SYSTEMS THINKING FOR THE DIGITAL ECONOMY: A SOCIOTECHNICAL PERSPECTIVE

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ABSTRACT

The digital economy has radically changed the way services and products are developed and deployed. Digital information and communication technology connects increasing numbers of people, organisations, and other systems. The interconnectedness of services and products in an organisation and the outside world drives complexity. These interactions include humans interacting in social networks with one another, the technology, and the environment. Therefore, systems thinking approaches are required to help develop these systems and resolve the complex problems encountered in this space. This paper proposes a systems thinking framework to address the challenges of the digital economy from a sociotechnical perspective, based on an exploratory literature review. This will serve as a guideline for implementing various systems thinking tools to support a successful digital transformation.

OPSOMMING

Die digitale ekonomie het die manier waarop dienste en produkte ontwikkel en ontplooi word radikaal verander. Digitale inligting- en kommunikasietegnologie verbind toenemende getalle mense, organisasies en ander stelsels. Die interaksie van dienste en produkte binne in 'n organisasie en met die buitewêreld dryf kompleksiteit. Hierdie sluit interaksies in tussen mense in sosiale netwerke, met tegnologie, en die omgewing. Daarom word sisteemdenkbenaderings vereis om hierdie stelsels te help ontwikkel en die komplekse probleme wat in hierdie ruimte teëgekom word op te los. Hierdie artikel stel 'n stelseldenkraamwerk voor om die uitdagings van die digitale ekonomie vanuit 'n sosiotegniese perspektief aan te spreek gebaseer op 'n verkennende literatuuroorsig. Dit sal dien as 'n riglyn vir die implementering van verskeie stelseldenkinstrumente om 'n suksesvolle digitale transformasie te ondersteun.

1. INTRODUCTION

The Fourth Industrial Revolution resulted from Industry 4.0, leading to cultural, political, social, and economic changes through the convergence of physical, biological, and digital innovations [1]. The proliferation and integration of digital technologies, such as artificial intelligence, genome editing, augmented reality, robotics, and 3-D printing, drive this revolution that changes how humans create, exchange, and distribute value to transform institutions, industries, and individuals. Also, connected and integrated machines communicate to form the Internet of Things, which generates the data needed for real-time feedback and control, contributing to increasing complexity [2]. Merging these technologies with the cognitive abilities and complexities of human understanding drives the Fourth Industrial Revolution [3].

The First Industrial Revolution saw the impact of the steam engine (18th to 19th centuries), while electricity caused the Second Industrial Revolution (19th and early 20th centuries), resulting in mass production and manufacturing. These two revolutions were based on harnessing new power sources to increase productivity. The digital revolution is regarded as the Third Industrial Revolution (1950 to the 1970s), driven by digitisation and information processing [1].

Each of these revolutions caused drastic changes in economics and communities. The systemic changes occurring across multiple aspects of human life are the result of the cross-cutting impacts of emerging technologies. With the internet becoming publicly available in 1991, access to information was made easier, resulting in various consumers becoming dependent on huge amounts of data. Also, the development of personal computers enabled storing and sharing of information through communication networks between these computers. Rapid shifts characterise the new digital era in how people live, transact, and relax, owing to accelerated technological innovations [4].

However, digitalisation cannot occur without digitisation. Digitisation is the conversion of analogue data and processes to digital. Digitalisation uses digital technology to collect data, establish trends, make better business decisions, and create new (digital) revenue streams. Digital transformation addresses a much broader adoption of digital technology to include the cultural change in people. Digitalisation also has tremendous opportunities to improve business and lives, but can cause disruptions and changes [4].

This glut of information has resulted in new vulnerabilities and challenges [5]. Therefore, artificial intelligence is increasingly implemented to manage and process information. Also, increasing processing power in lower-cost computing hardware and software enables its use. This has significantly lowered the entry barriers for start-up companies using neural networks, big data analysis, blockchain, augmented virtual reality, and quantum or cloud computing [6]. However, the consequences of the social and economic disruptions caused by innovation are unclear.

