Digital Transformation Management for CDOs

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The Digital Transformation is a complex process that poses managerial challenges. While the Digital Transformation has been the focus of extensive academic research, it has mostly focused on business models or strategies. However, little has been done to devise practical models that can act as tools for the CDOs of companies to navigate through it. The purpose of this paper is to devise a model of the digital transformation using both digital twins and system dynamics. To do so, a managerial digital twin model is developed. This model makes use of a system dynamics calculation engine for answering 'what if' questions. The paper serves as a basis on which practitioners can develop their own digital transformation management tools integrating digital twins and system dynamics.

Additional Key Words and Phrases: Digital Transformation, CDO, System Dynamics, Digital Twin.

1 INTRODUCTION

Digital Transformation is a process which companies across all industries currently strive to successfully master [2]. This phenomenon has become highly relevant in both research and practice as new technologies present both game-changing opportunities and existential threats for companies that succeeded before the digital age [14, 18]. Social, mobile, analytics, cloud and IoT are examples of such technologies [14].

Furthermore, one of the most urgent challenges companies face today is embracing the opportunities brought by new technologies; however, as Singh et al. [15] state, 63% of executives and managers consider the pace of the digital transformation in their companies to be too slow. Moreover, digital transformations bring about the generation of value and revenues via digital assets rather than mere digitalisation [15]. Therefore, companies need to seriously tackle digital transformation to ensure the attain competitive advantages and retain them in time. However, it is still important to have a clear definition of what digital transformation is.

Bekkhus [3] defines digital transformation to be the use of digital technologies to radically improve the company's performance. Furthermore, Digital transformation is also defined as a company-wide transformation [14] which incorporate the digital business strategies [14, 15] embracing the opportunities and addressing the risks originating from (digital) technologies [4, 14, 15].

In contrast, Vial [18] defines digital transformations after carrying an extensive literature review on the topic based on four core properties abstracted from the review; these are, (1) the existence of a target entity of the transformation, (2) a scope describing the extent to which the entity's properties will be subject to change, (3) the means necessary for such transformation is technology and (4) there is an expected outcome. These core properties are present to some extent in the previous definitions; however, Vial [18] provides a more holistic definition: "digital transformation is a process that aims to improve an entity by triggering significant changes to it's properties through combinations of information, computing, communication and connectivity technologies".

This definition of digital transformation will guide this research with the additional consideration from Barthel [2] where digital transformation is an innovation process based on digital innovations which are achieved via the combination of innovative digital business concepts and innovative technological solutions. Digital innovations; and therefore, digital transformations can drastically change an organisation's value proposition and thus its entire identity. Here Barthel [2] extends the understanding of the Digital Transformation to the origins of the technological disruptions that trigger the need to carry out this process. It is the case that technological and digital innovations create opportunities and risks for companies which can add to or reduce their competitive advantage.

This process of improving the organisation via the exploitation of new digital technologies brings new challenges to management [3]. Initially, the CIOs were expected to extend their roles from technologists to business strategists and spend less time managing the IT infrastructure of the company [3, 15]. However, a new role has been devised to deal with the digital transformation of organisations, this role is that of the Chief Digital Officer (CDO). The CDO orchestrates the digital transformation of the organisation by supporting top-management in formulating and executing a dedicated digital transformation strategy as this C-level executive has specialised knowledge of about digital business models and leading projects in this field [15]. Standard methods for business and change management often provide an oversimplified and linear perspective of the digital transformation given its dynamic nature such as feedback structure and their effect with time[1]. Therefore, it is necessary for the CDO to have a clear overview of how the organisation behaves and works to be able to develop and test digital transformation strategies that adjust to the complex nature of digital transformation.

1.1 Scope: Modelling the Digital Transformation

Given that the context of the present research is the Digital Transformation and the needs of the CDO in order to successfully navigate through it, it is important to research possible ways to model the process of the digital transformation of an organisation.

The concept of Digital Twins has been around for a few years. Galuzin et al. [5]provide three main properties of digital twins which constitute a definition in it of itself. (1) digital twins are a virtual representation of a physical object, which can be applied for planning and simulations, (2) they provide ongoing self-synchronization between the model and the real object and (3) they support autonomy of the digital object with respect to the real one. Furthermore, digital twins are defined to be created using 3D modelling, sensors, data and simulators for real-time prediction, optimization, forecasting, monitoring, identification of failures and general improved decision making [12, 13, 17]. This digital representation of objects, the

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organisation in the current context, could prove to be helpful for the CDO in managing the digital transformation by having a true digital replica of the company as can be.

Another concept that has been recently researched with regards to the digital transformation is that of system dynamics. System dynamics is an approach from systems theory that enables modelling and provides understanding of the non-linear behavior of complex systems over time by making use of stocks, flows, internal feedback loops, table functions and time delays [1, 6, 9, 10, 19]. In his research, Vial [18] discusses a research agenda for digital transformation. In this agenda he argues that one of the main points for future research within the digital transformation is the contribution of dynamic capabilities to digital transformation. Furthermore, he proposes dynamic capabilities of an organisation to be a theoretical foundation to study the mechanisms that allow firms to engage with the digital transformation to enable strategic renewal. System dynamics could be a useful tool for CDOs to understand the complex systems involved in the digital transformation and make the process of strategic decision-making easier and clearer by enabling predictive simulations.

