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# System of systems engineering governance framework for digital transformation: A case study of an Australian large government agency

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## Abstract

Current swift technological advances are significantly impacting how organizations operate and services are provided. Even with the multiple benefits for organizations that undergo digital transformation, the majority of transformation initiatives fail due to the challenges that arise. A primary reason for these failures links back to the lack of effective governance framework to support effective digital transformation efforts. This paper proposes such a framework through a system of systems engineering approach to understand the various constituent systems involved in digital transformation efforts and their interactive and emergent behaviors. The application and usefulness of the framework were demonstrated as part of a digital transformation initiative in an Australian Large Government Agency and documented as a case study.

**KEYWORDS**
digital transformation, governance framework, holistic, system of systems engineering

## 1 | INTRODUCTION

In today's rapidly changing world, digital transformation has a major impact on society, playing an increasingly important role in engineering efforts, particularly demonstrated in the context of the recent and evolving disruptions arising from COVID-19. Organizations can reap numerous benefits when they undergo digital transformation. Short term benefits include the measurable growth in availability of new services (online and through digital channels) while long term benefits include the improved effectiveness and client satisfaction with the products and services provided by an organization. Further advantages encompass cultural changes within the organization from a bureaucratic top-down structure to a relationship driven shared decision-making structure.[1] To derive more benefits, it is recommended incorporating complexity into the digital transformation modelling, planning, and engagement to allow various autonomous systems involved in digital transformation to naturally interact with each other and generate emergence. This includes the way information and data are collected, stored, and analyzed to support decision making in addition to the development of models and plans, focusing on cross and multidisciplinary methods and embedding these changes into the organization while encouraging feedback.[2] However, to benefit more fully from digital transformations, organizations need to be prepared to improve more than just their engineering and infrastructure practices.

The purpose of this research is to propose a SoSE governance framework used to support effective digital transformations. The framework requires the user/organization to consider the constituent systems (e.g., clients, employees, and businesses) as autonomous decentralized systems, while also viewing what happens when they come together as a collective and interact as a system of systems, working towards a common goal. Through the application to a case study, this paper argues that the success of the Australian Large Government Agency's

digital transformation was largely due to the application of the SoSE framework. Within this case study, it becomes clear that digital engineering is the digital transformation of engineering practices which includes infrastructure updates, along with interfaces, processes, and procedures. The case study sets a benchmark for effective digital transformation in large organizations, highlighting a number of best practices and lessons learned.

This effort requires effective governance of multiple integrated systems working together and sharing one common objective to successfully support digital transformation. Recently, System of Systems Engineering (SoSE) has emerged as a discipline to enable such efforts.[3] This includes digital engineering, which incorporates the integration of new technologies with models, systems, infrastructure, simulations, and components at a point in time and across the digital lifecycle.[3] Literature shows that by implementing digital engineering approaches, organizations can develop and support multidisciplinary simulations along with visualization opportunities and platform-based approaches.[3] This can subsequently provide a more detailed model of the current and future states. Within digital transformation, a data and client centric approach is supported by digital engineering models, which is a collaborative way of working that utilizes digital processes to create productive methods for planning, designing, and maintaining assets and outcomes throughout a lifecycle.[2]

Digital engineering is defined as "an integrated digital approach that uses authoritative sources of systems data and models as a continuum across disciplines to support lifecycle activities from concept through disposal".[2] For many organizations, digital engineering represents or forms a key part of a transformation in terms of how they normally conduct their engineering systems and transforming them digitally.[3] In addition, according to Merriam Webster, engineering is defined as the design, building and use of machines, engines, and various structures.[4] Therefore, digital engineering can be described as the digital transformation of engineering and can be supported by understanding the multiple different systems and factors that can potentially influence it.

Digital engineering provides continuous insight and oversight through a single source of truth shared among stakeholders involved in the system.[3] When design is integrated and validated multidimensionally as part of both modelling and transformations in digital engineering, organizational design, analysis, and optimization can be improved through continuous internal and external feedback.[3] Digital engineering is a form of digital transformation. Successful digital engineering endeavors require organizations to have a mechanism, which encourages and supports high quality outcomes that involve stakeholders, and are safe, cost effective and efficient. Unfortunately, it is a challenging task due to the many systems involved and as a result, an approach is needed that can consider each of these systems individually along with specific organizational performance outcomes. The domain of SoSE allows for the integration of multiple systems that come together to meet one common objective. SoSE is defined as a set of developing tools, methods and processes that are used for planning, adapting, and implementing system of system solutions.[5] The purpose of this research is to identify and apply best practices from SoSE on digital transformation processes.

