientific and replicable approach can be applied, this therefore frees humankind from needless acts of repetition, and instead allows for a focus on innovative and creative thinking.

Figure 7.1: The Venus Project. Source: https://www.thevenusproject.com/wp-content/uploads/2015/11/The-Venus-Project-concept-city-3.jpg

The Information Age of today already allows for this to occur in some part, whereby computerised algorithms may be able to interrogate the need for intervention to a far more sophisticated degree than the human mind ever could, which would be of particular use to the proposed methodology of this thesis particularly in the sphere of prototype options analysis and simulation. By applying a quantifiable systems approach to the problem of 'quality of life', or even the proposed sustainable development criteria through definition of early-stage protocols and algorithms, computation linked to municipally governed and accessible geographic information systems (GIS) could furthermore assume the analytical responsibilities of design, thereby facilitating integrated decision-making.

The methodology proposed in this thesis is intended to flexibly accommodate these advances; hence the means for integrated assessment within methodology stages

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[73] https://www.thevenusproject.com/

have been referred to but not dictated. This would allow the architect to concentrate on assimilating, interpreting, and applying information (knowledge) and assessment results, and be unnecessarily burdened with producing these, thereby freeing up time for innovation and creative decision-making, based on available scientific observation and analysis. This is the Information Age approach to which architecture should aspire – one where technological advancement on the basis of knowledge development is embraced. This proposed methodology therefore provides the framework, the direction, and the holistic vision upon which this integration of processes towards sustainable development can occur.

8. Bibliography

Ackoff, R.L. 1974. The systems revolution. *Long Range Planning*, vol. *7,* no. 6, pp. 2-20.

Akcamete, A., Akinci, B. & Garrett, J.H. 2010. Potential utilization of building information models for planning maintenance activities. *Proceedings of the international conference on computing in civil and building engineering*. [online] Available: https://www.academia.edu/2699359/Potential_utilization_of_building_information_models_for_planning_maintenance_activities [Viewed 10 June 2016].

Aghekyan, E., Coogan, M., & Dunham, J., et al. 2015. *Freedom in the World 2015 – Disregarding Democracy: a Return to the Iron Fist.* Freedom House. Washington DC. USA. [online] Available: https://freedomhouse.org/sites/default/files/01152015_FIW_2015_final.pdf [Viewed 10 June 2016].

Alexander, K. 2006. The application of usability concepts in the built environment. *Journal of Facilities Management*, vol. 4, no. 4, pp. 262-270.

Anderson, A., Marsters, A., Dossick, C. & Neff, G. 2012. Construction to operations exchange: Challenges of implementing COBie and BIM in a large owner organization. In: *Construction Research Congress*. pp. 688-697.

Argote, L., Ingram, P., Levine, J.M. & Moreland, R.L. 2000. Knowledge transfer in organizations: Learning from the experience of others. *Organizational behavior and human decision processes*, vol. 82, no.1), pp.1-8.

El Asmar, M., Hanna, A.S. and Loh, W.Y. 2013. Quantifying performance for the integrated project delivery system as compared to established delivery systems. *Journal of Construction Engineering and Management*, vol. 139, no. 11, pp.1-14.

Atkinson, R. D., & McKay, A. S. 2007. *Digital Prosperity: Understanding the Economic Benefits of the Information and Technology Revolution*. Washington, DC: Information Technology and Innovation Foundation [online] Available: http://www.itif.org/files/digital_prosperity.pdf [Viewed 21 March 2015).

Azhar, S. 2011. Building Information Modelling (BIM): Trends, benefits, risks and challenges for the AEC industry. *Leadership and Management in Engineering*, vol. 11, no. 3, pp. 241-252.

Azhar, S., Khalfan, M. & Maqsood, T. 2015. Building information modelling (BIM): Now and beyond. *Construction Economics and Building*, vol. *12* no. 4, pp. 15-28.

Azhar, S. and Brown, J. 2009. BIM for sustainability analyses. *International Journal of Construction Education and Research*, vol. *5*, no. 4, pp. 276-292.

Barkhuizen, W.F., Pretorius, J.H.C. & Pretorius, L. 2012. An integrated systems approach to risk management within a technology-driven industry, using the design structure matrix and fuzzy logic. *South African Journal of Industrial Engineering*, vol 23, no. 2, pp. 202-214.

Barr, S. 2008. *Environment and Society: Sustainability, Policy and the Citizen*. Hampshire, UK: Ashgate Publishing.

Basiago, A.D. 1995. Methods of defining 'sustainability'. *Sustainable development*, vol. *3*, no. 3, pp.109-119.

Battarbee, K. & Koskinen, I. 2005. Co-experience: user experience as interaction*. CoDesign*, vol. 1, no. 1, pp. 5-18.

Bauer, J. M. 2004. Governing the networks of the information society: Prospects and limits of policy in a complex technical system. *Institute of Technology Assessment Working Paper No. ITA-04-03.* [online] Available: http://unpan1.un.org/intradoc/groups/public/documents/APCITY/UNPAN025287.pdf [Viewed 10 June 2016].

Baum, S., Yigitcanlar, T., Horton, S., Velibeyoglu, K. & Gleeson, B. 2007. The role of community and lifestyle in the making of a knowledge city. *Urban Research Program, Policy and Practice Paper 2*. Brisbane: Griffith University:.

Beatley, T., & Manning, K. 1998. *The ecology of place: Planning for environment, economy and community*. Washington DC: Island Press.

Becerik-Gerber, B., Jazizadeh, F., Li, N. & Calis, G. 2011. Application areas and data requirements for BIM-enabled facilities management. *Journal of construction engineering and management*, vol. 138, no. 3, pp. 431-472.

Beckmann, J. 1998. *The Virtual Dimension – Architecture, representation and crash culture*. New York, NY: Architectural Press.

Bell, M., & Pravitt, K. 1997. Technological accumulation and industrial growth: contrasts between developed and developing countries. In: *Technology, globalisation and economic performance*. Edited by D. Achibuigi & J. Michie. Cambridge: Cambridge University Press. pp. 83-137.

BIM Industry Working Group. 2011. *A Report for the Government Construction Client Group Building Information Modelling (BIM) Working Party Strategy Paper*. [online] Available: http://www.bimtaskgroup.org/wp-content/uploads/2012/03/BIS-BIM-strategy-Report.pdf [Viewed 13 May 2016].

Birkeland, J. 2005. *Design for Sustainability – a sourcebook for integrated ecological solutions*. London:. Earthscan Publications.

Blanchard, B.S., Fabrycky, W.J. & Fabrycky, W.J. 2006. *Systems engineering and analysis*, vol. 4. Englewood Cliffs, NJ: Prentice Hall.

