A critical analysis of the potential impact of higher education on South African emerging building technologies

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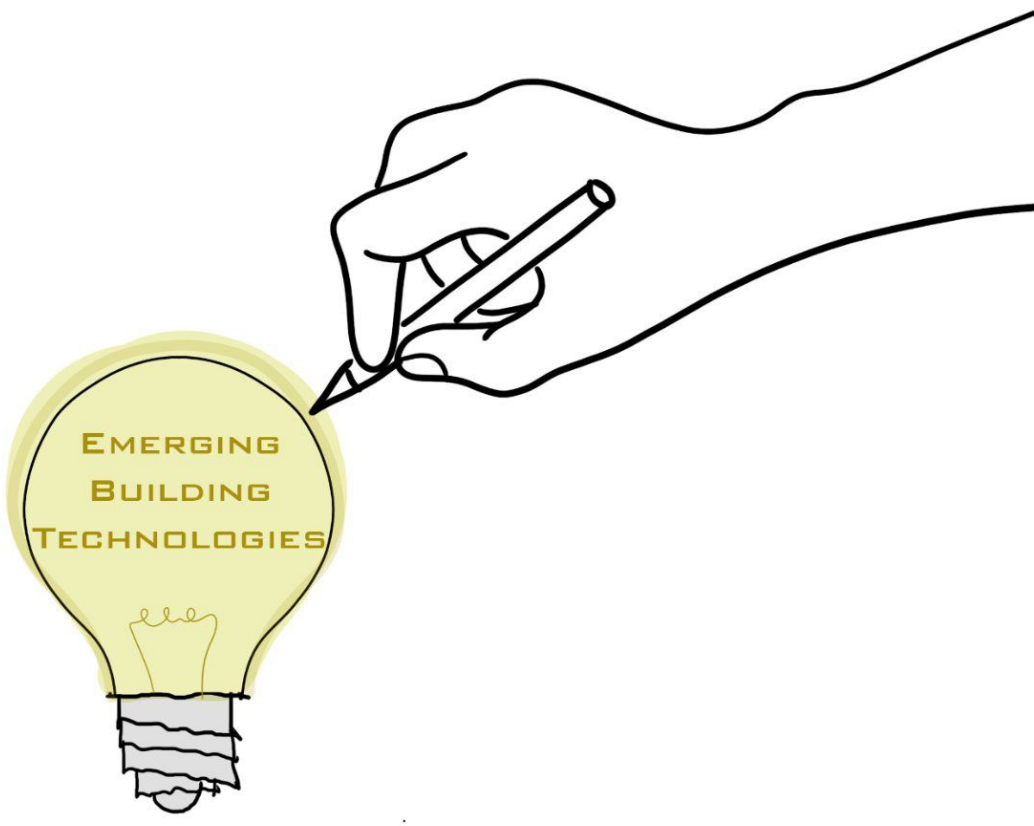

DECLARATION OF ORIGINALITY

I declare that the mini-dissertation, *A critical analysis of the potential impact of higher education on South African emerging building technologies*, which has been submitted in fulfilment of part of the requirements for the module of *Design Investigate Treatise (DIT 801*), at the University of Pretoria, is my own work and has not previously been submitted by me for any degree at the University of Pretoria or any other tertiary institution.

I declare that I obtained the applicable research ethics approval in order to conduct the research that has been described in this dissertation.

I declare that I have observed the ethical standards required in terms of the University of Pretoria's ethical code for researchers and have followed the policy guidelines for responsible research.

Signature: ……Kristel Botha……

Date: ……24/07/2023……

Abstract

The intrinsic values that emerging building technologies (EBTs) offer to the built environment are tremendous. The use of EBTs in South Africa is not merely an exciting new chapter within our built industry's development, but a crucial one. The South African built environment is one of resilience - although faced with many challenges, the industry has remained and has become a strong force that keeps on producing new structures. The steadfast continuation is however not untroublesome - the problem arises when one considers that the growth of innovation in the industry has reached a plateau causing severe issues, both environmental and economic. The tectonic trajectory is brought into consideration during this study along with its role players who determine how the industry's development could be improved through the implementation of EBTs. Current practitioners working in established firms are found to be making use of mainly conventional/non-EBTs in their projects, which currently hinders development. With the industry being one of the strongest pillars in the economy, this issue remains to be a major problem to be addressed. This paper investigates the EBTs in South Africa by compiling relevant case studies in a catalogue that reflects the material, construction process or structural system that makes use of an EBT. Inductive reasoning is then used in the data analysis to conclude that the knowledge produced in architectural academia could be the optimal solution to influence the built industry's current use of building technologies and as a result aid in the continuation of the tectonic trajectory that will minimise the issues caused by the built environment. Various practitioners were identified to make use of a range of EBTs, though low-tech and undeveloped construction processes are evident to be the best application of EBTs from academia's side. The study found that South Africa's built industry is experiencing the influx of *emerging building technologies,* which acts as a catalyst for the industry's initially identified stagnant state.

Keywords: emerging building technology, built industry, tectonic trajectory, current building practice, practitioner, innovation, waste production, built environment, architectural academia.

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“Technology is rooted in the past, dominates the present and extends to the future”
Mies van der Rohe

(Wu, Wei & Peng, 2019: 1)

1 Report

1.1 Key Terms

This report makes use of specific terminology that is suitable to the theme of this research paper. The definition of some terms are listed below to provide a clear understanding of what they entail.