Digital transformation requires taking into consideration more than just technology since it is vital to include other systems impacting the outcomes such as business processes, organizational structure, and stakeholder engagement, among others.[6] Utilizing the proposed framework, organizations can consider the various constituent systems, including cognitive, social, digital, infrastructure, business, and policy. The framework can further assist in answering a number of key questions regarding the different systems such as what, where, why, who, when and how. A productive digital transformation requires an organization to have a supporting environment, policy, and cognitive systems (people). A more integrated and inclusive SoS approach can be instrumental in gaining a deeper understanding of each element as part of this effort.

Using a case study, this paper outlines the application of the framework in the Australian Large Government Agency, which used the framework to effectively support their ongoing digital transformation. Through the application of the framework, readers can understand the different factors for consideration and how they were addressed for each constituent system (internally and externally). The findings of this research also present several different outcomes as well as best practices and lessons learned.

The structure of this paper is broken into seven sections. The first section is the introduction to the research. The second section summarizes published material on digital transformation and the third section provides an overview of the literature specific to SoS. This is followed by section four presenting the SoSE framework. Section five then describes the application of the framework to a case study. Section six is the conclusion and finally, section seven outlines future research for consideration.

## 2 | DIGITAL TRANSFORMATION

### 2.1 | Benefits

The benefits for organizations undergoing digital transformation often link back to the ultimate drivers influencing the initial organizational transformation to take place. One of the key benefits can be improvements to inefficiencies within business models through the growth of digital capabilities in staff and digital maturity of the organization that can have an impact on the business models and strategies that develop over time.[7] Economic benefits can include enhanced profitability (new or improved revenue growth), customer satisfaction and increased operational efficiency.[8] Economic benefits can further flow on savings to clients and the broader business. As part of digital transformation, client engagement can expand through the provision of digital services, convenience, standards of service, agility, and competitive advantage to other organizations. Therefore, digital transformation can lead to improvements to customer focus, specifically in value creation and appropriate client support.[7] Thus, organizations can be better equipped to respond to adapting client needs and expectations.

Organizational efficiency is often improved by digital transformation, through the automation of manual tasks and integration and

streamlining data use, workflow, and productivity.[9] Consequently, among key benefits can be optimization of business strategies, reduction of costs, and encouragement of client interactions through digital platforms. However, for these benefits to be realized, there needs to be more than just technologies driving the change. Ongoing digital capability enhancement, strategic development, organizational culture, and talent development/acquisition must be undertaken in conjunction.[10] Even with the significant number of benefits associated with an organizational digital transformation, a number within an organization, there are also a number of challenges that need to be considered and addressed in order for the benefits to be realized.

## 2.2 | Challenges

Although there are benefits to transforming digitally, specifically organizational performance improvement using technology,[11] there are challenges to be overcome in undergoing digital transformation. Digital transformation involves the application of technologies which impact all aspects of business and society.[12] A challenge arises from the efficiency of current processes, including the cost benefit of legacy system improvements, compared to the need to focus on meeting client needs.[13] This challenge links back to the difficulty of balancing the need for efficiency with the requirements to meet client expectations, encourage loyalty and improve overall satisfaction.[14] Efficiency becomes an additional challenge when it is prioritized incorrectly and influences overall quality.

Another noteworthy challenge is the difficulty integrating digital structure into the DNA of the organization, which includes services, business models and skills.[15] This encompasses the implementation of technology, along with the development of skills and expertise in the area.[16] Therefore, culture and skills form additional challenges associated with education, talents, and the digital environment.[17] In response, a significant effort needs to go into understanding requirements of clients, the organization, and staff, and providing resources, time, and support to everyone involved to upskill and move with the transformation. In addition, organizational challenges around digital transformation link back to knowledge management (e.g., accessibility of information and documentation) and to the issues of visibility and transparency.[18] Hence, both organizational and market challenges can often be connected back to a lack of visibility and transparency into the purpose and process of the digital transformation.