Boyo-Moriones, A., & Lera-Lopez, F. 2007. A firm-level analysis of determinants of ICT adoption in Spain*. Technovation*, vol. 27, no. 6, pp. 352-366.

Bradfield, V. J. 1983. *Information sources in Architecture*. London: Butterworth.

Branwyn, G. 1998. The desire to be wired. In: Beckmann, J. 1998. *The virtual dimension – architecture, representation and crash culture*. New York, NY: Architectural Press.

Broadbent, D.E. 2013. *Perception and communication*. Oxford: Elsevier.

Campbell, T. 2009. Learning cities: Knowledge, capacity and competitiveness. *Habitat International*, vol. 33, no. 2, pp. 195-201.

Carrillo, F.J. 2015. Knowledge-based development as a new economic culture. *Journal of Open Innovation: Technology, Market and Complexity*, vol. 1, no. 1, pp. 1-17.

Carrillo, F.J. & Batra, S. 2012. Understanding and measurement: perspectives on the evolution of knowledge-based development. *International Journal of Knowledge-Based Development*, vol. 3, no. 1, pp. 1-16.

Carr, N. 2016. *The glass cage: Where automation is taking us*. New York, NY: Random House.

Castells, M. 2010. *The Rise of the Network Society: The Information Age: Economy, Society and Culture*. Volume 1. Malden, MA: Blackwell.

Castells, M. 2013. *Communication power*. Oxford: Oxford University Press.

Chan, A.P. & Chan, A.P. 2004. Key performance indicators for measuring construction success. *Benchmarking: An International Journal*, vol. 11, no. 2, pp. 203-221.

Charter, M., & Clark, T. 2007. *Sustainable Innovation: Key conclusions from sustainable innovation conferences 2003-2006 organised by The Centre for Sustainable Design*. The Centre for Sustainable Design, University College for the Creative Arts. [online] Available: http://bic-innovation.com/static/bic/knowledge_base/documents/T160433.pdf [Viewed 15 April 2013].

Cheung, C.M.K., Chiu, P., & Lee, M.K.O. 2010. Online social networks: Why do students use Facebook? *Computers in Human Behaviour*, vol. 27, no. 4, pp. 1337-1343.

Christensen, B.T. and Ball, L.J. 2016. Dimensions of creative evaluation: Distinct design and reasoning strategies for aesthetic, functional and originality judgments. *Design Studies*, 45, pp. 116-136.

Chung, K.Y. 2014. Recent trends on convergence and ubiquitous computing. *Personal and Ubiquitous Computing*, vol. 18. No. 6, pp. 1291-1293.

Ciolfi, L. & Bannon, L.J. 2007. Designing hybrid places: merging interaction design, ubiquitous technologies and geographies of the museum space*.* *CoDesign*, vol. 3, no. 3, pp. 159-180.

Clark, W. and Holliday, L. eds., 2006. *Linking knowledge with action for sustainable development: The role of program management-summary of a workshop*. National Academies Press.

Clarke, R.Y. 2013. *Smart cities and the internet of everything: the foundation for delivering next-generation citizen services*. Alexandria, VA, Tech. [online] Available: http://www.cisco.com/c/dam/en_us/solutions/industries/docs/scc/ioe_citizen_svcs_white_paper_idc_2013.pdf [Viewed 11 June 2016].

Clayton, A.M. & Radcliffe, N.J. 1996. *Sustainability: a systems approach*. London: Earthscan.

Clements-Croome, D. 2004. *Intelligent Buildings: design, management and operation.* London: Thomas Telford Publishing.

Coats, D. 2005. *Ideopolis: Knowledge cities*. London: The Work Foundation.

Coffey, J.W. & Hoffman, R.R. 2003. Knowledge modelling for the preservation of institutional memory*. Journal of Knowledge Management*, vol. 7, no. 3, pp. 38-52.

Cole, R. 2012. Transitioning from green to regenerative design. *Building Research & Information*, vol. 40, no. 1, pp. 39-53.

Coleman, J. S. 1988. Social capital in the creation of human capital. *American Journal of Sociology*, vol. 94, S95-S120.

Conejos, S., Langston, C., & Smith, J. 2012. AdaptSTAR model: A climate-friendly strategy to promote built environment sustainability. *Habitat International*, 37, pp. 95-103.

Cooper, I. 2008. *Understanding Context*, in: Lorch, R., 2008. *Buildings, culture and environment: informing local and global practices*. pp. 11-17. Hoboken, NJ: John Wiley & Sons.

Crnkovic, G.D. 2010. Constructive research and info-computational knowledge generation. In *Model-Based Reasoning in Science and Technology.* pp. 359-380. Berlin: Springer.

Crosbie, T., Dawood, N., & Dawood, S. 2011. Improving the energy performance of the built environment: The potential of virtual collaborative life-cycle tools. *Automation in Construction*, vol. 20, no. 2, pp. 205-216.

Crotty, R. 2012. *The impact of building information modelling: Transforming construction*. New York, NY: Routledge.

David, P. A., & Foray, D. 2002. An introduction to the economy of the knowledge society*. International Social Science Journa*l, vol. 54, no. 171, pp. 9-23.

Davidavičienė, V., & Raudeliūnienė, J. 2010. ICT in tacit knowledge preservation. *The 6th International Conference "Business and Management 2010":* Selected papers, vol. 2. Vilnius, Lithuania: Vilnius Gediminas Technical University.

Davies, C. 1998: Changing space: virtual reality as an arena of embodied living. In: Beckmann, J. 1998. *The virtual dimension – architecture, representation and crash culture*. New York, NY: Architectural Press.

Dettmer, H.W. 1997. *Goldratt's theory of constraints: A systems approach to continuous improvement*. Milwaukee, WI: ASQ Quality Press.

De Vries, B.J. & Petersen, A.C. 2009. Conceptualizing sustainable development: An assessment methodology connecting values, knowledge, worldviews and scenarios. *Ecological Economics*, vol. 68, no. 4, pp. 1006-1019.

Ding, G.K. 2008. Sustainable construction - The role of environmental assessment tools. *Journal of Environmental Management*, vol. 86, no. 3, pp. 451-464.

Dong, A., Garbuio, M. & Lovallo, D. 2016. Generative sensing in design evaluation*. Design Studies*, 45, pp. 68-91.

Dorst, K. & Cross, N. 2001. Creativity in the design process: co-evolution of problem–solution. *Design Studies*, vol. *22*, no. 5, pp. 425-437.

Dreyfuss, E. Gadson, A., Riding, T., & Wang, A. *The IT Productivity Paradox.* [online] Available: http://cs.stanford.edu/people/eroberts/cs181/projects/productivity-paradox/background.html [Viewed 27 April 2015].