Digital innovation and transformation require policies and practices to ensure an equitable and safe use of technology [7]. Systems thinking provides a perspective, language, and set of tools to analyse this new and complex world in order to understand and support policy development [8]. Systems thinking is suited to interpreting this complex, interrelated, and sociotechnical environment. However, getting started is often a hurdle. This paper performs an exploratory literature review on applying systems thinking to enhance the transformation to the digital economy. The literature on the digital economy and digital transformation is discussed first. This is followed by a description of systems thinking and a brief overview of its most popular tools. A systemigram is then developed to derive a structure from the literature that relates the digital economy and transformation characteristics to systems thinking capabilities.

2. DIGITAL ECONOMY

E-commerce between firms started in the early 1970s, but gained prominence in the late 1990s through internet technologies [9]. Online transactions (banking, buying, payments, selling, etc.) have become the fastest way of doing business globally by exchanging information. The internet enables instantaneous and seamless communication and commerce around the globe, free of spatial constraints [10], [11]. Therefore, digital and mobile technologies diminish the distance between commodity producers and consumers to connect demand and supply. The borderless and virtual business platforms allow freely interacting suppliers, customers, and competitors to reduce transition costs, inventory, and marketing costs while improving customer service and sales opportunities [11]–[13].

The digital economy includes innovations in digital finance, e-commerce, and e-governance, increasing access to information and services in a virtual environment [7]. Improvements in digital technology to process, store, and analyse unprecedented data quantities drive the digital economy. It is more than digitising money to increase security or accelerate financial transactions. The digital economy now includes the datafication, production, exchange, distribution, and consumption of digital products and services. Datafication converts the information on human existence into digital data that disrupts existing service models [1], [11]. The Internet of Things also generates heterogeneous data from diverse sources and social media platforms. Generation, management, process, and storage can monetise data. The data value includes customer behaviour insights, improved product and service personalisation, and improved marketing [14].

Infomediaries organising large amounts of data to connect producers and consumers have started radically reorganising commodity chains [10], [15]. These virtual value chains can have new products, efficiencies in procurement and sales, and expanded market reach. Big data analytics also give organisations new capabilities to reengineer business processes that improve service delivery. Artificial intelligence systems allow for a finer discrimination between different customer groups to predict behaviour, price sensitivity, and search patterns [6], [10]. Therefore, firms in the digital economy also need to revisit their business models [1], [13], [16].

A business model guides value creation in a market segment. It defines the value chain and structure of the cost and revenue mechanisms in support of the business strategy. Modelling the business and its environment assists management in identifying current and future business development [17]. However, there is also a shift from value chain to value network. Networks enable information creation, flow, and resource allocation. Therefore, the primary sources of value in the digital economy are information and interactions [12].

The digital economy provides an opportunity for developing countries to grow and to reduce poverty. Historical competitive advantages are irrelevant because the internet allows small companies to secure new customers who were formerly restricted to larger firms [10]. However, there is a risk of amplified economic disparity as advantaged sections of the population dominate the market space. Often, developing countries suffer from a lack of infrastructure (reliable electricity, internet, and logistics), economies of scale for e-commerce, and trust in technology. To generate revenue, they need to establish digital information literacy, security competencies, and a business model [13].

The digital economy also operates in a competitive environment that is described as being characterised by volatility, uncertainty, complexity, and ambiguity (VUCA). Globalisation and technological disruption create a complex environment [18]. This environment is highly disruptive for incrementally focused organisations, because interactive technologies change how stakeholders interact and learn. Therefore, organisations must apply collaborative and co-creative learning inside and outside their organisational boundaries [4], [19]. Organisational agility that senses and uses market opportunities to adapt structures is a countermeasure to VUCA. They must match the complex and dynamic environment using cause-and-effect analysis, pattern-and-trend recognition, and knowledge acquisition. Therefore, proactively exploring cause-and-effect factors helps to understand the uncertain business environment. Organisational learning is key to surviving and thriving in the digital economy [19]. The digital economy requires information platforms to support participation, learning, and decision-making [2], [12].

3. DIGITAL TRANSFORMATION

Digital transformation is a process in which the ‘digital world’ merges with the ‘physical world’, forcing companies to manage the radical change and shocks of the uncertainty of the business environment [20]. It is associated with changes in an organisation’s infrastructure, products, services, business processes, business models, and strategies, including inter-organisational relationships in extended business networks [21].