Current practice

Architectural firms that are active roleplayers in the industry and thus the socio- and economic growth in South Africa (Windapo, 2013: 65) that make use of conventional building technologies. materials and products that are available from a predefined catalogue (Loh, 2019: 18), from the country's established built industry and often use current resources in an inefficient manner (Othman, 2009: 37). Current practice mainly follows a linear path of building design to the construction process, leaving practice detached from the fabrication process (Loh, 2019: 18).

Building Technology

A building technology is classified as a material, construction process or structural system that has in the past been created based on a particular geographical environment (Wu, Wei & Peng, 2019: 1). The history of the development of building technologies contains the development of buildings over time, meaning that building technologies are usually dynamic in nature in terms of its evolvement over time (Wu, Wei, Peng, 2019: 1-2).

Emerging Building Technology

An emerging building technology (EBT) is the development or continuation of a building technology that has emerged over the past 15 years within the South African built environment. Emerging building technologies are counter to the current/conventional building technologies that are mainly used in the industry and can be formulated in a variety of ways. It can be due to the hybridization of local and global technologies (Louw, 2022: 2) or the contemporary consideration of vernacular traditions/African building dynamics (Steyn, 2020: 2). Another way is by means of digital manufacturing with involvement of "craft practice as a knowledge-generating activity…" (Loh, 2019: 258), or the invention of a complete new material, construction process or structural system (Wu, Wei & Peng, 2019: 1). These building technologies can be placed on a spectrum of being low-tech (hand-based) or high-tech (industrialised) as a mode of production as well as receiving a development status within the local context. Emerging building technologies hold intrinsic value to the built environment by being either versatile, economic, socially responsible or contextually responsive.

1.2 Introduction

The tectonic trajectory, a topic that was prominently discussed by Kenneth Frampton, is a universal timeline of the built environment's development as it has been formed by the hands of architectural designers as one of the key actors in the construction industry (Othman, 2009: 36). This trajectory is a product not only of what happened in history, but of the continuous implementation of new technologies in the design processes of practitioners in the industry. This sustained manner of creating structures with new building technologies has created a well-established built industry that functions as a complex cluster with many individuals involved (Windapo, 2013: 65).

The architects, who can be considered as the main drivers of this trajectory, along with engineers and other professionals (Frampton, 1995: 335), have contributed to it by constantly employing new building technologies when designing structures. This has led to a strong relationship between practitioner and building technology. Building technology can be defined as a material, construction process or structural system (Wu, Wei & Peng, 2019: 1). This relationship is expressed through the architectural design process, also referred to as architectural production (Louw, 2021: 10) and the process of making by architects (Loh, 2019: 34).

Within the South African context the built industry has reached a plateau in terms of its development and growth (Windapo, 2013: 65). The built environment's stagnation is due to the lack of innovation and experimentation in the architectural design process in the industry. This can be directly linked to the lag in technological development as well as the slow pace of adoption of new technologies within architectural firms (McCoy, 2021: 1). The industrial revolution that brought about mechanised production tools, new construction processes and an increase in building material cost has led to this stagnant state (Wu, Wei & Peng, 2019: 1).

The built environment cannot afford to be static, due to the environmental circumstances that the built industry is currently causing for South Africa. The construction industry is a main contributor to climate change, pollution, energy use and the exhaustion of valuable and limited resources (Othman, 2009: 39) with the role that an architect plays as critical in the execution of sustainability (Sebake, 2008: 12). The built industry is not only a culprit in terms of its destructive impact on the natural environment, but acts as an essential role player in the country's economic and social development (Othman, 2009: 36). There is a crucial need for architects to include appropriate building technologies that would contribute to the further development of the tectonic trajectory in South Africa, which will benefit the economy and the natural environment. The practitioners using current building technologies within their practice are therefore proving to be a contributing factor to the industry's problem. The continuation of the tectonic trajectory is prohibited by these

practitioners which in turn leads to a multitude of environmental, economic and industry development issues.

The solution cannot be to simply continue with new building technologies that are void of specific values that contribute to the built environment, but to be innovative and include building technologies that will be able to add value to the built environment and larger context in South Africa. This introduction to the research is summarised in figure 1, where the starting point is stipulated and a link is drawn through to the solution. This paper investigates Emerging Building Technologies (EBTs) in South Africa and the intrinsic values that they contain. These values predominantly include that the building/structure should be versatile in its use in order to easily replicate it in different settings for different groups of people, contextually responsive, socially responsible and economic.

The development of EBTs are due to a number of factors; hybrid tectonics (Louw, 2021), digital manufacturing (Loh, 2019), blending traditional technologies with contemporary technologies (Steyn, 2020) as well as the correct application in each context which brings regionalization into the picture (Wu, Wei & Peng, 2019).