Du Plessis, C. D. 1999. Sustainable development demands dialogue between developed and developing worlds. *Building Research and Information*, vol. 27, no. 6, 378-389.

Du Plessis, C. D. 2002. *Agenda 21 for sustainable construction in developing countries.* Boutek Report No Bou/E0204. [online] Available: http://www.unep.or.jp/ietc/Focus/Agenda%2021%20BOOK.pdf [Viewed 10 June 2016].

Du Plessis, C. D. 2012. Towards a regenerative paradigm for the built environment. *Building Research & Information*, vol. 40, no. 1, pp. 7-22.

Du Toit, Y. 2011. *Incorporating a system approach to the decision making process.* Doctoral dissertation. Pretoria: University of Pretoria).

Dyson, F. 1998. Space, being and other fictions in the domain of the virtual. In: Beckmann, J. 1998. *The virtual dimension – architecture, representation and crash culture*. New York, NY: Architectural Press.

Eckblad, S., Ashcraft, H., Audsley, P., Blieman, D., Bedrick, J., Brewis, C., Hartung, R.J., Onuma, K., Rubel, Z. and Stephens, N.D. 2007. Integrated project delivery-a working definition. *AIA California Council, Sacramento, CA*.

Eden, S. 2000. Environmental issues: sustainable progress?. *Progress in human geography*, *24*(1), pp. 111-118.

Eighmey, J., & McCord, L. 1998. Adding value in the Information Age: uses and gratifications of sites on the World Wide Web. *Journal of Business Research*, vol. 41, pp. 187-195.

Elkington, J. 2004. Enter the Triple Bottom Line. In: A. Henriques and J. Richardson, 2004. The Triple Bottom Line, does it all add up? London, UK: Earthscan.

Erumban, A. A., & De Jong, S. B. 2006. Cross-country differences in ICT adoption: A consequence of Culture? Journal of World Business, vol. 41, no. 4, pp. 302-314.

European Commission (EC). *Digital Agenda in the European 2020 Strategy.* [online] Available: http://ec.europa.eu/digital-agenda/en/digital-agenda-europe-2020-strategy [Viewed 22 February 2015].

Evans, D. 2014. How the Internet of everything will shape the next 25 years of internet history [online] Available: http://blogs.cisco.com/ioe/how-ioe-will-shape-the-next-25-years [Viewed 15 May 2015].

Farmer, G., & Guy, S. 2010. Making morality: sustainable architecture and the pragmatic imagination. *Building Research & Information*, vol. 38, no. 4, pp. 368-378.

Faust, B. 2007. Implementation of tacit knowledge preservation and transfer methods. in: *International Conference on Knowledge Management in Nuclear Facilities*. Vienna: International Atomic Energy Agency.

Fellenz, M., & Brady, M. 2006. Managing the innovative deployment of information and communication technologies (ICTS) for global service organisations*?* [online] Available: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=989304 [Viewed 10 June 2016].

Fernandez-Maldonado, A.M. & Romein, A. 2010. The role of organisational capacity and knowledge-based development: the reinvention of Eindhoven. *International Journal of Knowledge-Based Development*, vol. 1, nos. 1-2, pp. 79-96.

Ferreira, S.D.M. & Neto, M., 2005. Knowledge management and social learning: exploring the cognitive dimension of development. *Knowledge management for development journal*, *1*(3), pp.6-19.

Fiksel, J. 2003. Designing resilient, sustainable systems. *Environment Science and Technology*, vol. 37, no. 23, pp. 5330-5339.

Forlizzi, J. & Battarbee, K. 2004. Understanding experience in interactive systems. In: *Proceedings of the 5th conference on Designing interactive systems: processes, practices, methods and techniques*, pp. 261-268. ACM.

Forlizzi, J. & Ford, S. 2000. The building blocks of experience: an early framework for interaction designers. In: *Proceedings of the 3rd conference on Designing interactive systems: processes, practices, methods and techniques,* pp. 419-423. ACM.

Fukuda-Parr, S. & Lopes, C. eds., 2013. Capacity for development: new solutions to old problems. Routledge.

Galloway, A. 2004. Intimations of everyday life: Ubiquitous computing and the city. *Cultural studies*, vol. 18 nos. 2-3, pp. 384-408.

Gallup. (2014). *The myth of social media*. [online] Available: http://online.wsj.com/public/resources/documents/ sac_report_11_socialmedia_061114.pdf [Viewed 14 May 2016].

Gann, D., M. 2008. *Trading Places – Sharing Knowledge about Environmental Building Techniques.* In: Lorch, R. 2008. *Buildings, culture and environment: informing local and global practices,* pp. 37-57. John Wiley & Sons.

Garrett, J.J. 2010. *Elements of user experience, the: user-centered design for the web and beyond*. Berkley, CA: Pearson Education.

Gerritsen, B. & Horváth, I. 2010. The upcoming and proliferation of ubiquitous technologies in products and processes. *Strojniški vestnik-Journal of Mechanical Engineering*, vol. 56 no. 11, pp. 765-783.

Gibberd, J. (2005). Developing a sustainable development approach for buildings and construction processes, in*: Smart and Sustainable Built Environments.* 300-310. Oxford, UK: Architectural Press.

Giddings, B., Hopwood, B. & O'brien, G. 2002. Environment, economy and society: fitting them together into sustainable development. *Sustainable development*, *10*(4), pp.187-196.

Glick, S. & Guggemos, A. 2009. *IPD and BIM: benefits and opportunities for regulatory agencies.* In: *Proceedings of the 45th ASC National Conference.* Gainesville, Florida, pp. 2-4.

Gotthard, V. 2004. Design for flexibility. *DFX 2004: Proceedings of the 15th Symposium on Design for X,* Neukirchen/Erlangen, Germany, 14–15 October 2004. [online] Available: https://www.designsociety.org/publication/27612/design_for_flexibility [Viewed 10 June 2016].

Gregory, G. 1997. Book Review: “Disconnected: Haves and Have-nots in the Information Age”. *Information Age*, vol. 14, no. 3, pp. 56.

Groat, L. N. & Wang, D. 2013. *Architectural Research Methods: Second Edition.* Hoboken, NJ: Wiley & Sons.

Guy, S., & Farmer, G. 2001. Reinterpreting sustainable architecture: the place of technology. *Journal of Architectural Education,* vol. 54, no. 3, pp. 140-148.

Habermas, J. 2015. *Communication and the Evolution of Society*. Cambridge: John Wiley & Sons.

Harris, F. 2012. *Global environmental issues*. John Wiley & Sons.

Harrison, A., Loe, E., & Read, J. 1998. *Intelligent buildings in South East Asia.* New York, NY: Taylor and Francis.