Economic challenges may present where new digital processes and technologies cause significant changes to the requirements of skills and expertise of staff.[19–25] In response, this can require costs of upskilling current staff, employing new staff and potential redundancies of staff no longer required. Furthermore, there has been a rise in the impacts of societal challenges that link back to social issues such as environmental sustainability, specifically related to resource efficiency and energy consumption.[26,27] Linking back to the need for integrating digital structure into the organizational DNA can support overcoming the presented challenges while reaping the benefits. With the significant number of challenges impacting digital transformation, a framework is needed to address the challenges and realize the benefits of the process within an organization. In response, the aim of this paper is to respond to the lack of a framework to support effective digital transformation through the introduction of a SoSE governance framework.

## 2.3 | Architecture

Digital architecture is used to refer to other aspects of architecture that feature or utilize digital technology in order to achieve business outcomes.[28,29] Digital architecture does not always include tangible materials (e.g., bricks and mortar), instead housing much of its architecture though intangible connections and formats.[28] As a discipline it redefines the solution and design process, while shifting the focus from a business problem solving process to one focused on client and staff experiences.[29] As a result, digital architecture involves shifting the paradigms with internal stakeholders away from solutions to incorporate the needs and expectations of external stakeholders.[29] This links to other research, which highlights that digital projects and transformations cannot be run separately from the rest of the work occurring as part of an organization. The architecture and infrastructure behind the digital transformation needs to consider the purposes of technologies, new solution development and business development.[30] Thus, the term architecture within digital engineering includes organizational processes, structure and constituents that can be within and outside the organization. It is important to understand the different processes within an organization, to effectively manage any transformation process implemented.

## 2.4 | Processes

The digital transformation process is a method of utilizing digital technology to support the development of business processes and optimization of various workflows. It focuses on improving the processes, activities and tasks that involve human interactions.[31] However, the process should find the right balance between providing generic digital transformation phases and maintaining a certain degree of flexibility that would allow for adapting it to different organizations.[32] Due to the complex and strategic nature of digital process improvement, there needs to be strong leadership and strategy to develop a more holistic and interconnected initiative rather than individual and isolated initiatives. Through fundamental changes to organizational management, the processes can improve and support development of new business models to encourage greater growth opportunities.[33] Different organizational structures impact how organizations manage their day-to-day operations including their internal processes and architecture, the organizational structure also can have significant impacts on the effectiveness of digital transformation efforts.

## 2.5 | Structure

Effective digital transformation of an organization requires overarching strategic alignment.[34] Strategic alignment supports consistency

across organizational structure and processes, technology strategy and information system infrastructure.[35] Additional research has identified the importance of organizational structure. This includes the impact of flattening the structure, decentralizing the decision making, encouraging collaboration, developing new knowledge, transferring processes between employees, networking across teams and areas, proactive communication and organizational flexibility and agility.[36-39] The development of new organizational structure should be completed early in the transformation, rather than maintaining rigid internal and external boundaries.[40] The organizational structure informs the boundaries within and outside the organization, indicating which stakeholders are important and how to identify them. In addition, the structure also supports the way constituents are identified, managed, and engaged with before, during and after an organizational transformation process.

## 2.6 | Constituents

The goal of digital transformation can vary across organizations and can have an impact on the environment outside of the organization. By highlighting the importance of sharing the purpose of digital transformation externally, an organization can obtain buy-in and support for the transformation and generate innovations that could occur as a result.[41] This section outlines the important constituent systems identified within the proposed framework.

The first constituent system, is the cognitive system, also referred to as an individual mental system, consists of multiple interrelated assumptions, beliefs, ideas, and knowledge.[42] This system consists of an individual's worldviews and determines how individuals act, think and filter information and cues from the outside world. The cognitive system influences the beliefs and attitudes of the staff and clients affected by the transformation, along with their willingness to adapt to change. The second constituent system identified is the social system composed of elements associated with the various interactions between the actors within the population. Social systems include persons within populations who adapt to their environment in order to survive and thrive, including ability to adapt to the environment and community.[43,44]

The third identified constituent system, is the digital system, which is an open, loosely coupled, demand-driven, domain-clustered, agent-based, self-organized collaborative environment (or a system).[45,46] Digital systems capture relationships between dynamic networks of interrelated complex systems.[45] The behaviors within the digital systems are similar to organisms within the biological system, including mitigation, ongoing evolution and the use of hybrid environments.[47,48] The digital system links into the infrastructure set up to support any digital materials within and outside of the organization. The fourth identified constituent system is the infrastructure system, which are referred to as the backbone of services and digital systems. They incorporate the basic physical systems of information technology, electricity systems and communication networks.[49,50] Infrastructure includes the fundamental facilities and systems which serve a country, state, or

region, and includes various facilities and services required for a government and economy to function.[49] The different components within an infrastructure system are broad, as it incorporates both public and private physical improvements. This system forms the foundation of the transformation.