2 PROBLEM STATEMENT

The importance of digital transformation for companies as well as the role and needs of the CDOs have been described. However, there still is a need for a proper way of the CDO to model the digital transformation of the company. In his research, Vial [18] has provided a framework with which the digital transformation can be understood. his framework also provides eight building blocks that describes the steps, necessary changes and possible impacts of the digital transformation. It is; however, not possible to use such framework in a practical situation as it is too abstract and the variables described in the framework are not operationalised. Furthermore, in his research, he discusses the necessity for companies to develop dynamic capabilities to develop mechanisms to enable repeatable and continuous adaptation to rapid change as relevant for digital transformation literature. It is due to these reasons that the goals of the present research are:

- **Goal 1:** Create a model of Digital Transformation as a system dynamics model
- **Goal 2:** Model the information system of a company so it becomes its digital twin
- **Goal 3:** Show how can the Digital Twin and system dynamics help the CDO on the Digital Transformation journey

To achieve these goals the answers to the following research questions are needed:

- **RQ1:** How can Digital Twins and System Dynamics models help the CDO in the Digital Transformation journey?
- **RQ2:** How can Digital Twins of Organizations be modelled within the context of the Digital Transformation?

3 RELATED WORK

To find relevant work for the research topic, Springer, IEEE, Scopus, Semantic Scholar and other literature databases and search tools such as Elicit were used. Searches were conducted using the search terms "digital transformation" in combination with "system dynamics" or "digital twins" or "KPIs" or "CDO" as well as various combinations of these terms. Additionally, papers in the reference list of several of these were also read, especially is the case with.

Regarding digital transformation and its KPIs a series of papers were found which provided a definition for it, discussed models, strategies, frameworks and success factors [2–4, 14, 15, 18]. These were also useful to gain an understanding of what digital transformation is and some of the necessary research in the topic is.

Regarding the modeling of digital transformation several topics were looked at. Digital twin literature is abundant; however, there is mostly a manufacturing focus with little to be found regarding organisational digital twins [5, 12, 13, 17]. Regarding system dynamics, [1, 6, 9**?** , 10] were the main sources of inspiration for the proposal.

4 RESEARCH METHODOLOGY

There are two main steps required to carry out this research in order to answer its questions. First an in-depth literature review must be carried out. It will initially be exploratory to cover breadth of the topic before becoming descriptive. This will be done on the topics of digital transformation KPIs, digital twins and system dynamics. Second, the findings will be then combined to model Digital Transformation as a system dynamic process, model the information system and therefore the digital twin of the organisation to show how digital twins and understanding Digital Transformation as a system dynamics model can help the CDO navigate through it.

5 EXPECTED RESULTS

There is extensive research on digital transformation strategies, models and success factors. However, there is a lack of research on methods and tools which the CDO can make use of to manage it as well as KPIs of digital transformation success. Furthermore, there is a lack of research on the use of system dynamics, digital twins and the combination thereof for digital transformation.

The present research can by researching on what are indicators of digital transformation success help broaden the understanding on what is meant by digital transformation success and how it can be measured. Furthermore, the research aims at providing a new view on the possible use of system dynamics for organisational twinning to help CDOs manage the digital transformation. This research would then open new avenues for possible research on the use of models for digital transformation management.

6 LITERATURE REVIEW

6.1 Digital Transformation

Digital transformation is a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication and connectivity technology [2, 18]. Barthel [2] considers that Digital Transformations should be considered innovation processes based on digital innovations. This explains the transformative nature of Digital Transformations as digital innovations can drastically change the company's value propositions which is also supported by Vial's [18] framework for digital transformation given that technological disruptions are the trigger for the Digital Transformation process

of the company. There are several philosophies regarding what improving the entity entails, Barthel [2] carries out an analysis of the current literature on the success of Digital Transformations to find clusters of KPIs of Digital Transformations success.

Furthermore, Vial's framework [18] is leading with regards to this research. It establishes Digital transformation as a process where disruptions coming from digital technologies lead to strategic changes in companies. These strategic changes are done via either Digital Business strategies or Digital Transformation strategies. Here the CDO of the company will establish the strategies by which he intends to navigate the Digital Transformation. These strategies will make use of the technologies which caused the disruption to in turn change the value creation paths of the company, which he defines as value propositions, value networks, digital channels and agility and ambidexterity. Furthermore, these changes in the value paths of the company can lead to positive impacts such as better organisational efficiency, organisational performance and, industrial and societal improvements with the possibility of negative impacts, especially in security and privacy. Vial [18] further argues that in order to change its value paths, the company must overcome organisational barriers such as inertia and resistance as well as undergo structural changes in organisation structure and culture, leadership and employee roles and skills. However, measuring how these elements of the framework are performing in the specific context of the Digital Transformation of a company is challenging.