Hassenzahl, M., Diefenbach, S. & Göritz, A. 2010. Needs, affect and interactive products–Facets of user experience. *Interacting with Computers*, vol. *22,* no. 5, pp. 353-362.

Haubelt, C., Teich, J., Richter, K. & Ernst, R. 2002. System design for flexibility. In: *Proceedings of the Conference on Design, Automation and Test in Europe*, p. 854, IEEE Computer Society.

Hayashi, C. 1953. Multidimensional quantification. *Annals of the Institute of Statistical Mathematics*, vol. *5* no. 1, pp. 121-143.

Heeks, R. 2014. *The Data Revolution will fail without a Praxis Revolution*. [online] Available: https://ict4dblog.wordpress.com/2014/08/14/the-data-revolution-will-fail-without-a-praxis-revolution/ [Viewed accessed 10 January 2015].

Heim, M. 1998: Virtual reality and the tea ceremony. In: Beckmann, J. 1998. *The virtual dimension – architecture, representation and crash culture*. New York, NY: Architectural Press.

Hemez, F.M. & Doebling, S.W. 2001, February. Model validation and uncertainty quantification. *Proceedings of IMAC-XIX. The 19th International Modal Analysis Conference*. Orlando, FL: SEM. pp. 6-12.

Hernández-Muñoz, J.M., Vercher, J.B., Muñoz, L., Galache, J.A., Presser, M., Gómez, L.A.H. & Pettersson, J. 2011. Smart cities at the forefront of the future internet*,* in: *The future internet assembly 2011: Achievements and technological promises*, pp. 447-462. Berlin: Springer.

Himanen, M. 2003. The intelligence of intelligent buildings: The feasibility of the intelligent building concept in office buildings. Espoo, Finland: TT Building and Transport. *VTT Publications.* [online] Available: https://www.researchgate.net/publication/27516137_The_Intelligence_of_Intelligent_Buildings_The_Feasibility_of_the_Intelligent_Building_Concept_in_Office_Buildings [Viewed 10 June 2016].

Hine, J., Swan, D., Scott, J., Binnie, D., & Sharp, J. 2000. Using technology to overcome the tyranny of space: information provision and wayfinding*. Urban studies*, vol. 37, no. 10, pp. 1757-1770.

Hoes, P., Hensen, J.L.M., Loomans, M.G.L.C., De Vries, B. & Bourgeois, D. 2009. User behavior in whole building simulation. *Energy and Buildings*, vol. 41, no. 3, pp. 295-302.

Hoffman, R.R., & Branlat, M. 2016. To know or not to know, what is the need?*. IEEE Intelligent Systems*, vol. 1, pp. 78-82.

Holmner, M.A., 2008. A critical analysis of information and knowledge societies with specific reference to the interaction between local and global knowledge systems (Doctoral dissertation, University of Pretoria).

Hopwood B, Mellor M, & O'Brien G. 2005. Sustainable development: mapping different approaches. *Sustainable Development*, vol. 13, pp. 38–52.

Howard, R. & Björk, B.C. 2008. Building information modelling–Experts' views on standardisation and industry deployment. *Advanced Engineering Informatic*s, vol. *22*, no. 2, pp. 271-280.

Hsee, C.K., Loewenstein, G.F., Blount, S. & Bazerman, M.H. 1999. Preference reversals between joint and separate evaluations of options: A review and theoretical analysis. *Psychological bulletin*, vol. 125, no. 5, pp. 576-590.

Inkpen, A.C. & Tsang, E.W. 2005. Social capital, networks and knowledge transfer. *Academy of Management Review*, vol. 30, no. 1, pp. 146-165.

Intille, S.S., Larson, K., Beaudin, J.S., Nawyn, J., Tapia, E.M. & Kaushik, P. 2005. A living laboratory for the design and evaluation of ubiquitous computing technologies.

In: *CHI'05 extended abstracts on human factors in computing systems*, pp. 1941-1944. ACM.

ITU. 2003. *World Telecommunication Development Report – access indicators for the information society.* [online] Available: http://www.itu.int/net/wsis/tunis/newsroom/stats/WorldTelecomDevelopmentReport-2003_E.pdf [Viewed 8 March 2015].

ITU World Telecommunication / ICT Indicators database. 2015. *The world in 2014 – ICT facts and figures.* [online] Available: http://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2013-e.pdf [Viewed 8 March 2015].

Jabareen, Y. 2008. A New Conceptual Framework for Sustainable Development. *Environment, Development and Sustainability*, vol. 10 no. 2. pp. 179-192.

Jensen, K.B. ed. 2013. *A handbook of media and communication research: Qualitative and quantitative methodologies*. London: Routledge.

Jung, Y. & Joo, M. 2011. Building information modelling (BIM) framework for practical implementation*. Automation in Construction*, vol. 20, no. 2, pp. 126-133.

Kalay, Y. E. (2006). The impact of information technology on design methods, products and practices. *Design Studies*, vol. 27, no. 3, pp. 357-380.

Kaplan S., & Kaplan, R. 1982*. Cognition and environment.* New York, NY: Praeger Publishers.

Kasarda, M. et al. 2007. Design for adaptability (DFAD)—a new concept for achieving sustainable design. *Robotics and Computer-Integrated Manufacturing*, vol. 23, no. 6, pp. 727-734.

Kates, R.W., Clark, W.C., Corell, R., Hall, M.J., Jaeger, C.C., Lowe, I., McCarthy, J.J., Schellnhuber, H.J., Bolin, B., Dickson, N.M., et al. 2001. Sustainability science. *Science*, vol. 292, pp. 641–642.

Kent, D.C. and Becerik-Gerber, B. 2010. Understanding construction industry experience and attitudes toward integrated project delivery. *Journal of construction engineering and management*, vol.136, no. 8, pp.815-825.

Keohane, R. O., & Nye, J. S. Jr. 1998. Power and interdependence in the Information Age*. Foreign Affairs*, vol. 77, no. 5, pp. 81-94.

Kibert, C.J. 2008. *Sustainable construction: green building design and delivery*. Hoboken, NJ: John Wiley & Sons.

Kinder, K.E., Ball, L.J. & Busby, J.S. 2008. Ubiquitous technologies, cultural logics and paternalism in industrial workplaces*. Poiesis & Praxis*, vol. 5, nos. 3-4, pp. 265-290.

Kriščiūnas, K. & Daugėlienė, R., 2015. The assessment models of knowledge-based economy penetration. *Engineering Economics*, vol. 50, no. 5, pp. 36-46.

Komninos, N. 2013. Smart cities and the future internet: Innovation ecosystems of embedded spatial intelligence*. International Conference for Entrepreneurship, Innovation and Regional Development (ICEIRD 2013).* Istanbul: Istanbul Sehir University.