The fifth constituent system identified is the business system, which focuses on the micro-economic view of business networks as well as the macro-economic perspective.[51,52] The business system highlights the different views and considerations of different groups and individuals within the market, affecting infrastructure, cognitive and social systems while also being affected by them. The sixth constituent the system identified is the policy system, which is a deliberate system of principles, based on specific policies of an organization, country, or international entity. Policies are defined as a statement of intent, implemented as a procedure or protocol.[53,54] This system impacts the environment in which the organization operates and what an organization needs to comply with in order to run lawfully. Each identified constituent system provides a view of the different considerations and interdependencies which impact the outcomes of digital transformation efforts. These systems highlight the importance of understanding the role of technology and the role of people within a transformation.

## 2.7 | Role of technology/digital engineering

Understanding the role of technology within a digital transformation is crucial, especially as it forms the infrastructure and encourages ongoing changes in the organizational processes. One of the most significant external pressures come from changes in technology in line with the environment.[1] The perceptions and use of technology are constrained by organizational requirements while endorsed technology influences the organization. The role of technology differs depending on the organization and the individuals (e.g., staff and clients) within the organisation.[1] Research suggests that technology does not necessarily change an organization, and instead, the manner in which organizations work and use their technologies to change work practices.[55,56] In addition, the use of technology creates a feedback loop whereby technology is utilized and further influences internal and external processes and changes how technology is used by the organisation.[57] Technology is critical to triggering the digital transformation process, but it is not enough to establish the long-term effects.[1]

To support successful digital transformation, organizations need to consider technology along with human factors. Technology and engineering enable change. Yet, this change must be supported by the organization and stakeholders. Research highlights four elements that can support transformation and are captured in digital engineering approaches, including (1) models should be adapted to the nature of the workforce, (2) processes should remain adaptive (e.g., risk management methods), (3) the focus should be on the result of the process, (4) knowing who produces what and when, in conjunction with common language (supports the how).[58] The implementation of new technology into an organization is only a small part of a digital transformation since there are also considerations of the integration with legacy services

and how people and human factors will be considered and responded to.

## 2.8 | Role of people/human factor

It is not sufficient to consider technology in isolation. There is a need for skilled employees to implement the change and skilled clients to utilize new or upgraded services.[16,59] When updating technology and services provided to staff and clients, organizations need to consider the usability, satisfaction, wearability, safety, and aesthetics of what is provided.[60] Research suggests that digital transformation incorporates cultural and organizational transformation, which includes organizational cultural change such as structure, terms, processes, attitudes, beliefs, and behaviours.[61] In addition, organizational and cultural transformation is vital to the successful implementation of new technology through the establishment of digital culture and cultural change.[62,63]

Human factors around innovative culture, risk tolerance, team collaboration, trial and error mentality and agility have significant impacts on the effectiveness of digital transformation endeavors within an organisation.[64–66,10] This includes ensuring that leaders encourage digital maturity within the organization and encompasses people, processes, technology, engagement models, structures, and business models.[67] Furthermore, this change and leadership requires supporting staff to implement the transformation and encouraging clients to utilize new technology and services, thus ensuring organizational readiness to implement changes, and making ongoing adjustments to the business models.[67] Therefore, digital transformation necessitates strong and clear leadership to sustain and drive change in an organization, and a vision for what the organization needs and wants to transform.[65] To benefit from digital transformation, organizations need people who are open to change and collaborative, take risks and innovate to improve the way they work, collaborate, and execute business processes.[65] With advancements to technology and the services offered and provided by organizations, the internal and external boundaries can be blurred. As a result, the need to understand the varying needs and expectations of clients and staff, along with the impacts of changing environments to the acceptance of change.