Digital transformation must consider the direct and indirect effects of digital technologies and techniques on organisational and economic conditions along with the new products and services [22]. These include changes in value creation, value proposition, and customer interaction. Technology influences value creation, including business processes, the organisation of the enterprise, and its workforce. The value proposition influences the selection of products and services for the market and its revenue models. Customer interaction includes all types and mechanisms of interaction with customers [22].

Digital transformation leverages technology that changes existing business processes to reposition for the digital economy. Digital commodities include the fundamental technologies (hardware and software), digital infrastructure, and services for digital economy participation [7]. Mobile devices in particular enable stakeholders to develop new and possibly easier ways to interact and trade. They drive new customer experiences and change habits [23]. Small and medium-sized enterprises also deploy digital technology to improve their strategic competitiveness. Digitalisation not only includes the digitisation of paper documents to electronic format; it also involves implementing mobile devices, cloud computing, smart sensors, Internet of Things platforms, big data analytics, three-dimensional printing, and augmented reality to support economic activity [4].

Sustainable digital transformation depends on the available digital capabilities and skills. The COVID-19 pandemic forced many employers and educators to move online, highlighting the realities of the digital economy in developed and developing nations. It increased global dependence on digital technologies with the required digital skills to participate in society’s social, economic, and democratic aspects. To implement digitalisation, stakeholders require literacy in technology-related and soft skills [4], [7]. Digitalisation and automation also transform how economies and societies interact, resulting in new forms of employment. Local app-based platforms are typically used for delivery, ride-hailing, or domestic services that provide flexible opportunities for income generation, even for people with limited mobility [24]. The evolving nature of work will accelerate as humans and machines increasingly collaborate on tasks [25].

Therefore, digital transformation requires organisational reorganisation to optimise implementing technologies. However, by making changes to the technical subsystem, the social system in the organisation is affected [26]. Modifications may cause unintended consequences, counterintuitive stakeholder behaviours, or policy resistance that diminish the digital transformation benefits. The conventional ways of doing work may be disrupted, and sources of stakeholder power may change [15], [16].

A sociotechnical system is an organisation with people (the social system) using tools, techniques, and knowledge (the technical system) to produce goods or services that are valued by stakeholders [27]. Complex interactions exist between humans, machines, and the environment while producing organisational goods/services. Technology cannot simply be technical or social: it includes the outcome of socio-material routines created through a process that is interwoven with the material nature of innovation and social practice [28]. The key digital transformation strategic values are value chains to create new products and business processes, channels to find solutions to customer problems (client interactions), and networks for client-partner interaction through mediation technologies [28].

A human-centred design may transform the business model to serve customers in more agile ways. Business models must evolve to exploit the innovative potential of digital information technologies. Organisations need the requisite variety to cope with the challenges, making managing the consequences of digital transformations increasingly difficult. However, digitalisation could suffer from environmental risks, cyberattacks, and data fraud that may cause reputational damage and financial losses [4], [16]. The digital economy requires a system operating within a ‘digital ecosystem’. However, establishing and sustaining this capability involves capital investment and operating expenditure. Therefore, governments are important stakeholders in the form of policymakers, regulators, and distributors of mobile networks [4].

Artificial intelligence may help to process the vast amounts of available data to support decision-making under the risk and complexity of the modern world. It employs natural language processing, image recognition, automatic text generation, and machine translation in this environment [6]. Digital technologies facilitate productivity improvements to stimulate growth. A job consists of a set of tasks, and automating some of these tasks necessitates changes to job profiles. The skill-biased technologies will determine a job’s profitability and whether joblessness and inequality among low-skilled workers will increase. However, the re-skilling and up-skilling of workers may reduce the consequences. Artificial intelligence-based systems offer expert knowledge on a situation to non-specialists and replace mentally heavy tasks. The three factors impacting jobs and wages are the direction of technical change, the substitution elasticity between capital and labour, and the price elasticity of the supply of capital vs the elasticity of work. However, developing countries have a large supply of unskilled labour, which reduces incentives to invest in artificial intelligence technologies [6].