Kucukvar, M. & Tatari, O. 2013. Towards a triple bottom-line sustainability assessment of the US construction industry*. The International Journal of Life-Cycle Assessment*, vol. 18, no. 5, pp. 958-972.

Kushner, M. 2014. Why the buildings of the future will be shaped by … you [Video file]. [Online] Available: http://www.ted.com/talks/marc_kushner_why_the_buildings_of_the_future_will_be_shaped_by_you [Viewed 26 May 2015].

Langheinrich, M. 2002. A privacy awareness system for ubiquitous computing environments. In: *UbiComp 2002: Ubiquitous Computing,* September-October 2002, Göteborg, Sweden pp. 237-245. Berlin: Springer.

Laurel, B. 2003. *Design research: Methods and perspectives*. London: MIT press.

Lawson, B. & Loke, S.M. 1997. Computers, words and pictures. *Design studies*, vol. 18, no. 2, pp. 171-183.

Lenhart, A., Purcell, K., Smith, A. & Zickuhr, K. 2010. Social Media & Mobile Internet Use among Teens and Young Adults. Millennials. *Pew internet & American life project*. Washington DC, USA: Pew Research Centre.

Lennon, D. 1999. The future of ‘free’ information in the Age of the Internet*. Aslib Proceedings*, vol. 51, no. 9, pp. 285-289. doi: http://dx.doi.org/10.1108/EUM0000000006988.

Leupen, B., Grafe, C., et al. 1997. *Design and analysis*. Rotterdam: 010 Publishers.

Lipson, H., Pollack, J.B. & Suh, N.P. 2001. Promoting modularity in evolutionary design. In: *Proceedings of DETC*, vol. 1, no. 2001, pp. 9-12.

Liu, C.C., & Milrad, M. 2010. One-to-One Learning in the mobile and ubiquitous Computing Age. *Educational Technology and Society*, vol. 13, no. 4, pp. 1-3.

Lloyd, P., & Scott, P. 1994. Discovering the design problem. *Design studies*, vol. 15(2), pp. 125-140.

Lorch, R., & Cole, R., J. 2008. Introduction: Knowledge, values and building design. In: Lorch, R. 2008. *Buildings, culture and environment: informing local and global practices*. pp. 1-13. Hoboken, NJ: John Wiley & Sons.

Macagnano, M. 2015. The future of the built environment in the Information Age: Integrating concepts of sustainability, Information and Communication Technology and architecture*.* In: *Smart and Sustainable Built Environments (SASBE) 2015 Conference Proceedings,* pp. 443-457.

MacDonald, S., Anderson, P., & Kimbel, D. 2000. Measurement or management?: Revisiting the productivity paradox of information technology*. Vierteljahrshefte zur Wirtschaftsforschung*, vol. 69, no. 4, pp. 601-617.

Mahmoodi, A.S. 2001. *The design process in architecture: a pedagogic approach using interactive thinking* (Doctoral dissertation, University of Leeds).

Manley, K. & McFallan, S. 2003. *Innovation adoption behaviour in the construction sector: The case of the Queensland road industry*. Queensland University of Technology.

Mansell, R. (2002) *From digital divides to digital entitlements in knowledge societies.* Current sociology, vol. 50 (3). pp. 407-426. DOI: 10.1177/0011392102050003007

Mansell, R. & Tremblay, G. 2013. *Renewing the knowledge society's vision for peace and sustainable development*. UNESCO. Paris, France.

Mansell, R., & When, U. 1998. *Knowledge societies: Information technology for sustainable development*. New York, NY: Oxford University Press.

Mason, R. O. 1986. Four Ethical Issues of the Information Age*. MIS Quarterly*, vol. 10, no. 1, pp. 5-12.

Massumi, B. 1998. Stelarc: the evolutionary alchemy of reason (an excerpt). In: Beckmann, J. 1998. *The virtual dimension – architecture, representation and crash culture.* New York, NY: Architectural Press.

May, T. A. 2011. Managing the fears that define the Information Age. *Computerworld*, vol. 45, pp. 19.

Mayer, R., et al. 2009. *Connecting the continent: Costing the needs for spending on ICT infrastructure in Africa*. *Background Paper 3 (Phase II)*. Africa Infrastructure Country Diagnostic (AICD). Washington DC: The World Bank.

McCullough, M. 2004. *Digital ground: architecture, Pervasive computing and environmental knowing*. Cambridge, MA: The MIT Press.

McCullough, E. and Matson, P. 2012. Linking knowledge with action for sustainable development: A case study of change and effectiveness. In *Seeds of Sustainability* (pp. 63-82). Island Press/Center for Resource Economics.

McGraw-Hill Construction. 2010. *Green Outlook 2011: Green trends driving growth.* 2011 Industry Forecast and Trends Executive Conference [online] Available: http://aiacc.org/wp-content/uploads/2011/06/greenoutlook2011.pdf [Viewed 4 July 2015].

McKay, J. 2004. *Knowledge Management Governance: A Multifaceted Approach to Organizational Decision and Innovation Support*. School of Information Management and Systems. Melbourne: Monash University. pp. 889-899.

Meadows, D.H., Meadows D.L. & Randers, J. 1975. *The limits to growth: A report for the Club of Rome's project on the predicament of mankind*. New York, NY: New American Library.

Mebratu, D. 1998. Sustainability and sustainable development: historical and conceptual review. *Environmental Impact Assessment Review*, vol. 18, no. 6, pp. 493-520.

Mitchell, W. J. 1998. Architectonic: the poetics of virtuality. In: Beckmann, J. 1998. *The virtual dimension – architecture, representation and crash culture*. New York, NY: Architectural Press.

Moloney, S. & Strengers, Y. 2014. 'Going Green'?: The limitations of behaviour change programmes as a policy response to escalating resource consumption. *Environmental Policy and Governance*, vol. 24 no. 2, pp. 94-107.

Moravec, H. 1998. The senses have no future. In Beckmann, J. (ed.) 1998. *The virtual dimension – architecture, representation and crash culture.* New York, USA: Architectural Press.

Munro, A.J., Höök, K. and Benyon, D. eds. 2012. *Social navigation of information space*. Springer Science & Business Media.

Myburgh, S. 1999. Book review: 'Understanding Information Retrieval Interactions: Theoretical and Practical Implications'. *Journal of the American Society for Information Science*, 1999, vol. 50, no. 13, pp. 1257.

Myro, R. L., Vega, J., & Álvarez, E. (2009). *Information Technologies and Economic Growth: Do the Physical Measures Tell Us Something?* [online] Available: https://www.researchgate.net/publication/228295406_Information_Technologies_and_Economic_Growth_Do_the_Physical_Measures_Tell_Us_Something [Viewed 10 June 2016].