## 2.9 | Role of supporting environment

Culture is an important component in any transformation. If there is not support from the users and the employees, the likelihood of success is very low. Research demonstrates that 70% of digital transformations fail, this failure can be linked to several factors within the organization and surrounding environment.[69] However, a primary cause of failure within digital transformation efforts has been identified as not having a supportive environment both internally and externally.[69] Consequently, in order to respond to the rapidly changing environment, there is a need for organizations to understand the critical role of a supportive environment. This requires a fundamental transformation and restructuring of a business model to respond and survive within

a disruptive environment.[69] Organizations are affected by changes from the external environment, which includes political, social, and economic factors.[70] The external conditions influence and affect the development of the organization, and often, this encompasses the following five elements: technological, economic/business, infrastructure, social and political.[71] In addition, when the external environment is considered, performance can be measured in accordance with the changing conditions. This includes the attractiveness of the organization to clients and potential employees.[72,73] As a result, a supportive environment is encouraged by seeking buy-in and input from external sources such as clients, social groups, technological firms, political figures, and broader groups outside of the organisation.[68] The effectiveness of a digital transformation can be improved by having a supporting environment, this includes where new innovations are implemented, and legacy services are modified or phased out to support new service offers.

## 2.10 | Innovation and legacy

As the digital transformation often occurs progressively and overtime, a key consideration is what role will legacy systems and interfaces have in future improvements. A legacy system is often defined as an out of date or old method, technology, system, or program, which is still in use, paving the way for the standards and expectations of future systems.[74] It is commonplace that when a system is referred to as legacy, that the system is out of date and may require replacement.[74] Research suggests that successful digital transformations often limit the continuation of legacy systems wherever possible, instead of making improvements to outdated systems by replacing them with newer and more efficient options.[75] Legacy improvements or modifications are often required to innovate user interfaces (services), business models and upgrades to technology, business processes and tools.[76] Therefore, although short-term investments in legacy systems may be necessary, greater focus on the scaling of innovation across the organization is vital for long term success.[77]

Especially in the beginning, it can be challenging for organizations to foster innovation when attempting improvements to their service offers or legacy systems. These challenges can include technology, processes, and culture However, by utilizing the legacy systems as a minimum viable service standard, innovation can be encouraged and supported.[78] It is important to note that a legacy system provides a level of stability as it is pre-established and can serve as a core to supporting systems when implementing innovations and improvements into the future.[79] Innovation is defined by the practical implementation of ideas or concepts that result in the introduction of new or improved services, systems, or processes.[80] Progressive innovation can often support cultural changes, skill development and technology purchases overtime, rather than pushing a radical change and focused commitment.[76] For radical innovation to be successful, leadership needs to stress the importance of change management, especially as failure becomes more likely when this does not occur progressively.[78] Thus, the need for up-to-date technology, a supportive environment

and role of human capital cannot be ignored. To implement successful digital transformation, each of the constituent organizational systems must be considered holistically, which can be done through a system of systems engineering approach.

# 3 | DIGITAL TRANSFORMATION AS A SYSTEM OF SYSTEM (SOS)

Complexity grows with digital transformation as many large organizations seek to integrate various systems that work together to develop and accomplish their organizational goals. Within SoS approaches, accomplishing organizational goals cannot be achieved by the constituent systems alone. It is the integration of these constituents working together to meet their goals which is referred to as a system of systems.[81] SoS are based on the coordination and integration of multiple constituent systems that jointly perform a function, purpose or behavior that the individual constituent systems are unable to perform on their own.[81] A SoS is more complex than a system due to the additional requirements for integration, and the different emphasis and approach for design and validation.[82] Therefore, the SoS approach focuses on the system as a whole, and not on independent parts.[83]

There are multiple definitions of SoS, but it is commonly defined as a network of systems functioning together to achieve a common purpose.[84] SoS's are naturally observed, as they are derived from systems interoperating with other systems.[85,86] Hence, as SoS comprise numerous constituent interdependent systems and are integrated complex systems, they provide a different perspective to understanding the complexities of an environment.[86,88] Systems are autonomous and heterogenous.[85] However, when they form part of a SoS, their interactions produce capabilities of unintended consequences as a result of emergent behavior which does not originate from a single constituent system.[88] SoS are most commonly referred to as the combination of components that are themselves significantly complex, enough so that they may be regarded as systems assembled into a larger system.[89]

SoS performs within a dynamic environment, and thus, a governance toolset is needed to address the complex problems of both industry and academia more effectively.[90] Through the SoS lens, decision-makers can manage their system more effectively.[90] The categorization of systems can be based on certain attributes of systems such as flexibility, adaptability, agility, or resilience.[90] SoS are task-oriented systems that pool their resources and capabilities together, which in turn creates an additional, more complex system.[91] This system offers additional functionality and performance than the sum of the constituent parts or systems.[91] A SoS views multiple, dispersed, and independent systems within the context as part of a larger and more complex system.[92]