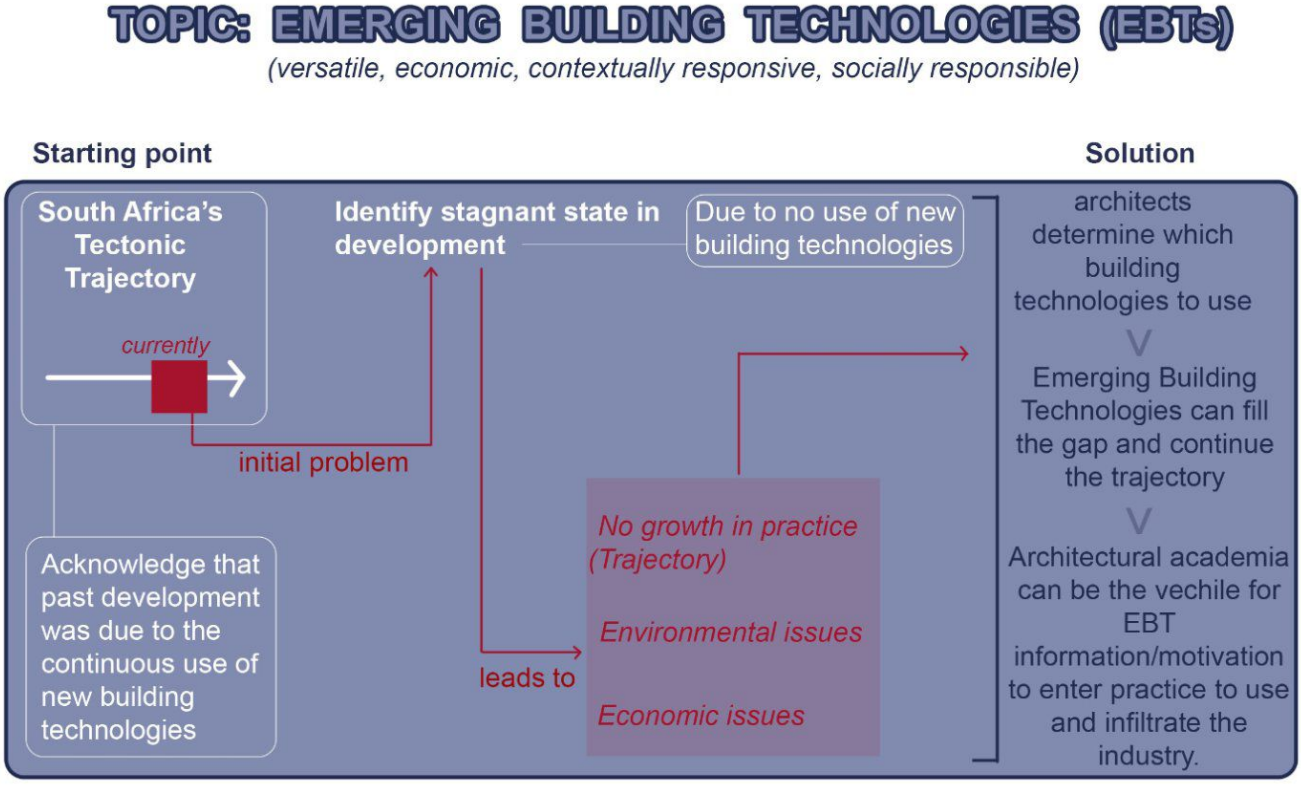

Figure 1: A visual representation of the introduction to the study (Author 2023)

Although it is important to shed light on these processes and principles, the main emphasis will be on how these technologies can be absorbed into the built environment in order to release these intrinsic values into the industry and eventually

the broader environment in South Africa. The success therefore of EBTs will lie in the inclusion of them within the built industry - the origin of this will be in practices that will adopt EBTs in their projects. This places architectural practitioners at the forefront of the discussion with the need to evaluate how they can be implemented by professionals.

The relationship between practitioners and academia is a point of discussion that remains vital to this study, as these role players are involved in the industry as current and training professionals in the built environment system. The current architecture firms consist of established professionals that mainly work with current/conventional building technologies with the majority of these practices not actively working on involving new materials, techniques or structural systems in their design processes. On the other hand, the academic institutions produce a multitude of information regarding EBTs that remains within university/academic institutions.

Academia challenges individuals to apply their minds to combine creativity and knowledge in order to derive the best architectural solutions (Danaci, 2015: 1310), which is an optimal environment for innovation where EBTs can be learned about as well as the correct way of designing with them. The minds that enter the built environment are therefore currently busy with explorations of EBTs and how it could be implemented in the industry in order for their inherent values to benefit the larger built environment. Schwartz (2016: 17-18) acknowledges the challenges that architecture students are faced with in terms of the infrequent intersections between design and construction that arises as a complexity in the learning process, but suggests that with the correct study methods, students of architecture can become a strong driving force in the integrative potential of architectural tectonics. This is depicted in figure 2, where architectural academia stands as the solution to the industry's problem.

Architecture schools are thus viewed as a possible vehicle of success when it comes to employing knowledge on EBTs into South African architectural practice.
A realignment of the future workforce is currently being taught in academia (Gerber, Gerber, Ku, 2011: 411) which equips students of architecture to not only enter architectural firms with valuable knowledge that can have a broader impact on the built environment, but creates an opportunity for current practitioners to become part of a system where EBTs are considered as an integral part of the architectural process.

Academia/architecture schools are considered as a solution due to the experimentation and development of EBTs within the institutions. The time that academia can allocate towards this makes it less restrictive than the built environment's involvement with EBTs. The main reason why the experimentation and investigation process of EBTs is not interwoven into practice is due to the fact that all firms aim to generate an income from their design services, which is usually

on a time schedule, leaving hardly any time to become involved with building technologies that are not established in the industry and readily available for use in projects. This system, from practices' side, is crucial to the economy, since it creates job opportunities, new infrastructure and systems with each project, but is unfortunately contributing to the problem as identified in figure 1, due to the exclusion of EBTs.