Navrat, P. 2012. Cognitive traveling in digital space: from keyword search through exploratory information seeking. *Open Computer Science*, vol. *2*, no. 3, pp.170-182.

Ness, B., Urbel-Piirsalu, E., Anderberg, S. and Olsson, L., 2007. Categorising tools for sustainability assessment. *Ecological Economics*, vol. 60, no. 3, pp. 498-508.

Ngwenyama, O., and Morawczynski, O. 2010. Factors affecting ICT expansion in emerging economies: An analysis of ICT infrastructure expansion in five Latin American countries. *Information Technology for Development*, vol. 15, no. 4, pp. 237-258.

Nofera, W., Korkmaz, S., and Miller, V. 2011. Innovative features of integrated projects delivery shaping project team communication. In: *Engineering Project Organisations Conference (EPOC) 2011 Working Paper Proceedings*. Colorado, USA.

Nonaka, I. & Konno, N. 1998. *The concept of "ba": Building a foundation for knowledge creation*. *California Management Review*, vol. 40, no. 3, pp. 40-54.

Nonaka, I. & Toyama, R. 2003. The knowledge-creating theory revisited: knowledge creation as a synthesizing process. *Knowledge Management Research & Practice*, vol. 1, no. 1, pp. 2-10.

Norris, P. 2001. *Digital divide: Civic engagement, information poverty and the Internet worldwide*. Cambridge: Cambridge University Press.

Owen, R.L., Palmer, M.E., Dickinson, J.K., Tatum, C.B., Kazi, A.S., Amor, R. and Prins, M. 2009. *CIB White Paper on IDDS Integrated Design & Delivery Solutions*.

Owen, R.L., Amor, R., Dickinson, J.K., Drogemuller, R.M., East, E..W., Katoaka, M., Samad, A., Kiveniemi, A., McCoy, A., Moum, A., Palmer, M.E., Pawsey, N., Prins, M., Regan, J.T., Shen, G. 2012. *CIB Priority Theme Improving Construction and Use through Integrated Design & Delivery Solutions (IDDS) - Research Trajectories Paper.*

Penttilä, H. 2006. Describing the changes in architectural information technology to understand design complexity and free-form architectural expression. *ITcon*, vol. 11, Special Issue. The Effects of CAD on Building Form and Design Quality, pp. 395-408.

Perugia, F. 2015. Stating the need for an architectural design process: The role of the space syntax method in a case study of Western Australia project homes. In *SSS*^{10} *Proceedings of the 10th International Space Syntax Symposium.*

Pohl, J. 2011. *Building Science: concepts and application*. Oxford: Wiley-Blackwell Publishing.

Poizat, G., Fréjus, M. and Haradji, Y. 2009, September. Analysis of activity in domestic settings for the design ubiquitous technologies. In *European Conference on Cognitive Ergonomics: Designing beyond the Product---Understanding Activity and User Experience in Ubiquitous Environments*, pp. 14. VTT Technical Research Centre of Finland.

Popov, V., Mikalauskas, S., Migilinskas, D. & Vainiūnas, P. 2006. Complex usage of 4D information modelling concept for building design, estimation, scheduling and determination of effective variant. *Technological and Economic Development of Economy*, vol. 12, no. 2, pp. 91-98.

Poston, B. 2009. Maslow's Hierarchy of Needs. *The Surgical Technologist,* August 2009, pp. 347-353.

Prensky, M. 2001. Digital natives, digital immigrants part 1. *On the Horizon*, vol. 9, no. 5, pp. 1-6.

Prensky, M. 2009. *H.* Sapiens digital: From digital immigrants and digital natives to digital wisdom*. Innovate: Journal of Online Education*, vol. 5, no. 3, pp. 1-11.

Prins, M. and Owen, R. 2010. Integrated design and delivery solutions. *Architectural Engineering and Design Management*, vol. 6, no. 4, pp. 227-231.

Probst, G.J. 1998. *Practical knowledge management: A model that works*. Cambridge MA: Prism.

Rajan, P., Van Wie, M., Campbell, M., Otto, K. & Wood, K. 2003. Design for flexibility-measures and guidelines. *DS 31: Proceedings of ICED 03, the 14th International Conference on Engineering Design,* Stockholm.

Ranft, A. 2006. Knowledge preservation and transfer during post-acquisition integration. *Advances in Mergers and Acquisitions*, vol. 5, no. 1, pp. 51-67.

Redclift, M. 1991. The multiple dimensions of sustainable development. *Geography*, vol.76. no. 1, pp.36-42.

Roberts, S., Magpantay, E., Gray, V., Teltscher, S., Gil, S. F., & Korka, D. (Partnership on Measuring ICT for Development). 2008. *The Global Information Society: a Statistical View*. New York, NY: United Nations Publication.

Romano, K., Rusert, M., & Reeve, H. 2015. *Integrated and intelligent buildings: an imperative to people, the planet and the bottom line.* Council on Tall Buildings and Urban Habitat (CTBUH). Paper published in conference proceedings: The Future of Tall: a selection of written works on current skyscraper innovations. [online] Available: http://global.ctbuh.org/resources/papers/download/2404-integrated-and-intelligent-buildings-an-imperative-to-people-the-planet-and-the-bottom-line.pdf [Viewed 12 May 2016].

Riaz, M. T., Gutierrez, J. M., & Pederson, J. M. 2009. Strategies for the next generation green ICT infrastructure. In *Applied Sciences in Biomedical and Communication Technologies*. ISABEL 2009. 2nd International Symposium, pp. 1-3. doi: 10.1109/ISABEL.2009.5373604.

Roland, L., & Bawden, D. 2012. The future of history: Investigating the preservation of information in the Digital Age. *Library & Information History*, vol. 28, no. 3, pp. 22 -236.

Roozenburg, N. F. M., & Cross, N. G. 1991. Models of the design process*. Design Studies*, vol. 12, no. 4, pp. 247-278.

Rondoni, J.C. 2003. *Context-aware experience sampling for the design and study of ubiquitous technologies.* Doctoral dissertation. Cambridge, MA: Massachusetts Institute of Technology.

Rosen, D. E., & Purinton, E. 2004. *Website design: viewing the web as a cognitive landscape*. *Journal of Business Research*, vol. 57, pp. 787-794.

Ross, S. 2000. *Changing Trains at Wigan: Digital preservation and the future of Scholarshi*p. National Preservation Office. [online] Available: http://www.webcitation.org/5vC9RzSSq [Viewed 12 July 2015].

Ruby, A. 1993. Architecture in the age of its virtual disappearance – an interview with Paul Virilio. In: Beckmann, J. 1998. *The virtual dimension – architecture, representation and crash culture*. New York, NY: Architectural Press.

Salingaros, N. A. 1999. Architecture, patterns and mathematics*. Nexus Network Journal*, vol. 1. nos. 1-2, pp. 75-78.