By not being able to properly measure how the company is performing in all these elements and stages of the Digital Transformation, the CDO will have difficulties knowing whether and how the objectives set by him are being achieved. Barthel [2] states that this can lead to situations where the CDO does not have proper oversight of the value contribution of the Digital Transformation activities they have set out to do and, therefore, end up struggling prioritizing high value activities while terminating low value ones. He, therefore, has found four main clusters in literature for Digital Transformation success which could be mapped to the building blocks of Vial's [18] framework. Barthel [2] has found two main philosophies regarding the success of Digital Transformations. The first one focuses on the paradigm of Digital Transformation success where the success is measured either on the extent to which the company's core objectives have been achieved and the progress of the company's Digital Transformation process which focuses more on the extent to which the Digital Transformation objectives have been attained. The second philosophy is focused on the orientation of the measurement of Digital Transformation success, this can either be internal focusing therefore more in the internal aspects and performance of the company and external which focuses the performance of those activities which are oriented externally with regards to the company.

6.2 Digital Twins

Organizations are required to continuously improve their business processes to react to dynamically changing situations in business environments [11]. This dynamic change can be caused by digital disruptions as it is the case for the context of the Digital Transformation. Furthermore, these changes do not only stop by the business processes, they affect the company at all levels and its structure as well as value paths, as was stated above. Singh et al. [16] define digital twins to be a combination of logically integrated models of a physical asset to give useful insights using data associated with those models. They claim that digital twins encapsulate software objects or models that mirror a physical asset and perform analytics based on this digital information. Furthermore, this information must be based on historical data related to the asset. Park et al. [11] discuss the concept of digital twins of organisations, for the rest of the paper they will be referred to as DTO as an extension of the digital twin to the whole organisations where such objects and processes belong.

The main objective of digital twins is to be linked to a physical counterpart and be used to analyse the state of the product, system or process; respond to the changes, improve operations, and add value to the overall enterprise atmosphere [16]. This objective serves the CDO well in the development of digital business strategies and digital transformation strategies by providing him with the oversight of the company, its state and that of its processes. Furthermore, Singh et al. [16] have developed a methodology for data management for digital twins based on ontological modeling. Using this methodology a minimum data structure can be obtained which will be especially useful in the initial stages of the development of the digital twin. Moreover, the ontology model offered by them fulfills two requirements: (1) that domain knowledge of the asset behaviour can be analysed in operation with essential semantics and (2) the potential representation of a digital twin for an asset in operation phase can be accessed. This will allow the CDO to create useful dashboards to evaluate the success or progress of the Digital Transformation of the company based on the KPIs developed by [2] which are mapped into Vial's [18] framework.

Furthermore, Park et al. [11] have developed a digital twin interface model for digital twins of organisations focused on processes. This model allows the business process analysts to elicit constraints by analyzing the state of business processes and define actions based on the possible configurations. However, this model can be modified to serve the needs of the CDO who can also be in contact with business process analysts to gain insight into the organisation's processes and the impact they have on the Digital Transformation.

6.3 System Dynamics

Well-constructed system dynamic models can be used as thinking engines for digital twin systems [19]. As has been stated above, system dynamics modelling is an approach to understanding nonlinear behaviour of complex systems over time. Hanoum et al. [7] state that the purpose of system dynamics is to understand how each component of a system influence each other and, based on that understanding, finding the best decision and policies to improve the system's performance. System dynamics uses a number of different tools to support decision-making, these tools are qualitative and quantitative [1, 6].

Causal loop diagrams (CLDs) are very useful for describing and understanding the circular character of a system, they can be used to quickly define hypotheses about the causes of dynamics, obtaining the mental models of individuals or teams and communicating

the important feedback to be considered in the problem [6]. Furthermore, Wijnhoven [19] states that causal loop diagrams help ascertain the behaviour of a system by capturing the structure of a system and the relations between its components. Ganzarain et al.[6] state that CLDs represent causal loops, also called feedback loops, which are closed sequences of causes and effects that constitute a closed path of action and information and therefore reflecting the complex nature of the system. These diagrams consist of variables connected by arrows which denote the causal inferences between the variables. A positive link means that if the variable increases, the effect increases with it and vice versa. If the link is negative the opposite is true, if the variable increases, the effect decreases and vice versa.

After conceptualizing the model via the CLD, it must be computerised. This is achieved by making use of stock and flow diagrams. In stock and flow diagrams, the stocks represent the accumulations [6, 19]. Ganzarain et al. [6] argue that stocks give systems inertia and provide them with memory, they create delays by accumulating the difference between the inflow and the outflow of a process – also supported by [19] even though he considers stocks to be he storage of populations. Inflows and outflows are represented by pipes pointing either in or out of the stock respectively and they move the entities between the stocks [6, 19].