The complex interactions between humans, systems, and the real world cause ‘wicked and messy’ problems for decision-makers to solve. These give rise to social issues that tend to be multi-layered, circular, and systemic, with many different variables. It may not be clear how to approach the problem and decide between alternative solutions [29]. Unfortunately, decision-makers attempt to simplify these systems into hierarchical and linear models with simple relationships, using reductionist thinking. The consequence of this approach is that interventions tend to work only for the short term, if they work at all, or they have significant unintended consequences [30].

Systems thinking is discussed in the next section as an approach to addressing these problems.

4. SYSTEMS THINKING

A system can be described as interconnected tangible or intangible components within a boundary. The system receives and transforms information, energy, or matter from the environment into output. The system’s components may include combinations of products (hardware, software, firmware), processes, people, information, techniques, facilities, services, and other support elements that exist and operate in an environment. The system’s elements and interactions form a complex whole, with feedback between the parts themselves and the environment that determines its functioning [1], [31], [32]. The interactions between the elements cause emergent behaviour that cannot be derived from observing the parts in isolation, that may surprise observers. Therefore, Bertalanffy (1972) described the whole as more than the sum of the parts.

A system may also be a subjective mental construct that depends on the observer's viewpoint, which defines the system's boundary to limit its function and purpose [1], [34]. A system's structure is derived from repeated events or patterns described through stakeholders' mental models [8] – that is, the implicit structures of assumptions and meanings, preconceived ideas, values, beliefs, and personal philosophies of individuals and in groups that act as the inner rules of causal relationships. In purposeful human systems, individuals may have disparate conscious or unconscious goals that are guided by these mental models – and that is a source of complexity [16], [31].

'Complexity', derived from the word 'plexus', meaning braided or entwined, is not a new concept. Therefore, complexity refers to many system elements or environmental effects that are intricately intertwined, with high interconnectivity, to form a 'whole' [35]. The non-linear interactions under dynamic situations are difficult to understand. Therefore, complexity may even exist in simple systems owing to interactions and feedback between elements over time [36]. Developing a system of humans using technology may be complex because of humans' flexible and unpredictable behaviour in dynamic environments. These complexities may lead to beneficial (robustness, adaptiveness, fault-tolerance, adaptability, and flexibility) or harmful (low predictability, reliability, understandability, and controllability) emergent behaviour [37]. The difficulty is to allow for such emergence while maintaining control of the system to continue achieving its designed purpose.

Successful digital transformation depends on understanding the intended consequences of the sociotechnical change and being able to identify the potential unintended consequences. Linear thinking often leads to inappropriate management transformation theories, and does not address the unexpected side-effects of these initiatives. Systems thinking provides a powerful language for representing and operationalising the mental models that strategic decision-makers bring to the table [16].

There is not yet a commonly accepted definition or understanding of systems thinking. Barry Richmond defines systems thinking as the art and science of making reliable inferences about system behaviour by understanding the underlying structure [38]. Peter Senge defines systems thinking as a discipline for seeing wholes and a framework for analysing interrelationships rather than things [39]. Systems thinking can also be summarised as a philosophy, methodology, perspective, language, and set of tools for understanding the behaviour of complex dynamic systems [8], [16]. Therefore, systems thinking, as the opposite of linear and analytic (dissective) thinking, is a system of holistic (integrative) thinking about systems. Systems thinking, with its foundation in general systems theory [33], has been applied to a wide range of fields and disciplines to solve complex problems that are not solvable using conventional reductionist thinking [8], [38].

Systems thinking focuses on the whole system to study its structures and behaviours to understand better how the deep roots of complex behaviours adjust their outcomes. Systems thinking recognises the importance of feedback mechanisms in the system [8], [34], [38]. Identifying the patterns and interrelationships can help to solve complex problems. Repeated events or patterns derive from systemic structures that, in turn, derive from mental models [8], [30]. According to Arnold and Wade [38], cause-effect feedback loops explain the causes of the system's behaviour. Modelling the system's conceptual structure helps to reduce complexity in order to improve understanding at different levels of abstraction and scales.