Research suggests that focusing on the characteristics of a SoS is more beneficial than seeking a definition. According to Boardman and Sauser, there are five distinguishing characteristics of a system of systems.[92,93] Firstly, autonomy, defined as the ability of a system to make independent choices, including but not limited to managerial and operational independence while accomplishing the purpose of the SoS.[86,94] Secondly, belonging, defined as constituent systems that have the right and ability to choose to belong to the SoS, based on their own needs/beliefs and/or fulfillment. Thirdly, connectivity is the ability to stay connected to other constituent systems.[94,95] Fourth, diversity is the evidence of visible heterogeneity. Increased diversity in system of systems capability is achieved by released autonomy, committed belonging and open connectivity. Fifth, emergence is the formation of new properties as a result of developmental or evolutionary processes.[96] The SoS approach provides an avenue for understanding the various constituent systems impacting the organization or SoS under review. The approach can assist in understanding and determining whether systems (e.g., infrastructure, social, political, business, or cognitive) are interrelated and, if interrelated, their common goal or objective.

Although there are various definitions of SoS across the field, the shared finding is that a SoS is composed of multiple autonomous and heterogenous constituent systems that work individually and choose to come together for one joint goal. Constituent systems are defined as part of one or more SoS, each a system on their own. They have their own development, management goals and resources, while also interacting with the SoS to meet a common objective.[5] Therefore, due to the number of different systems impacting digital transformation, the authors argue that for it to be effective the identification of the primary constituent systems is required. This research highlighted the most important systems as cognitive, social, digital, infrastructure, business, and policy. As individual systems they highlight important roles and views within the organization and external to it that could impact the outcomes of digital transformation.

# 4 | SoSE GOVERNANCE FRAMEWORK

## 4.1 | Framework

The SoSE Framework outlined in figure 1 highlights the most influential constituent systems impacting successful digital transformation. By understanding the various constituent systems and the SoS as a whole, a systemic and more holistic picture of the systems affecting digital transformation emerges. For this framework, a system is defined as a collection of interrelated elements, including relationships and interactions that are often the result of emergence.[97–99] Furthermore, the definition of emergence is the result of the cumulative actions and interactions of the multiple constituent systems within the SoS, involving both understanding and supervising emergent behavior affecting the success of the SoS.[99] The use of constituent systems allows for emergent properties to appear which is more representative of the problem space. The identified systems are not all inclusive. There are a number of external factors that should be considered as having an impact on the efficiency and efficacy of digital transformation. These external factors can be within or outside of the reach and control of the organization undergoing the transformation, by understanding individual constituent systems these factors can be better understood and identified.
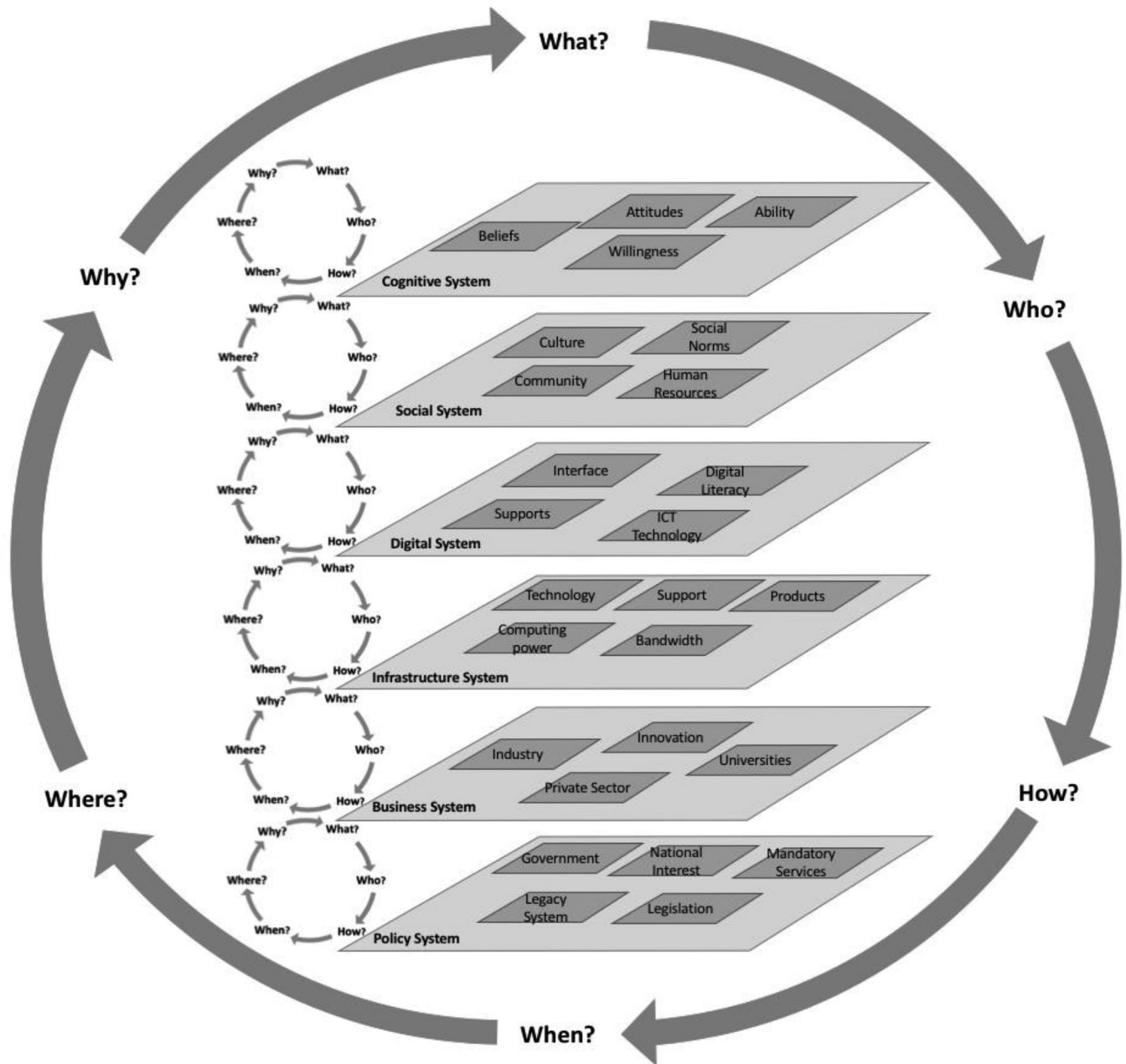
**FIGURE 1** SoSE Governance framework for effective digital transformation.[103]