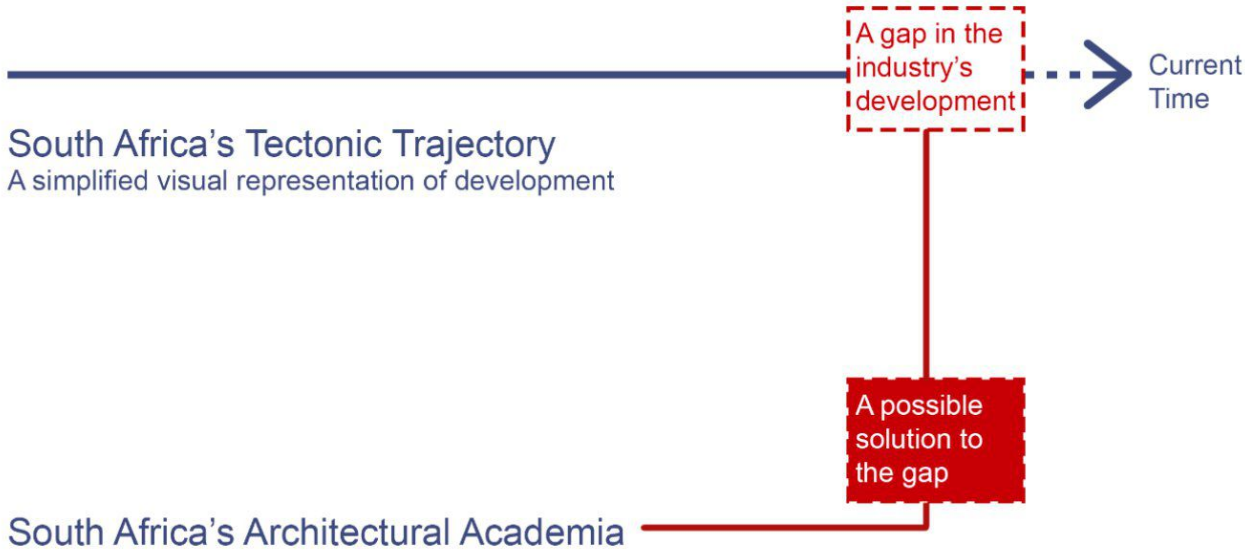

Figure 2: A diagram depicting a simplified visual representation of the development of South Africa's tectonic trajectory, with the current problem as well as the possible solution being architectural academia (Author 2023)

1.3 Problem statement

The built environment plays an important role on both a local and global scale (Othman, 2009: 36), which consequently means the development and growth of the industry is crucial on a universal level (Windapo 2013). Recent studies indicate that the industry's development has faced various constraints, highlighted in the introduction.

Within the South African context, it seems as though the country is seen to be "influenced rather than influencing," (Louw, 2021: 3), which places the country at a disadvantage in terms of architectural development. This does not only hinder the evolution of building technology within the built environment, but causes the current values of conventional building technologies to damage the environment. A recent study done on the impact on the natural environment caused by the built industry showed that the manufacturing of construction materials is responsible for 50% of material resources taken from nature, with another 50% total waste produced while

consuming 40% energy during production (Othman, 2009: 36). This narrative is set to continue since the majority of industries in the built environment make use of conventional technologies that do not support sustainability (Sebake, 2008: 490). On the economic side, the industry is failing to grow and produce the required economic levels, while building material costs keep on increasing (Windapo, 2013: 70).

A possible solution could be to change the technologies we use in the built environment i.e. to include EBTs in the architectural practice. These EBTs are in existence in South Africa, however they are currently under-implemented and thus cannot translate any positive value into the built environment or growth of the industry and eventually the local tectonic trajectory. The next answer would therefore be to focus on how the current architectural practice can adopt EBTs in order to get the rest of the system into action.

Current practitioners continue with their use of conventional building technologies and train graduates to do the same when they enter practice. The problem also comes in where the information taught on EBTs to architecture students become lost when they graduate and are not able to implement it in projects in practice due to the way current practitioners are working. Architecture firms that render themselves inaccessible for the newest information on EBTs discovered in academic and research institutes, only continue to cause more damage due to their architectural design processes. The rationale of the research is unpacked in figure 3 that views this problem through the lens of EBTs.

This model has been presented in earlier years within the South African context by a group of architectural students and professionals, namely the “Building Design Group,” operative from 1968-1977 in Durban, KwaZulu-Natal. These individuals worked in collaboration with each other in an investigative and experimental manner, with shared responsibilities in practice, which “operated at the fringes of conventional practice” (Sanders, 2003: 4). This model is viewed as significant in the field of architecture as it presented and achieved new milestones in the profession from a group of graduates that were “testing boundaries and expanding architectural horizons,” which will be discussed later on in the paper (Sanders, 2003: 235).