The multifaceted nature of 'wicked and messy' problems is not only technical, but also includes cultural, political, infrastructural, and regulatory concerns. The nature of the problem calls for multiple perspectives on the multifaceted situation to see the big picture and to make connections between and among seemingly disparate events and processes in order to identify high-leverage actions, changes, and interventions and so address the problem [34]. However, systems thinking has limitations. The feedback loops may be incomprehensible owing to the inherent complexity in systems, with minor input variations in preceding periods that significantly impact system behaviour. A typical system thinking approach has the following process steps [7]:

1. Identifying the problem using dynamic, system-as-cause, forest, or loop thinking. Dynamic thinking investigates patterns of behaviour over time. System-as-cause thinking focuses on the causes of change in a system that can solve the problem. Forest thinking defines the system's boundaries to identify its context and relationships. Loop thinking focuses on the bi-directional cause-and-effect relationships that form a continuous loop.

2. Employing operational, closed-loop, or quantitative thinking to construct a hypothesis or model. Operational thinking identifies the causality and patterns of behaviour. Closed-loop thinking investigates the feedback relationships between system elements, while quantitative thinking quantifies the core variables.
3. Testing the hypothesis or model.
4. Communicating the understanding to the stakeholders, and implementing changes.

Innovators in the digital economy need to find alternative solutions to problems under conditions of uncertainty. They need to explore customers' interaction with a product or service to develop business ideas and create prototypes to gain empathy and creativity. Systems thinking is becoming increasingly relevant when dealing with global challenges, from terrorism to energy and healthcare. Addressing these seemingly intractable systemic problems in our society involves seeing the whole system and looking at the interrelationships that impact one another through feedback loops. Systems thinking promotes the interactive learning of stakeholders and challenges mental models to capture the multiple perspectives of 'wicked and messy' problems [40].

5. SYSTEMS THINKING TOOLS

Different systems thinking tools help to understand and deal with the underlying complexities in business, economic, environmental, political, and social systems [8]. This section discusses some of the more popular systems-thinking approaches.

5.1. Iceberg model

The iceberg model, which argues that hidden systemic structures and mental models cause observable events and patterns, is a core element of systems thinking. Systemic structures include the organisational hierarchy, interrelationships, rules and procedures, authorities, process flows, incentives and fears, goals, corporate culture, and underlying forces in an organisation. Mental models establish these structures, which in turn cause behaviours. The iceberg model represents a broader context, and demonstrates how the underlying structures impact our daily lives in observable ways. Systems thinking applies concepts from the iceberg model to develop causal loop diagrams through a language of feedback, self-organisation, system dynamics, emergence, and unintended consequences [8], [41].

5.2. Systemigrams

A systemic diagram, or 'systemigram', helps to translate a system problem from structured text into a storyboard-type diagram of the system's principal concepts, actors, events, patterns, and processes. The diagram is a network comprising nodes, links, flows, inputs, and outputs that fit on a single page. The systemigram reads from the upper left to the lower right corner of the page to communicate the story's message. Colours may also indicate key elements with linked or similar concepts. One useful output is defining feedback loops between elements to start the generation of formal causal loop diagrams [8]. A systemigram is applied in this paper to show how systems thinking relates to the digital economy and digital transformation.

5.3. Soft systems method

The soft systems method is an organised and systemic inquiry to address complex, messy, and ill-structured problems. Unlike standardised hard-systems engineering processes, it takes cognisance of world views using models of purposeful activity that is relevant to the problem situation without relying on the models to describe it. These models explore the situation through structured debate, even though they are inaccurate [42], [43]. Therefore, the approach helps to deal with diverse stakeholder cultures [34]. The models support interaction with stakeholders to compare their understanding with the real world. They help to identify the changes that are required to improve the real-world situation and so achieve the desired future state [43].

5.4. System dynamics

System dynamics analyses and studies dynamic system behaviour through feedback loops with time delays over time that are present in the underlying system structure. Often the behaviour observed over time is non-intuitive and difficult to understand. System dynamics combines qualitative top-down modelling with quantitative simulation. System feedback mechanisms may cause stabilising or de-stabilising (reinforcing) behaviour. It is not easy to perform mental simulation without parameters, functional forms, external inputs, and initial conditions. System dynamics modelling helps to understand system behaviour and to identify the driving variables or control points in order to influence or change the system [8], [32], [44].