The next stage is to build an easy to understand and adopt representation of the constituent systems that influence digital transformation processes in the public sector in a vertical and layered manner to provide a separate view of each system. Vertical integration is an arrangement often of a supply chain, within a company, which is owned by that specific company.[100,101] Within vertical integration, each member of the supply chain is responsible for producing different elements or components of a product or service, and the combination of the elements are used to satisfy a common goal or need.[100,101] Vertical integration represents the systems interacting vertically, with arrows pointing in the direction in which the system or component has impact on the broader system.[100] However, with balanced vertical integration, the arrows move in both directions and are able to skip levels, and the

interactions can go in any direction.[102] The balanced vertical integration approach was applied to the presentation of this framework, as it provides a vertical visualization and does not limit the interactions between constituent systems in either direction. Similar to vertical integration, the constituent systems are independent and autonomous. In addition, like vertical integration, when a constituent system chooses to be part of the system of system, they give up a portion of their autonomy to join and move towards a common goal or purpose.

Digital transformation is most effective when adequate incentives that encourage joining the SoS for each constituent system are provided. It should be noted that the whole SoS is greater than the sum of its parts as a result of integration of system interactions within and between one another. This is a paradox since through participation

**TABLE 1** Description of key questions of the guidelines for application.

| Questions | Purpose |
| --- | --- |
| What? | These questions highlight the approach and purpose of each constituent system and how they relate to different measures of success, specifically related to the constituent systems and the system of systems under review. |
| Who? | These questions outline the various actors involved, specifically the decision-makers, users, and service designers and how they relate to the constituent system and the system of systems under review. |
| How? | These questions summarize by what means the performance will be measured and actors will be identified and engaged in each constituent system and the system of systems under review. |
| When? | These questions highlight at what time performance reviews will occur and how feedback provisions will improve the approach, and how they relate to the constituent system and the system of systems under review. |
| Where? | These questions determine the boundaries of the constituent system and system of systems under review and where the approach will be located, and how that relates to the specific constituent system and the system of systems under review. |
| Why? | These questions outline the motivation behind the approach being applied and how it relates to the specific constituent system and the system of systems under review. |

in the SoS, the constituent systems are both collaborating and competing with one another in order to develop and work together for a unified SoS direction. Consequently, the autonomous constituent systems with separate goals and purposes integrate as part of a system of systems to achieve the common goal. Therefore, the representation of the framework shown in Figure 1 demonstrates how each constituent system changes how the entire SoS operates. The representation also demonstrates how they remain independent simultaneously, achieving the shared goal of bringing about effective digital transformation.