After computerization of the model, policies can be formulated and validated [6]. The authors define policies to be much more than just changing the values of the variables in the CLD. Policy formulation is the combination of the creation of new strategies, structures and decision rules – such as changing feedback rules, eliminating time delays or defining new decision processes. The principal objective of formulating policies using the system dynamics model is to improve the performance of the organisation.

The current research is focused on modeling the digital transformation of a company as a system dynamics process. Within the digital transformation, the business model, strategic needs and as a result its business processes, structure and projects change or new ones are created. Therefore, critical and reliable prediction of performance of the organisation during this process is critical for its success. System dynamics modelling fits these needs. The role of system dynamics models is to gain insight into a complex problem and influence thinking and actions in management teams [1]. Furthermore, Lyneis et al. [9] state that system dynamics models facilitate the strategic management of projects, including planing, determining measurement and reward systems, evaluating risks, and learning from past projects. This methodology has also proved to be useful in overcoming the limitation of the strategic learning process [7]. There is extensive research being done regarding system dynamics modelling and project management[8, 10]. Lyneis et al [9] concluded in their research that system dynamics models have demonstrated their ability to improve significantly the quality and performance of management on complex problems. Therefore, in this research, system dynamics is presented as a tool for the CDO to formulate policies and strategies which can then be validated via simulations.

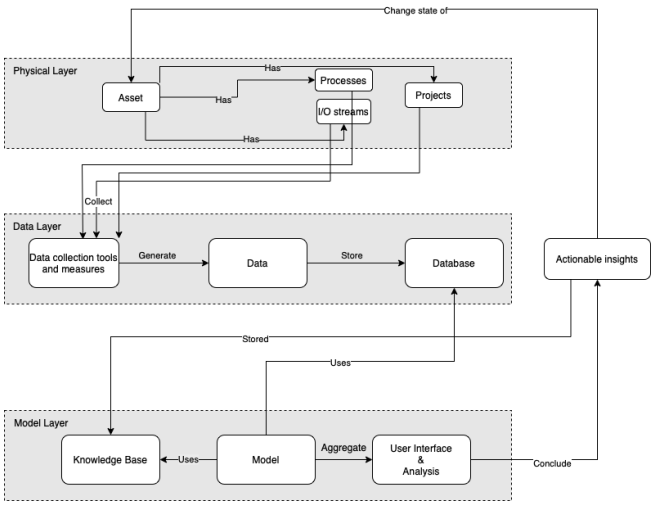

Fig. 1. Digital Twin of Organisation Ontology Model.

7 DIGITAL TWIN MODEL

The ontological approach from Singh et al. [16] has been chosen for the digital twin of an organisation as it will help with the understanding of data flows, properties and constraints of the DTO. However, changes have been made for both the information flow and ontology model described in their research. Given the context of the Digital Transformation and the purpose of the model described in this paper, the database and the knowledge base have been separated. The knowledge base in the DTO, contains only the business rules, causal rules and any other set of rules necessary for the model to meaningfully manipulate the data generated by the business in order to generate the desired user interface and analyses for the CDO to use in decision-making.

The information flow of the DTO can be seen in Figure 1. Given the changes with the flow described in Singh et al.[16] the model layer no longer modifies the data layer. The Physical Layer refers to the organisation itself, the data from the organisation is measured using measurement and data collection tools. These tools must be designed based on the understanding of the way the company should be managed. The data collected in the data layer is structured in a meaningful way in the database. This layer will then provide the model layer with the historical data which it will then manipulate to help the CDO come up with actionable insights that will modify the organisation at the physical layer.

In the model, the company has processes, projects and, input and outflow streams. These streams are being measured using data collection tools. These tools then generate the data which is subsequently organised following the data structure derived from the ontology. This ontology model clarifies the separation between the database and the knowledge base. Together, both will act as the DTO model's memory; however, the database will provide the model with the historical data while the knowledge base will provide it with the rules and axioms. These rules and axioms will help the model make meaningful use of this data to aggregate it into the user interface for analysis. This analysis will subsequently help the CDO make