Feedback may cause complexity in a system. Delays in making decisions and converting them into actions slow down learning loops as a result of dynamic complexity. Therefore, the system structure is the source of system behaviour. System dynamics employs causal loop diagrams (CLDs) and stock-and-flow diagrams (SFDs) to present the structure using stocks, inflows, and outflows [32], [44]. The CLD is a flexible and useful tool to illustrate the basic feedback structure in a problem domain through capturing a hypothesis on its systemic dynamics causes. CLDs consist of system variables that are connected by arrows to show the causal influences and relationships to form reinforcing or balancing loops. An SFD supports the understanding of model system behaviour through computer-based simulation [8], [16].

5.5. Systems archetypes

Systems thinking archetypes are common and repeat problem-causing structures in many environments, situations, and organisations [8]. The systems thinking pioneers (Donella Meadows, Peter Senge, and Jay Forrester from the 1960s to the 1980s) found several recurring systemic structures in organisational systems [45]. Archetypes help to identify a causal storyline or theory in a system. Identifying these archetypes provides effective diagnostic and prospective tools for gaining insight into systemic patterns of behaviour that are consistent with the underlying structures. They can diagnose archetypal patterns of behaviour that are already present in organisations. Prospectively, archetypes help managers to plan policies and structures to alter the organisational structure and so produce the required behaviour [46].

Finding the lurking archetype requires listening to the story's theme and analysing the behaviour or trends over time in order to develop causal loop diagrams. The causal loop diagram captures balancing and reinforcing loops that may fit more than one archetype. The archetypes may also provide structural pattern templates as 'lenses' for exploration and mapping of the situation to gain insight. They help to create a theory about what we do not know, based on something we do know, to process raw data and extract causal relationships. However, these generic archetypes are rarely sufficient models in themselves. Therefore, implementing archetypes requires a deeper analysis using system dynamics to reveal important systemic structure variables [45], [46].

5.6. Other systems thinking methods

Because of space constraints, not all systems thinking tools can be covered in this section. Other prominent systems thinking tools include design thinking, critical thinking, and root cause analysis.

6. SYSTEMS THINKING FOR THE DIGITAL ECONOMY

Clark *et al*. [7] also applied a systems thinking approach to understanding the relationships between the main drivers of the digital economy sustainable development goals. They found that society may take advantage of the technological revolution, and its employment with closed-loop feedback between digital technologies, capabilities, governance, and infrastructure are interrelated constructs [7].

As a test case for demonstrating the utility of systems thinking for analysing and developing the digital economy through a digital transformation, the systemigram tool is used to encapsulate the theoretical discussion in this paper. The systemigram in Figure 1 interprets and relates the digital economy, digital transformation, and systems thinking theory. The diagram highlights how systems thinking tools may contribute to understanding the environment.