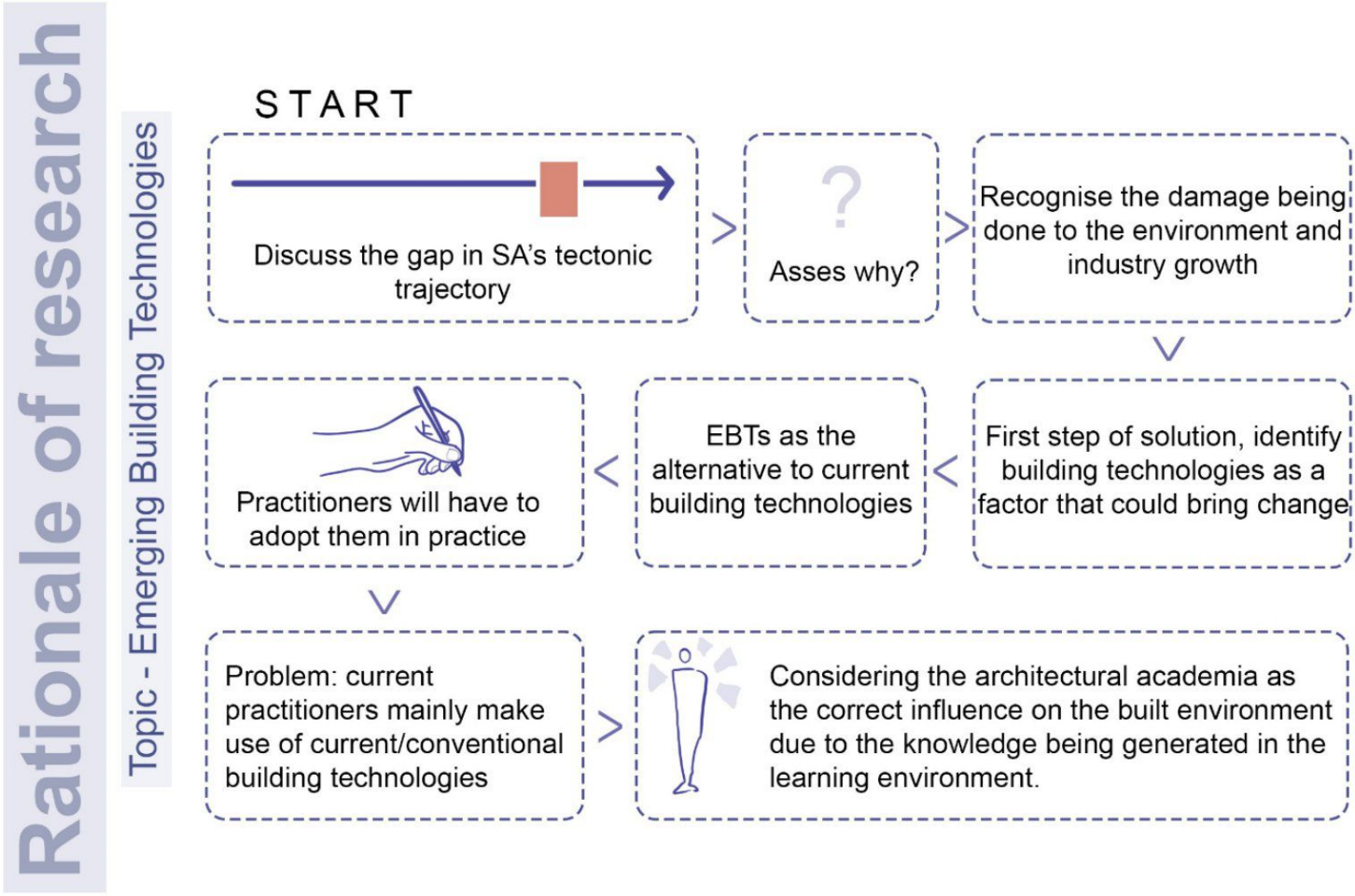

Figure 3: A diagram depicting the rationale of the research through the lens of EBTs (Author 2023)

This study has identified a gap, explained in figure 3, within the published literature regarding EBTs in South Africa. As a result, these EBTs are not widely known and the implementation thereof is limited causing them to make a marginal positive impact on the built industry. This gap will be addressed by the research done by the author, to arrive at the objectives set out in the section below.

1.4 Research objectives

The research objectives are:

- To establish that there is a gap in South Africa's current tectonic trajectory due to the conventional building technologies employed by current practitioners.

- Substantiate why this gap is a problem - no growth in the building industry, environmental and economic issues.

- To find out what types of *emerging building technologies* are currently being adopted by practice in South Africa. The data collection and analysis will be conducted with the primary goal of discovering more information regarding EBTs in practice and then to uncover what their values are by looking at the projects that consist of these technologies.

- To gain an understanding of how EBTs are used by selected practitioners - understanding the systems/thinking that designers employ when using EBTs in their projects.

- To investigate the possibility of architectural academia influencing current practitioners with information on EBTs that is being generated within academic institutions.

The answers to these questions will form part of a larger research objective within the built environment with specific relation to the architectural practice and the opportunities for improvement due to the implementation of emerging building technologies as a result of experimentation to enhance/ provide more options than the current technologies employed in practice.

The data analysis will lead to the extraction of information from the catalogue that will answer the research questions and eventually point the author in a direction of formulating a conclusion.

1.5 Research questions

The aim of this research project will be achieved by asking the following questions:

Primary question:
What building technologies can be considered to form part of current building practice in the South African built environment and which can be considered as emerging building technologies?

From this the following sub-questions arise:

Sub-question 1:
Can the inclusion of Emerging Building Technologies within the built industry contribute value to the environment such as being more versatile, economical, contextually responsive and socially responsible in the South African context? Can this cause the EBTs to be catalysts for the development of the current stagnant state of the tectonic trajectory in South Africa?

Sub-question 2:
In what aspects can academia be valuable to the current industry's practitioners regarding their knowledge on EBTs to become integrated in the built environment by implementing these technologies in practice?

1.6 Limitations

The initial search for applicable projects will be done by means of searching for information available on a digital platform. The selected projects' site visits, undertaken as part of the data collection process, will not be done outside the boundaries of Gauteng. This will be due to the fact that the research team is situated in Gauteng and will have a short period of time to execute the site visits.