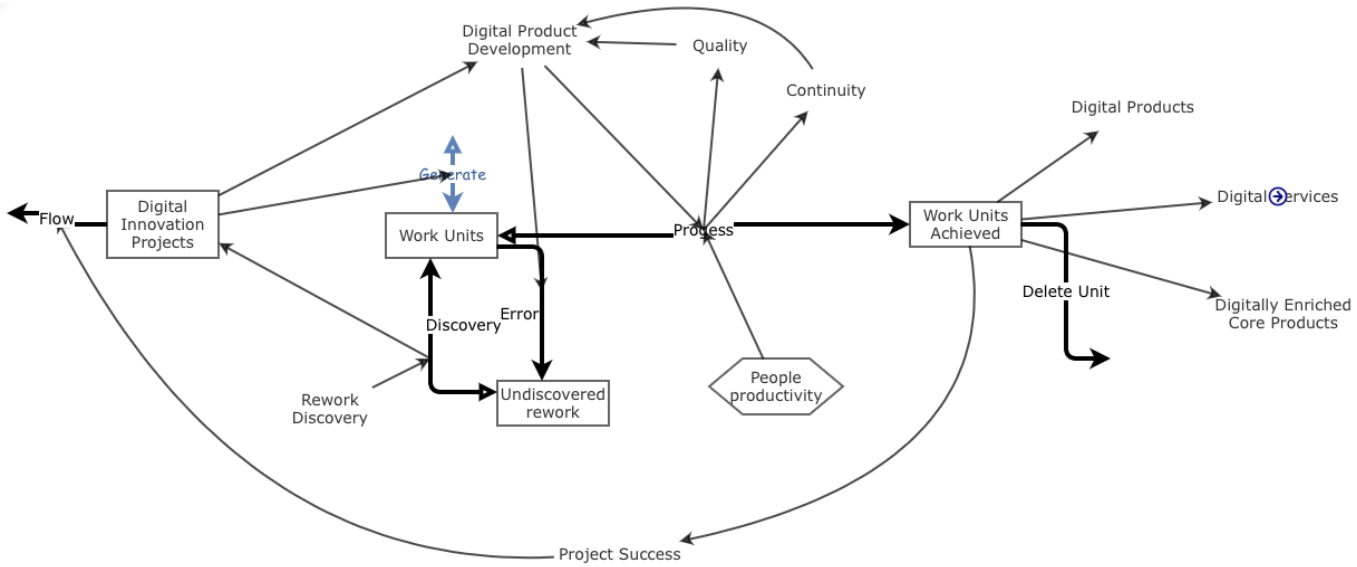

Fig. 2. System Dynamics Model of specified KPIs.

the appropriate decisions. Furthermore, as can be seen in the figure, the model will constitute the calculation engine of the digital twin in charge of doing the system dynamics simulations.

The user interface gives the CDO the ability to generate dashboards of relevant digital transformation KPIs and the ability to manipulate and create system dynamics models focused on specific KPIs to simulate strategies and changes in policies. After the CDO reaches a conclusion, any change in the business rules will be stored and the effects of the decision will automatically be reflected on the digital twin as it is synchronised to the company.

8 SYSTEM DYNAMICS MODEL

Figure 2 represents the system dynamics model related to the value propositions of the company. The KPIs pertaining the value propositions are the number of digital innovation projects, the number of digital products, the number of digital services, the number of digitally enriched core products and the quality, continuity and responsiveness of digital product development, which can be seen in Table 1. The value propositions correspond with the value creation paths building block from Vial [18]. This building block describes the use of digital technologies that enables the company to uncover new ways of generating value while leveraging these technologies. The changes on these KPIs will reflect a redefinition of the company's business model regarding its value proposition to customers.

Table 1. KPIs for Value Creation Paths

Success Dimension [2]	**KPI** [2]
Number of Digital products and service innovation	- Number of digital products and services - Number of innovation projects - Quality, continuity and responsiveness of digital product development
Digitalization of current product and services	- Existence and number of digitally enriched core products

The model of Figure 2 simulates the project management aspect resulting from the decision of undertaking digital innovation projects with the goal of creating new digital products, services and digitally enriched core products. The model aims at simulating how the workflow will result on the creation of this products and changes while also tracking the performance of the projects and the digital product development, its quality, continuity and responsiveness. All of which are KPIs for digital transformation as defined by Barthel [2].

This model was done using the InsightMaker software and takes a project management approach to the modelling and simulating of the system dynamics regarding the KPIs. It implements a simplified version of the rework cycle for project management where the tasks or work units of projects when done can either be successfully carried out work units that lead to progress in the projects or become rework in the future [8, 10]. When a work unit becomes rework, it is not identified as such right away; however, it might be discovered to be so later on in the development of the project [10]. Once discovered it will become a task again and can be tackled again. Progress of work units is defined by the amount of work units, the productivity of the people involved and the digital product development quality and continuity. If these are above a certain threshold then the work unit will be successfully achieved, if not they will become rework. Once achieved there is a series of conditions established by the project management that define how a digital innovation project is considered to be successful. Such completion of digital innovation projects would then reduce the amount of projects being developed; thus, also reducing the number of work units to be done. The main goal of such digital innovation projects would be to generate digital products and services as well as digitally enriching current core products.