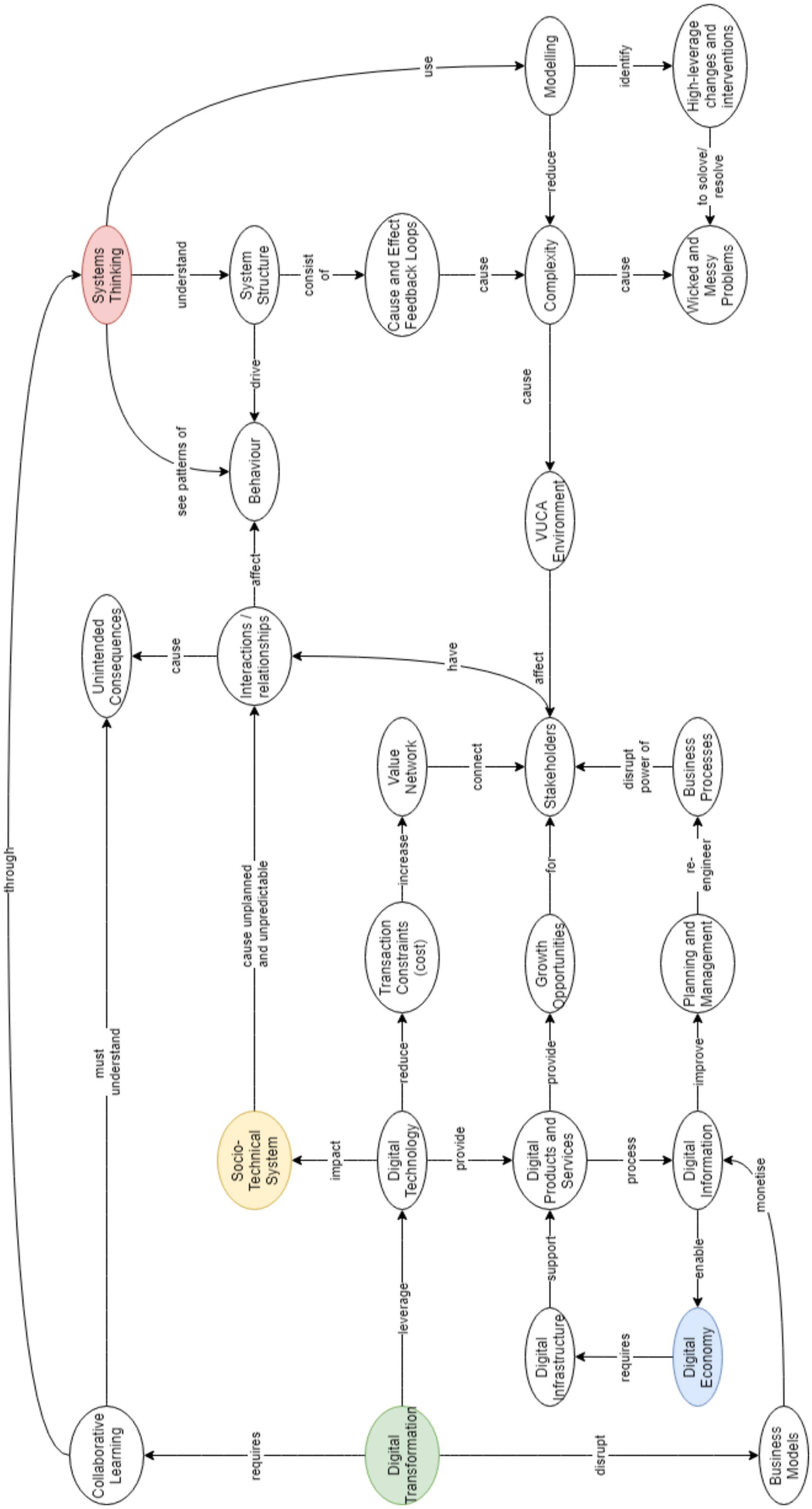

Figure 1: Systemigram of applying systems thinking to address issues in the digital economy

Digital transformation enables the development and operation of products and services to link sellers and buyers across traditional boundaries. However, digitalisation disrupts these traditional industry boundaries to form new cross-boundary ecosystems. Digital transformation leverages technology to create intelligence (value) networks that meet customers' demands. This may require a restructured organisation to increase wealth and value creation throughout the system. Systems thinking helps identify the feedback triggers to initiate and manage change in these ecosystems [4].

The ecosystem fuses digital and physical worlds that co-evolve with multiple stakeholders. Therefore, organisations in digital transformation must connect data and artificial intelligence systems for automated product or service delivery. Systems thinking helps to make sense of the many interconnected parts and stakeholders to solve complex social and economic issues for improved collaboration across boundaries [7]. A better understanding of the stakeholders' interactions should improve responses to changes in the complex system [4]. Systems thinking has an underlying philosophy that is more than just a collection of tools and methods: it is a disciplined approach to examining problems in depth to ask better questions before deciding on solutions.

Systems thinking is an important factor in organisational learning in order to understand the interrelationships between the parts that determine the characteristics of the whole. Because organisations consist of a collection of parts that exchange internal and external information to coordinate systems and subsystems, systems thinking helps to overcome learning barriers in order to help organisations to deal with complexity. Systems thinking tools enable the integration of complex knowledge throughout organisational systems to improve understanding as a whole [19], [41]. Systems thinking can add insights and nuances to our current understanding of innovation in general, and of sustainable innovation in particular [47].

As seen in Figure 1, systems thinking can assist in the digital transformation to an improved digital economy through collaborative learning between all of the stakeholders. Systems-thinking approaches focus mainly on the relationships and interactions between stakeholders, physical systems (technology), and the environment to understand the structure of the larger and more complex sociotechnical system. Identifying and understanding the system's structure enables one to develop and manage interventions in the VUCA operating environment. Since systems thinking has many tools that are suitable for facilitation, stakeholders should be able to solve these complex problems cooperatively. Systems thinking implementation should follow a process from capturing stakeholder mental models to structuring the system and then simulating the behaviour to support learning.