1.7 Delineations

All projects done before the year 2000 will not form part of this study. This will be due to the fact that per this report's definition of EBT's, these building technologies employed in the projects before the year 2000 will no longer fall within the 15 year bracket from the current date, excluding them as being an EBT in the South African context. These building technologies are, in this report, then considered to be adopted building technologies.

2 Literature review

2.1 Introduction - key terms and how they relate to the study

This literature review consists of key terms that are arranged accordingly to create a coherent flow that will enhance the rationale of the study. These key terms include the *tectonic trajectory,* largely covered by Kenneth Frampton, which is used as a starting off point for the review to investigate how the history of architectural production in broad. This key term will provide more insight into the current built industry's condition in terms of its production and quality of building technologies and its impacts. *Emerging building technologies* is the next major term that will introduce the solution identified by the author along with all the benefits the intrinsic values present. The *architectural practitioners and academia* will be the final key term in this literature review that will highlight the role players of the solution by discussing the two relevant parties in depth based on published resources.

2.2 Tectonic Trajectory

In Kenneth Frampton's *Studies in the Tectonic Culture (1995)* captures various architects' design processes and reviews their work in comparison to one another, unearthing the path of modern architecture. This investigation is summarised as "tracing the history of contemporary form as evolving poetics of structure and construction" (Frampton, 1995). Schwartz conducts his own study on the tectonic trajectory and, similar to Frampton, views the development as a continuation throughout history with modernisation and digitalisation as part of the theoretical evolution (Schwartz, 2016: 14).

The tectonic transitions of the past, with specific focus on the last three centuries, had an influence on architectural production (Louw, 2021: 10). Frampton recalls Pier Nervi stating that unparalleled prospects can be achieved with construction due to executions made with new building materials and techniques, allowing architectural themes to grow in complexity (Frampton 1995: 336).

Within the South African context the built industry has reached a plateau in terms of its development and growth (Windapo, 2013: 65), which can be due to a few reasons. McCoy highlights the lag in technological development as well as the slow adoption of new technologies in architectural firms is highlighted by McCoy, stating that this is why there is no innovation and experimentation and thus no development (McCoy, 2021: 1). The industrial revolution led to the use of mechanised production tools, leading to construction processes (Wu, Wei & Peng, 2019: 1) that removed the architect from the making process, once again leaving marginal space for experimentation with building technologies in practice. The abovementioned causes

lead to negative effects in the industry, which can be identified as environmental issues as well as economic problems.

The concept of “sustainable development” has been part of the construction world since the term has been published in 1980 by the International Union for the Conservation of Nature and Natural Resources, which stipulates it as “development efforts which seek to address social needs while taking care to minimise potential negative environmental impacts,” (Hill, Bergman, Bowen, 1994: 13). Architects do not only have an important role to play in creating a sustainable environment but has the duty of continuously acquainting themselves with new issues and ensure that they are capable of designing infrastructure that counts as solutions rather than additions to the ever-occurring environmental problems (Sebake, 2008: 482). South Africa’s natural environment is under immense pressure due to the depletion of natural resources, energy consumption from building material production etc. (Othman, 2009: 36).

The economic problems caused are due to the performance and growth that are static within the trajectory while building material costs keep on increasing (Windapo, 2013: 70). The golden thread throughout history in architecture is that building technologies will keep on developing as time passes (Wu, Wei & Peng, 2019: 1) - it is a dynamic part of building-making and within the South African context, the trajectory needs to be continued by practitioners through the inclusion of new building technologies, not only to ensure optimal design processes in practice, but to address the current issues caused by the industry in a proactive and responsible way. The adoption of new technologies in firms could lead to major benefits for the construction industry (McCoy, 2021: 1). Emerging building technologies are therefore turned to as an alternative to current building technologies.

2.3 Emerging Building Technologies

Although a building technology in its essence is described as materials, construction techniques and structural systems (Wu, Wei & Peng, 2019: 1), Steyn contradicts this by stating that technology in architectural terms is a combination of ‘technics’ and ‘knowledge’ with the former consisting of climate control, energy, materials and construction techniques and the latter referring to socio-cultural needs, the artistic use of space and form and history as informant (Steyn, 2020: 1). This study considers Wu, Wei and Peng’s definition as the essence of a building technology, and adds socio-cultural needs, history, artistic expression and climate control as values that stem from the use of building technologies.

The purpose of including EBTs would be twofold: to bridge the current gap in South Africa’s tectonic trajectory by intercepting in the current design processes that make use of conventional and current building technologies as well as to enhance the

impact it has in the built environment. Community involvement and the way that the local qualities are reflected is counted as a benefit (Steyn, 2020: 6) as well as the economical, social, political and cultural benefits (Jekot, 2007: 74).

Emerging building technologies can also be beneficial in the way that it will mainly include saving on labour costs and time needed to execute these technologies (McCoy 2021: 1). In addition to this, EBTs can also provide firms with social and economic benefits (McCoy 2021: 30) depending on how quickly they become incorporated within the industry, which will differ from each company as different risks should be considered by individual companies.

Steyn suggests that a fusion between informal vernacular, conventional and innovative building technologies can lead to a recipe for growth in the industry (Steyn, 2020: 16). This is seen as one of the ways in which emerging building technologies can be formulated, along with hybrid tectonics (Louw, 2021) and digital manufacturing (Loh, 2019) and what positive contributions the inclusion of South Africa's "underdeveloped" elements in "developed" technologies can have, not just on a local scale, but on a global one as well (Jekot, 2007).