The model simulates the dynamic of these digital innovation projects for a total of three years being every step a month. Figure

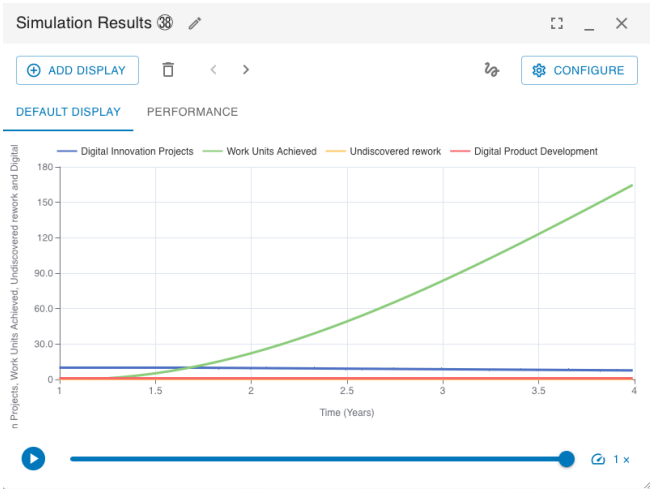

Fig. 3. System Dynamics Model Dashboard.

3 depicts the dashboard resulting from the simulation carried out by the model, it can be seen how the work units achieved grow with time while the digital innovation projects diminish over time as these units are achieved. This model and subsequent simulation dashboard aim at exploring how system dynamics modelling can help the CDO answer 'what if' questions by making simulations. In the current model, the logic for the flow of units and the values of every variable can be modified to reflect strategic choices for which simulation can be ran to gain useful insights in the performance of the company with regards to the KPIs.

9 DIGITAL TRANSFORMATION MODEL

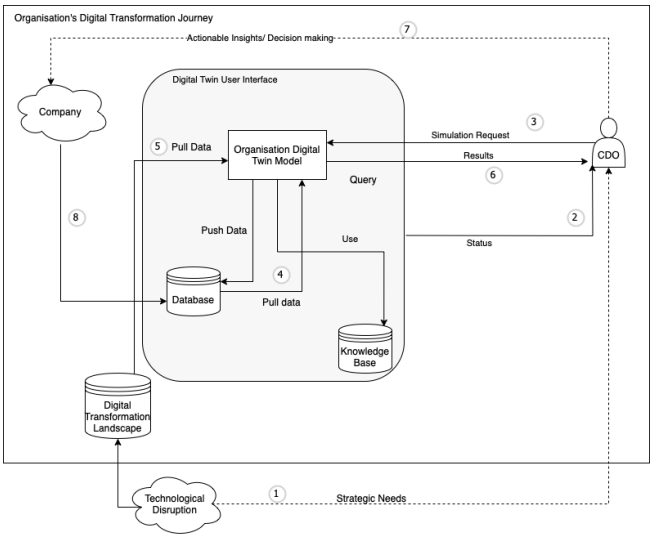

Fig. 4. Model of Digital Transformation of company using Digital Twins and System Dynamics.

Figure 4 represents the Digital Transformation model that the CDO can make use of to navigate the Digital Transformation by combining digital twins and system dynamics. This model aims at helping the CDO to succeed in the digital transformation journey of the company. To do so, the model makes an important choice with regards to its scope. The model represents the digital transformation process instance triggered by a single technological disruption either as a result from a technological innovation or from a new use found to an existing technology. As Vial [18] states, this disruption can lead to the surge of a new strategic need for the company either from new opportunities or risks tied to the disruption – (1) in Figure 4. This strategic need requires the CDO to take action, this could be new digital business strategies or digital transformation strategies. Therefore, it is important for the CDO to be able to have clear and accurate oversight over the projects, processes and activities happening within the company. This oversight will be helpful in the development of the strategies; furthermore, it will also be helpful in the modelling and simulating of the impact of the strategies on the company. This oversight comes from using a digital twin of the organisation and a system dynamics model that uses said twin for simulations.

Number (2) in Figure4 represents the CDOs use of the Digital Twin user interface which gives an accurate image of the company's performance and current state and acts as a decision component for the CDO. The user interface allows the CDO to generate dashboards of relevant KPIs of digital transformation to track performance of the company. Furthermore, this user interface grants the CDO access to the calculation engine of the digital twin, which is the system dynamics engine, so that the CDO can design new strategies and policies to answer "what if" questions. Once the CDO has formulated such strategies, he can then make use of the system dynamics model to simulate the effect of such strategies on the company, numbers (3) and (6) in Figure 4 reflect the query for simulation.

As has been said, the process of the digital transformation in this paper is centered around the use of digital twins and system dynamics. The digital twin is the model that represents the organisation in its complexity as a user interface that is manipulated by the CDO. The user interface will be based on the success factors described in Table A1 in the Appendix which will allow the CDO to understand the performance of the company along the building blocks of the Digital Transformation as described by Vial [18]. Furthermore, these KPIs will also help the CDO understand the performance of the company regarding the extent to which the digital transformation is taking place in it as well as its performance in both internal and external metrics, as proposed by Barhtel [2].