Figure 2 provides a generalised and simplified process model for implementing systems thinking [48]–[50]. The first objective is to capture stakeholder mental models that identify problem symptoms. This includes the system's behaviour over time, preferably in graphs. However, stakeholder involvement is key in order to supplement data from reports and literature. The second step is to extract the unwanted or unexpected behaviour of the system from the observed patterns. This is where most systems thinking tools will be useful, such as the iceberg model, the soft systems method, systemigrams, and system archetypes.

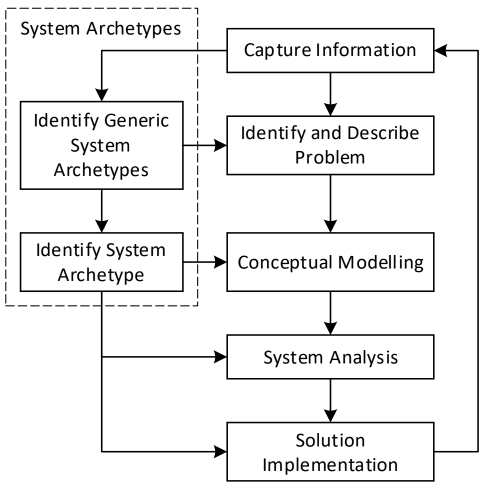

Figure 2: Typical systems thinking modelling process

In the next step, conceptual modelling captures a dynamic hypothesis to describe the structure and behaviour of the system or a problem situation. The causes and effects among variables are linked in causal loop diagrams. System archetypes may play an important role in identifying common patterns that support insight into the underlying system structures. System archetypes help to confirm the complex system's structure, variables, interconnectivity, underlying processes, and behaviour to develop the dynamic hypothesis. Furthermore, system archetypes help to identify possible leverage point(s) to address the root causes of behaviour. A deeper analysis of system behaviour through system dynamics simulation (stock-and-flow diagrams) leads to recommendations about how to improve system performance. Solutions to these high-level complex system behaviours may include the design of policies.

7. CONCLUSION

This paper has presented an understanding of how systems thinking can be applied to support the development of complex sociotechnical systems as part of the digital economy. Digital transformation has been accelerated by the core technologies of the Fourth Industrial Revolution such as artificial intelligence, and has affected not only economic paradigms but also social systems. The digital economy, driven by digital transformation, requires multidisciplinary solutions, increasing the difficulty of implementing systemic changes. Digital innovation affects all elements of the business model, and therefore adds levels and extra dimensions to the complex and dynamic nature of business models. Digital information and communication technology connect increasing numbers of people, organisations, and other systems and so increase the complexity. Therefore, digital transformation impacts the economic sector, technology, and complex sociotechnical systems.

Systems thinking tools and methods help to understand the impact of the digital transformation that is driving the age of the digital economy. These methods and tools highlight the importance of complex sociotechnical systems as the fundamental driving force of the future of technological advancement. This paper proposes a systems thinking framework to address the challenges of the digital economy from a sociotechnical perspective. Therefore, it is crucial to apply systems thinking methods and tools to analyse the impact of these multidisciplinary digital transformation challenges. However, systems thinking is already embedded in many theories, ontologies, concepts, and tools that are currently employed by different disciplines to realise changes and the transition to a circular, sustainable future. A systems-based approach that can transcend disciplinary boundaries can be extremely powerful in enabling well-informed and meaningful decision-making processes that challenge current norms, values, and practices.

The framework presented in this paper can serve as a guideline for implementing various systems thinking tools to support a successful digital transformation. The underlying premise of sociotechnical systems thinking is that system design should be a process that considers both the social and the technical factors that influence the functionality and usage of computer-based systems. Dealing with complex challenges will benefit from using a systemic lens to map the system's dynamics and to investigate how the relationships between system components affect the system's functioning. Therefore, systems thinking can become a critical tool for innovation in the digital economy to address 21st-century goals and challenges. Future work on the concepts captured in this paper include investigating detailed case studies of implementations of systems thinking in actual digital transformation projects in order to evolve the framework.

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