Samuels, W. J. 2002. *Economics, governance and law: Essays on theory and policy*. Cheltenham: Edward Elgar.

Sapsed, J., Gann, D., Marshall, N. and Salter, A. 2005. From here to eternity?: The practice of knowledge transfer in dispersed and co-located project organizations*. European Planning Studies*, vol. 13, no. 6, pp. 831-851.

Sariyildiz, S. and Ozsariyildiz, S. 1998. The Future of Architectural Design Practice within ICT Development. In *Computerised Craftsmanship, eCAADe Conference Proceedings, Paris, September 24-26.*

Schlick, J. 2012. Cyber-physical systems in factory automation-Towards the 4th Industrial Revolution. In *Factory Communication Systems (WFCS), 2012 9th IEEE International Workshop*, pp. 55. IEEE. doi: 10.1109/WFCS.2012.6242540

Selwyn, N. 2004. Reconsidering political and popular understandings of the digital divide. *New Media & Society*, vol. 6, no. 3, pp. 341-362.

Sepasgozar, S.M. & Bernold, L.E. 2012. Factors influencing the decision of technology adoption in construction. In: *Developing the Frontier of Sustainable Design, Engineering, and Construction–Proceedings of the 2012 International Conference on Sustainable Design and Construction (ICSDEC 2012)*, pp. 654-661.

Seo, S., Tucker, S., Ambrose, M., Mitchell, P., & Wang, C.H. 2006. *Technical evaluation of environmental assessment rating tools.* Research and Development Corporation, Project No. PN05.1019. [online] Available: http://www.fwpa.com.au/images/marketaccess/PN05.1019.pdf [Viewed 10 June 2016]

Shackel, B. 1990. Human factors and usability. In: *Human-computer interaction,* pp. 27-41. Upper Saddle River, NJ: Prentice Hall.

Sharma, R.S., Ng, E.W., Dharmawirya, M. & Samuel, E.M. 2012. A policy framework for developing knowledge societies*.* In: Lytras, M., & Novo-Corti, I. (eds.). 2012. *Trends and Effects of Technology Advancement in the Knowledge Society*. Hershey, PA: Information Science Reference. pp. 24-46.

Sheldon, K.M., Elliot, A.J., Kim, Y. & Kasser, T. 2001. What is satisfying about satisfying events? Testing 10 candidate psychological needs. *Journal of Personality and Social Psychology*, vol. 80, no. 2, pp. 325-339.

Singh, R.K., Murty, H.R., Gupta, S.K. & Dikshit, A.K. 2009. An overview of sustainability assessment methodologies*. Ecological Indicators*, vol. 9, no. 2, pp. 189-212.

Singh, R.K., Murty, H.R., Gupta, S.K. & Dikshit, A.K. 2012. An overview of sustainability assessment methodologies. *Ecological Indicators*, vol. 15, no. 1, pp. 281-299.

Smith, P. 2003. *Sustainability at the Cutting Edge: Emerging technologies for low energy buildings.* Oxford: Architectural Press.

So, A. T.P., Wong, K.C., & Leung, A. Y. T. 2001. *The intelligent building index (IBI) manual: version 2.0.* Hong Kong: Asian Institute of Intelligent Buildings.

Stenslie, S. 1998. Flesh Space. In: Beckmann, J. 1998. *The Virtual Dimension – Architecture, representation and crash culture*. New York, NY: Architectural Press.

Stock, W.G. 2011. Informational cities: Analysis and construction of cities in the knowledge society. *Journal of the American Society for Information Science and Technology*, vol. 62, no. 5, pp. 963-986.

Succar, B. 2009. Building information modelling framework: A research and delivery foundation for industry stakeholders. *Automation in Construction*, vol. 18, no. 3, pp. 357-375.

Succar, B. 2009. Building information modelling maturity matrix. In: J. Underwood, & U. Isikdag. (eds.). *Handbook of Research on Building Information Modelling and Construction Informatics: Concept and Technologies*, pp. 65-103. doi: 10.4018/978-1-60566-928-1.

Szulanski, G. 2000. The process of knowledge transfer: A diachronic analysis of stickiness. *Organizational Behavior and Human Decision Processes*, vol. 82, no. 1, pp. 9-27.

Thinyane, H. 2010. Are digital natives a world-wide phenomenon? An investigation into South African first year students' use and experience with technology. *Computers & Education*, vol. 55, no. 1, pp. 406-414.

Tongia, R. et al. 2004. *Information and communications technology for sustainable development: Defining a global research agenda*. Bangalore: Allied Publishers.

Trinius, W., and Chevalier, J. 2005. "Sustainable construction in ISO/TC59." *Proceedings of the SB05 Tokyo: Action for Sustainability – The 2005 World Sustainable Building Conference*. pp. 4617-4623.

UNESCO. 2015. *Building Inclusive Knowledge* Societies. [online] Available: http://en.unesco.org/post2015/building-inclusive-knowledge-societies [Viewed 28 February 2015].

UNESCO. 2015. *The Power of Culture for Development.* [online] Available: http://en.unesco.org/post2015/power-culture-development [Viewed 28 February 2015].

United Nations Conference on Environment and Development (UNCED). 1992. *Agenda 21*. New York, NY: Oxford University Press for the United Nations World Commission on Environment and Development.

United Nations (UN). 2000. *Resolution 55/2 United Nations Millennium Declaration*. New York, NY: Oxford University Press for the United Nations General Assembly.

Van Dijk, J.A. 2006. Digital divide research, achievements and shortcomings. *Poetics*, vol. 34, no. 4, pp. 221-235.

Van Winden, W., Van Den Berg, L. & Pol, P. 2007. European cities in the knowledge economy: towards a typology. *Urban Studies*, vol. 44, no. 3, pp. 525-549.

Vetere, F., Howard, S. & Gibbs, M. 2005. Phatic technologies: Sustaining sociability through ubiquitous computing. In: *First International Workshop on Social Implications of Ubiquitous Technology.* ACM Conference on Human Factors in Computing Systems, CHI. [online] Available: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.436.7506&rep=rep1&type=pdf [Viewed 10 June 2016].

Vischer, J.C. 2008. Towards a user-centred theory of the built environment. *Building Research & Information*, vol. 36, no. 3, pp. 231-240.

Von Krogh, G., Ichijo, K. & Nonaka, I. 2000. *Enabling knowledge creation: How to unlock the mystery of tacit knowledge and release the power of innovation*. Oxford: Oxford University Press.

Wardah, E.S.A.A. and Khalil, M.O. 2016. Design Process & Strategic Thinking in Architecture. In *Proceedings of 2016 2nd International Conference on Architecture, Structure and Civil Engineering (ICASCE'16)*, pp. 32-45.