In the thesis, "The search for hybrid tectonics in contemporary African architecture Encounters between the global and the local," the author works with an ongoing process of compiling a catalogue to show how contemporary works in African architecture are becoming hybrid in tectonic nature (Louw, 2021: 7) while the act of making, with repetitive acts that form objects with meaning within digital manufacturing, is considered by Loh as a viable means to create new building technologies (Loh, 2019: 34). There are then authors who state that architectural practice also contains many identities that are involved, therefore delivering different technologies. The writer refers to the 'they' and 'we' of first and third world countries, while considering South Africa to be a part of the latter. The South African context contains many examples of underdeveloped technologies that hold much potential when they can become combined with developed technologies (Jekot 2007).

When considering the combination of technologies on a global scale, it is important to note that although this cross-pollination of knowledge can be beneficial to the development of more EBTs, the traditions and knowledge needs to be managed according to their specific contexts of origin (Jekot, 2007: 69). This is supported by other authors who note that building technologies cannot be viewed in isolation of their context (Wu, Wei, Peng, 2019: 165). Much of this notion to stretch the formulation and usage of EBTs on a global scale is due to globalisation, which happens not by choice (Steyn, 2020: 77) and contains both positive and negative impacts (Jekot, 2007: 66).

Architecture in South Africa needs to be considered as a separate topic than architecture on a global scale, although they fall within the greater trajectory, it is

unique due to the local factors such as identity and design skills and solutions (Jekot, 2007: 67). It is stated that South African architecture is “...the material expression of the cultures that build it,” and due to the cross-cultural diversity in our country, has benefited from this local complexity in architectural influences (Jekot, 2007: 74).

2.4 Architectural practitioners and academia

There is a sense of incoherence within the industry due to its complex and fragmented structure of parties involved (McCoy, 2021: 1), but eventually architects stand as the key role players in the design process. As architecture becomes fabricated through design and construction (Schwartz 2016), it is crucial to realise the critical role that the practitioner plays. The current architectural practitioners are an integral part of the country’s economic sectors since the work they do stimulates growth in the industry, leads to job opportunities and creates many links to other sectors (Othman, 2009: 36). This renders current architects in practice to be extremely valuable in the current ways they are working and the systems that are influenced as a result. In order to make these established professionals relevant to the broader discussion, their specific processes of making (Loh, 2019: 34) will have to be seen as prominent - this will refer to the building technologies they employ.

Besides the use of predefined sources, architecture firms are also predominantly caught in a contractual association that binds them to work in a linear manner from building design to construction process (Loh, 2019: 18). This results from the constant use of current building technologies in a linear manner, excludes the process of experimentation and leads to unexamined assumptions to the challenges in the construction industry (Windapo, 2013: 65).

Loh looks at how the architectural practice’s products concerning detailing and aesthetics can be delivered as better outcomes due to enhanced ways of ‘making’. These are labelled to be affordances for design, namely procedural logic, iterative prototyping as well as material interfaces and how the act of making can become knowledge and generative thinking based (Loh, 2019: 64), which could be a way that current practitioners can involve EBTs in their practices.

Even with these affordances, the lack of adequately trained professionals (Gerber, Gerber, Ku, 2011: 412) creates a problem within the architectural practice. Windapo states that there is “a skills gap and a decline in the capacity of the professional sector within the construction industry (Windapo, 2013: 67). Academia is considered by the author as a viable role player that could influence practice with knowledge on EBTs. To bridge the gap between the academic institutions and the industry will require an understanding of both spheres (Gerber, Gerber, Ku, 2011: 428).

Research done in any discipline can be done to serve as the production of knowledge within the institution or it can also be done to improve practice with the knowledge (Vanderlinde, Van Braak, 2010: 300). Candy refers to this as practice-led research as it guides the researcher to new knowledge that has “operational significance” in practice since it focuses on the nature of practice (Candy, 2006: 3). New approaches to architectural education are being demanded, along with the curriculum of other professions such as engineering and construction (Gerber, Gerber, Ku, 2011: 411). Loh states that his own involvement in academia influenced the way in which he experiments with his work in practice. He continues to say that academia is a privileged space where the space to have enquiries about materials go beyond the restrictions of daily practice (Loh, 2019: 22)

Schwart states that there is thought to be a potential for positive influence from students of architecture from lessons learnt due to the understanding of the application of tectonic theories (Schwartz, 2016: 67). He goes on to investigate the intersection between the construction and design stages to render more insights into the architectural practice to young designers as well as the rest of the practitioners.

Academic collaboration will lead to growth in strategic research (Gerber, Gerber, Ku, 2011: 411), which means that the potential for students and practitioners to work together to implement EBTs is a tangible reality. Steyn argues that the South African built environment is unique because of what a structure can do for a community through involvement, spaciality, the internal economy, materials et. that is in tune with the country’s context (Steyn, 2020: 8). The mixture of these values along with the correct combination of professionals could lead to exponential growth within the industry and fantastic repercussions in South Africa’s broader built environment.

The Building Design Group (1968-1977) was a South African architecture practice that was set up in a way that involved both architecture students and professionals. Their non-conventional approach to architecture challenged the conventions of spatial relations, building form and economics as well as technology (Sanders, 1984: 4). Although their approach to building technology focused more on the detailing of buildings, their proposals toward it was to “readdress” the conventional, with their motivation being innovation within the industry (Sanders, 1984: 227). Here the intersection between education and practice was integrated into a system that had an impact on the industry through the hands of designers that had a goal of contributing to South Africa’s built environment outside of the boundaries within which current practice was working.