In order for the digital twin to be a digital representation of the company; the data generated by the company, its processes, activities and projects must be stored in a database. The database of the digital twin in this Digital Transformation model is implemented following Singh et al.'s [16] method for ontologically modelling a digital twin's data management – especially given that they focused on creating a managerial digital twin with less focus on engineering. However, changes have been made to said methodology and model to better suit the needs of the CDO in the development of a DTO. One of such differences is the separation of both the database and the knowledge base, which is number (4) in Figure 4. The database

contains the data generated by the company in exclusivity, allowing for synchronized availability of historical data following the ontology of a company. This ontology is; however, subject to the purpose for which it has been made – in this case the Digital Transformation. The representation of the company will also be inevitably tied to this goal. The knowledge base on the other hand will contain the business rules, causal rules and logical rules necessary for the creation of both, the digital twin and the system dynamics model. By using both the knowledge base and the database the digital twin model will generate the aforementioned user interface. The data flow and ontological model have been further discussed in section 7.

The system dynamics model is formulated based on the management's understanding of how the KPIs should be measured and the goals for which they are being measured. This way it can serve both as a control system and as a calculation mechanism to calculate predictions to 'what if' questions. This is done by having the system dynamics model use the most up to date digital twin version, this digital twin can be modified to reflect the strategic changes or activities the CDO wishes to simulate via the user interface, this constant updating of the DTO can be seen in number (4) in 4. The system dynamics model will then use the digital twin and the digital transformation database data, (5) in Figure 4, to simulate the effects of the choices made by the CDO on the company. This model will help answer 'what if' questions over time. After analysing the dashboards generated by the system dynamics calculation engine within the digital twin, the CDO will then come to conclusions regarding the strategies and can formulate actionable insights and decision which will then translate to changes in the company as represented in (7) in Figure 4.

Lastly, any changes on the company as a result from decisions of the CDO or any other manager will be reflected in the digital twin as its database is synchronized to the company (8) in Figure 4. This is useful for the CDO as not only the interplay of the system dynamics model within the digital twin is useful for predictions but also for the tracking of the progress being made in the digital transformation journey. This tracking allows the CDO to make decisions throughout this journey such as measuring how much value certain activities bring. Eliminating those bringing little value while prioritizing those that bring higher value. Therefore, this model would serve as a tool for the CDO to not only strategise for the digital transformation but also to track the company's performance through the process. This allows for agile decision making and changes during operational phase.

10 DISCUSSION

This research set out to show how can digital twins and system dynamics models help the CDO navigate through the Digital Transformation of the company. To achieve this, a model of the digital transformation of companies using digital twins and system dynamics models was devised. Additionally, the information management model of the digital twin and an example of a system dynamics model focused on modeling strategies for value creation in the context of project management have been provided.

The literature on the different components of the digital transformation model supports the possible use of digital twins and system dynamics for understanding and managing a process as complex as the digital transformation. Firstly, a connection between Vial's [18] inductive framework of the digital transformation and digital transformation success KPIs was established in Table A1. Having these KPIs would now allow modelling of digital transformation endeavours while being able to track progress or run quantitative simulations. Additionally, these KPIS could prove of great importance in the design of the ontology of the data structure of the digital twin. It is this way that the current research tackles the level of abstraction of Vials'[18] framework to make it possible to measure the performance of the company in the different building blocks.

Based on the literature, in the research a model of the data flow and ontology for the management of data for the digital twin was developed. However, changes to the method and approach of Singh et al. [16] were made to better suit the goal of being a tool for the CDO. This model for data management could prove useful in the design and development of a digital twin of an organisation as it shows how the data would flow from measurement and collection to decisions which then affect the organisation itself. Furthermore, the design of the digital twin not only enables the CDO to have an accurate managerial view of the company for decision making but it also supports the CDO in the formulation of strategies, their implementation and evaluation.

The system dynamics model serves as an example of how the CDO could make use of the methodology to formulate strategies in which parts or the company as a whole will be embedded and more importantly test them by simulation, encouraging this way evidence-based decision making. The fact that when using system dynamics the policies can be changed and tested could prove of great value to the CDO for making better informed decisions.

The digital transformation model represents a possible dynamic problem solving process that the company could make use of to enable repeated and reliable performance of activities towards strategic change instead of recurring to ad hoc problem solving as described by Vial [18]. This model starts with the identification of a technological disruption and allows the CDO to formulate strategies based on current state of the company and strategic objectives. These strategies will then be tested using the system dynamics engine. The effects of the decisions made will then be reflected on the digital twin allowing for performance tracking and reformulation and modification of decisions. Therefore, this tool could be useful in increasing the dynamic capabilities of firms for dynamic problem-solving. Here, the present research adds to the current literature regarding the creation of processes for dynamic problem-solving and decision-making.

The digital transformation model concept received feedback from a practicing CDO. The CDO stated that the model could be useful for CDOs in the digital transformation of companies; however, it would be limited to areas of business where using this model would end with results which are close to the actual outcome. As a tool to measure the performance of the company it could prove to be difficult as business, logic and causal rules have been proven to be challenging for smaller subsets of the enterprise that cover performance such as operations and finance. Furthermore, what is considered to be

difficult for prediction in the company is human behaviour, which is relevant for management.