Weiser, M. 1999. The computer for the 21st century*. Mobile Computing and Communications Review*, vol. 3, no. 3, pp. 3-11.

Welman, C., Kruger, F., & Mitchell, B. 2005. *Research Methodology – Third Edition.* Oxford University Press, South Africa.

Webster, F. 2001. *Culture and Politics in the Information Age*. London: Routledge.

Wertheim, M. 1998: The medieval return of cyberspace. In: Beckmann, J. 1998. *The virtual dimension – architecture, representation and crash culture*. New York, NY: Architectural Press.

Williams, D. E. 2007. *Sustainable design: ecology, architecture and planning.* Hoboken, NJ: John Wiley and Sons.

Williams, J. I. 2000. Ready, set, stop: Reflections on assessing quality of life and the WHOQOL. *Journal of Clinical Epidemiology*, vol. 53, pp. 13-17.

Wilson, E. O. 2003. Biodiversity in the Information Age. *Issues in Science and Technology*, vol. 19, no. 4, pp. 45-48.

Wong, A.K., Wong, F.K. & Nadeem, A. 2010. Attributes of building information modelling implementations in various countries. *Architectural Engineering and Design Management*, vol. 6, no. 4, pp. 288-302.

Wong, D. 2014. Study reports 20% of overall traffic comes from Facebook and Pinterest. *Search Engine Journal*. [online] Available: http://www.searchenginejournal.com/study-reports-20-overall-traffics-comes-facebok-pinterest/87413 [Viewed 24 May 2015].

Wong, D. 2015. *In Q4 social media drove 31.24% of overall traffic to site [report]*. Shareaholic reports: Social media. [online] Available: https://blog.shareaholic.com/social-media-traffic-trends-01-2015/ [Viewed 24 May 2015].

Wong, J.K., Li, H. & Wang, S.W. 2005. Intelligent building research: a review. *Automation in Construction*, vol. 14, no. 1, pp. 143-159.

World Commission on Environment and Development (WCED). 1987. *Our common future (The Brundtland Report)*. New York, NY: Oxford University Press for the United Nations World Commission on Environment and Development.

World Health Organisation Quality of Life Group (WHOQOL Group). 1995. The World Health Organisation Quality of Life Assessment (WHOQOL-100): Position Paper from the World Health Organisation. *Social Sciences and Medicine*, vol. 41, no. 10, pp. 1403-1409.

World Health Organisation Quality of Life Group (WHOQOL Group). 1998. The World Health Organisation Quality of Life Assessment (WHOQOL): Development and general psychometric properties. *Social Sciences and Medicine*, vol. 46, no. 12, pp. 1569-1585.

World Summit on the Information Society. 2003. *Declaration of Principles – Building the Information Society: a global challenge in the new Millennium*. Document WSIS-03/GENEVA/DOC/4-E. [online] Available: http://www.itu.int/dms_pub/itu-s/md/03/wsis/doc/S03-WSIS-DOC-0004!!PDF-E.pdf [Viewed 27 April 2015].

Wresch, W. 1996. *Disconnected: Haves and have-nots in the Information Age*. New Brunswick, NJ: Rutgers University Press.

Wright, P. & McCarthy, J. 2004. *Technology as experience*. Cambridge, MA: MIT Press.

Yan, H. & Damian, P. 2008. Benefits and barriers of building information modelling. In: *12th International conference on computing in civil and building engineering,* vol. 161.

Yang, J., Brandon, P., & Sidwell, A. 2005. *Smart and sustainable built environments*. Oxford: Blackwell.

Yilmaz, S. & Daly, S.R. 2016. Feedback in concept development: Comparing design disciplines. *Design Studies*, vol. 45, pp. 137-158.

Yigitcanlar, T., & Lönnqvist, A. 2013. Benchmarking knowledge-based urban development performance: Results from the international comparison of Helsinki. *Cities*, vol. 31, pp. 357-369.

Yigitcanlar, T., O'Connor, K. & Westerman, C. 2008. The making of knowledge cities: Melbourne's knowledge-based urban development experience. *Cities*, vol. 25, no. 2, pp. 63-72.

Young, N.W., Jones, S.A., Bernstein, H.M. & Gudgel, J. 2008. *SmartMarket report on building information modeling (BIM): Transforming design and construction to achieve greater industry productivity*. [online] Available: http://www.aia.org/aiaucmp/groups/aia/documents/pdf/aias077483.pdf [Viewed 10 June 2016].

Zhu, Y.Q. & Chen, H.G. 2015. Social media and human need satisfaction: Implications for social media marketing. *Business Horizons*, vol. 58, no. 3, pp. 335-345.

Zubcsek, P.P., Chowdhury, I., & Katona, Z. 2014. Information communities: The network structure of communication. *Social Networks*, vol. 38, pp. 50-62.

Zucchella, A. & Urban, S. 2014. Futures of the sustainable firm: An evolutionary perspective. *Futures*, vol. 63, pp. 86-100.

8.1. Further reading

Ball, M., Callaghan, V., & Gardner, M. 2010. An adjustable-autonomy agent for intelligent environments. *Intelligent Environments (IE), 2010 Sixth International Conference on Intelligent Environments* (pp. 1-6). IEEE.

Chen, J. Y., Ma, Y. P., Jeng, T.S., & Chang, C. C. 2010. An assessment of user needs for intelligent living space. *Intelligent Buildings International*, vol. 2, no. 1, 20-40.

Gibberd, J. 2003. *Integrating sustainable development into briefing and design processes of buildings in developing countries: an assessment tool*. Doctoral thesis. Pretoria: University of Pretoria.

Ghaffarian Hoseini, A. 2012. Ecologically sustainable design (ESD): theories, implementations and challenges towards intelligent building design development. *Intelligent Buildings International*, vol. 4, no. 1, pp. 34-48.

Komninos, N. 2006. The Architecture of Intelligent Cities - Integrating Human, Collective and Artificial Intelligence to Enhance Knowledge and Innovation. Dissertation (Degree Unknown). Thessaloniki: Urban and Regional Innovation (URENIO) Research Unit, Aristotle University of Thessaloniki, Greece.

Poston, A., Emmanuel, R., & Thomson, C. 2010. Developing holistic frameworks for the next generation of sustainability assessment methods for the built environment. *Proceedings of the 26th annual ARCOM conference,* Leeds pp. 6-8.

Riese, M. 2012. Technology-Augmented Changes in the Design and Delivery of the Built Environment. In *Digital Urban Modelling and Simulation* (pp. 49-69). Berlin: Springer.

Whyte, J., & Sexton, M. 2011. Motivations for innovation in the built environment: new directions for research. *Building Research & Information*, vol. 39 no. 5, pp. 473-482.