3 Research methodology

3.1 Introduction

The research methodology, as set out in figure 4, will provide insight into the study's layout as well as further explanation of the research methods and theoretical framework employed in the research.

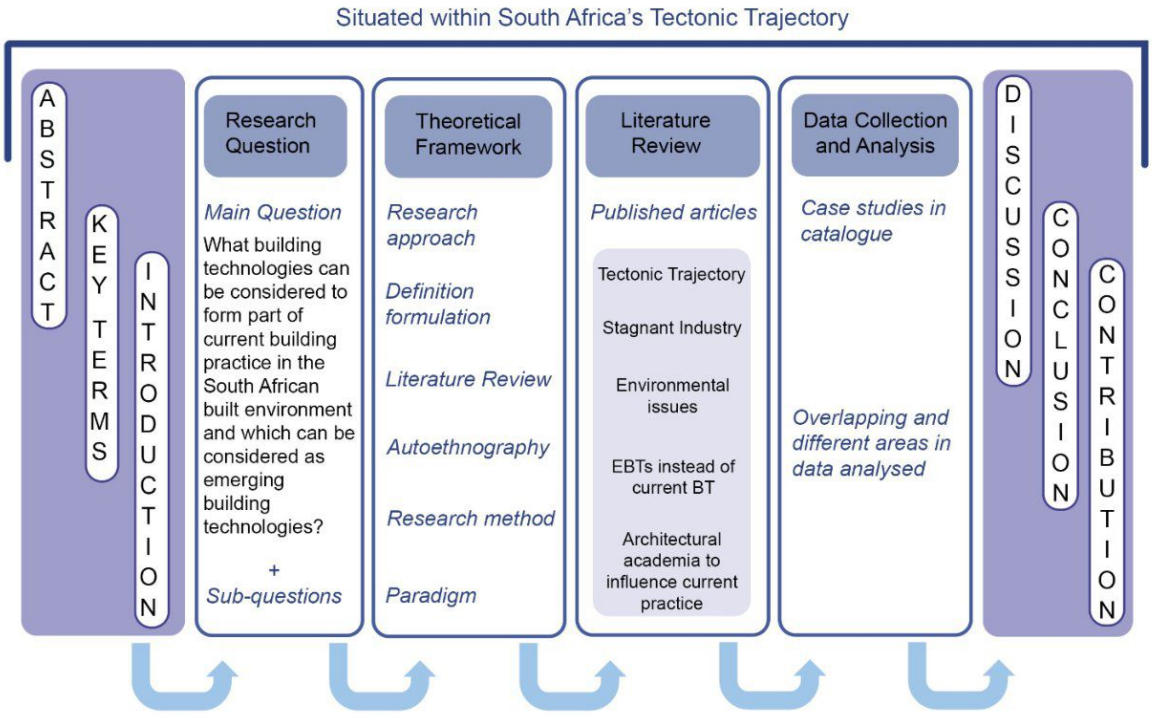

Figure 4: An overview diagram of how the research article is structured (Author 2023)

3.2 Research approach

The research methodology will support the larger theoretical framework that the study is situated within. This paper starts with the larger theme of EBTs and sets out to collect qualitative data in the form of case studies that will be compiled into a catalogue. The data analysis will then be executed and the results will aid in the process of inductive reasoning and the results will be viewed along with the literature review in the discussion. A final conclusion will be drawn at the end of the study and highlight a possible solution to the problem that this study focuses on.

The researcher will work with inductive reasoning methods when reviewing the case studies, in order to build a greater understanding of Emerging Building Technologies, when looking at the separate cases that exhibit and encourage it (Johansson 2007). During the discussion the author will summarise the data collected and the literature

read to formulate a final conclusion that will reveal new insights into EBT and contribute to the current research problem in the conclusion.

The approach of this study will not be to merely add knowledge to an individual's goals within the architectural practice but to contribute to the nature/understanding of practice. This report will be practice-led research as it will lead to new understandings regarding the architectural practice (Candy, 2006: 1-2).

3.3 Case Study Method

The research method used is the case study method, being a determined field research method - occurrences that take place in a field without the involvement of the researcher (Fidel, 1984: 274). This method was developed within the social sciences but branches out to many other fields as well, including the architectural discipline (Johansson, 2007: 50). The benefit of using the case study method is that it does not only capture the intricacy of a specific case, but it takes account of the case's surrounding context and many other variables, that in turn can be compared to other cases. The criteria can be tailored according to the research project and changed as the process evolves. The emphasis on the success of the case study method is placed on the fact that it could contain many combinations of theories, strategies and techniques that strengthens the investigation and eventually the conclusion (Johansson, 2007: 53).

The case study method can be seen as flexible as the data gathering and analysis process is decided by the nature of the study. This method can be applied to a broad set of data, with the goal of extracting particular information from each case (Fidel, 1984: 273).

The mode of reasoning used to analyse these cases along with the published literature will be inductive reasoning - working from facts in a case to theory, thus working from the specific to the general. The procedure is *theory generating* from facts in the various cases with the result of conceptualisation (Johansson, 2007: 52).

Procedure	Mode of reasoning	Result	Generalisation
THEORY GENERATING A principle (theory) is generated from facts in the case	Inductive	Theory (Conceptualisation)	From facts in a case to theory

Figure 5: An section of the table that shows modes of generalisation and reasoning within the case study method from Johansson's research article (Johansson, 2007, p. 52)