There are some limitations to the current research. The first of which is that the digital transformation model is not operational as the digital twin is not fully designed. However, it is only possible to test this model if digital transformation goals are defined based on a company's structure and needs – a dataset is needed for this. This also applies to the design of system dynamics model, as it is also invariable tied to the organisation it is devised for. Another limitation to the current project is the possible technical complexity in the development of the operational structure. The model has not been validated nor tested either, each component has been developed separately with a focus on its fit in the digital transformation model.

Future research could focus on the testing and validation of such model by interviewing practitioners and making use of case-studies with actual datasets and strategic needs to formulate and simulate strategies.Further research could be done in the system dynamics relationships between the variables in Table A1. Lastly, a focus on the modelling of human behaviour could prove useful in the performance of the digital transformation efforts.

11 CONCLUSION

To conclude, the current research has built on the research from Vial [18], Barthel [2] and Singh et al. [16] with a more practical focus. A digital transformation model has been developed which integrates the use of digital twins and system dynamics into a tool which can help the CDO strategize and keep track of performance. A modelling of the data flow and ontology of a digital twin of an organisation has been provided together with an example of a system dynamics model simulating a simple project management strategy.

Firstly, this paper demonstrates that Vial's [18] framework for digital transformation can be operationalised by mapping to it the digital transformation success KPIs described by Barthel [2]. This framework, together with the KPIs and the role of the CDO in companies delineated the goals of the model.

Secondly, the digital twin data management and flow models show how digital twins can be beneficial to CDOs in the digital transformation process, not only in the decision making process at the strategic level but also in the tracking of company performance during the process.

Thirdly, the system dynamics model is an example of how the CDO could devise strategies to tackle the digital transformation and test those strategies via simulation. Furthermore, as system dynamics is focused on improving the performance of organisations the models can be fully manipulated to test diverse strategies by modifying causal loops, delays and other rules and decision making processes giving CDOs flexibility.

Fourth, the digital transformation model tackles the dynamic capabilities of firms in the digital transformation by delineating a process for dynamic problem solving and decision-making. This is done by seizing technological disruptions through strategic responses to them and simulating and tracking the reconfiguration of the firm's resources and structure throughout the process.

Overall, it can be concluded that even though the digital transformation has been extensively researched, there has been a lack of focus on the complex dynamic behaviour of this process. The current digital transformation model gives the CDOs an approach to the digital transformation that provides them with oversight of the company's performance as well as the ability to formulate strategic responses to technological responses via accurate simulations of the complex system that is the organisation. To conclude, current paper has shown how digital twins of organisations can be modelled within the context of the digital transformation as well as how system dynamics models could serve CDOs in this process.

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A DIGITAL TRANSFORMATION KPIS

Table A1. KPIs for each Building Block from Vial [18]

Building Block [18]	**Variable [18]**	**Success Dimension [2]**	**KPI [2]**
Strategic Responses	Digital Business strategy	Digital Business model innovation	Number of realised digital business innovations
		Strategy	Maturity, acceptance and transparency of digital vision, agenda and strategy
	Digital Transformation Strategy	Strategy	Maturity, acceptance and transparency of digital vision, agenda and strategy
Changes in Value Creation Paths	Value propositions	Number of Digital products and service innovation	- Number of digital products and services - Number of innovation projects - Quality, continuity and responsiveness of digital product development
		Digitalization of current product and services	- Existence and number of digitally enriched core products
	Value Networks	Partner network	- Maturity of partner network - Hybrid value creation
		Partner Management	Maturity of precesses for cooperating with partners
	Digital Channels	Digitalisation of customer interaction	- Number and degree of digital customer channels utilised - Maturity of digital customer touchpoints
	Agility and ambidexterity		
Structural Changes	Organisational Structure	Structure, Collaboration and Governance	- Maturity of organisational structure - Agility - Digital team setup - Teamwork - Management support
	Organisational Culture	Culture and leadership	- Maturity of innovation culture - Digital Affinity - Digital Mindset
	Leadership	Culture and leadership	Leadership
	Employee roles and skills	Competence and Knowledge	- Maturity of digital skills - Competencies - Knowledge Management
Positive Impacts	Organisational Efficiency	Efficiency and Profitability	- Earnings per share - Operating Margin - ROA
		Processes	- Process Efficiency
	Organisational Performance	Processes	- Process effectiveness - Maturity of processes - Number of process innovations
		IT	- Maturity of IT infrastructure - Reliability - Availability - Performance of IT
		Revenue from Digital Business	- Revenue from digital products and services - Sales from online channels
		Relative importance of digital business	- Ratio of new digital business revenue on the total revenue - Share of revenue from all online resources
		Profitability of digital business	- Digital Products' and services' profitability - Online sales profitability
		Company value	- Market cap - Market-to-book ratio
		Sales volume and customer base	- Total turnover - Market share growth - Growth of customer base
		Company reputation and customer satisfaction	- Online brand KPIs - Brand index score - Customer satisfaction score
		Workplace quality	- Employee turnover - Online sales profitability