Figure 1 further shows cycles within the constituent systems and across the broader SoS. The cycles highlight the need for agility and flexibility across each constituent system, which includes asking the questions at different stages of the transformation and utilizing different resources and stakeholders to support interpretability across different constituent systems and the SoS as a whole.

## 4.2 | Explanation

The purpose of the SoSE governance framework is to identify the key components, issues and opportunities within the various constituent systems and SoS. Table 1 summarizes the purpose of each of the primary questions, providing guidance on the purpose of each of the sub-questions within the constituent systems and SoS. The process of

answering these questions assists in gaining a more comprehensive understanding of the dynamics within the SoS, thus recognizing the multiple needs and beliefs of the involved stakeholders.

Figure 2 outlines the guidelines for applying the governance framework. Each question guides the service designer and policymakers to identify and consider the diverse views and stakeholders that are relevant to the transformation in various ways. These questions should be responded to for each of the constituent systems and at the SoS level, while also being considered at multiple different stages of the transformation to support a holistic understanding of the environment in its current state and any interventions required to improve the effectiveness of the digital transformation.

Through the application of this framework, digital engineering processes can be supported within an organization (e.g., supported by the workforce and infrastructure) while also considering the external impacts on clients and vendors (e.g., client service expectations). The following sections will outline the application of the framework on a real-life case study within a Large Australian Government Agency. Within this agency, the framework was developed in response to the digital transformation efforts across multiple cycles. This case study identified that in order for digital transformation to occur and be successful, organizations require a holistic and integrated approach, thus encouraging research into constituent systems to ensure the transformation is as effective and efficient as possible. With the aim to identify and create a solution on how to integrate all systems, a number of methods were tried and tested, until the adoption of this SoSE approach. As a result, this research proposes the framework and approach that facilitates the integration of systems through the SoS. The trigger for this research and development of the approach was to assist the Agency in becoming a leading service provider, known for being client centric and offering a broad scope of applicable and useful services.

## 5 | CASE STUDY

### 5.1 | Introduction

In 2015, the Australian Government implemented the Digital Continuity 2020 Policy, which mandated the implementation and creation of digital services for all public sector services. This required all federal government organizations to upgrade their services, systems, technologies, and infrastructure to support digital first service provision. A centralized Digital Transformation Agency was established to provide support and governance to the process.[104] However, each government agency was responsible for the development of their own digital transformation process and framework to address the needs of the staff, clients, and infrastructure. Each agency took a different approach. Within this case study, the focus will be on the Australian Large Government Agency (LGA), which has been defined as the industry leader in its approach to the creation of new digital services for clients.[105] This is in large part due to the extensive planning, consultation and support obtained during the initial discovery and planning phases. The LGA is

| What? | How? | When? | Who? | Where? | Why? |
|---|---|---|---|---|---|
| What is the purpose of the system? | How external factors might affect the system? | When do reviews occur? | Who are the stakeholders in this system? | Where in the system is the feedback coming from? | Why is this approach meaningful to stakeholders? |
| What are the areas in the system that need development? | How well can the approach perform in this system? | When is feedback provided? | Who are the decision makers in the system? | Where are the boundaries of the system? | Why this approach was chosen? |
| What is the approach? | How is feedback provided? | When is feedback received? | Who is responsible for providing support? | Where are the constituent systems within their respective lifecycles? | |
| What are the known constraints/risks? | How are the needs being met? | When is change documented? | Who manages risks in this system? | Where are the interfaces between systems? | |
| What's the role of people? | How management constraints are taken into consideration? | When is system intervention most effective? | Who will use the system? | | |
| What's the role of technology? | How do constituent systems interact with each other? | When interactions between constituent systems occur? | Who defines success measures in this system? | | |
| What are the characteristics of an acceptable solution? | How is emergent behavior documented and observed? | When are legacy components considered? | | | |
| What are the measures of success in the system? | How are risks addressed within this system? | | | | |
| What are the incentives for the constituent systems to belong to the SoS? | | | | | |

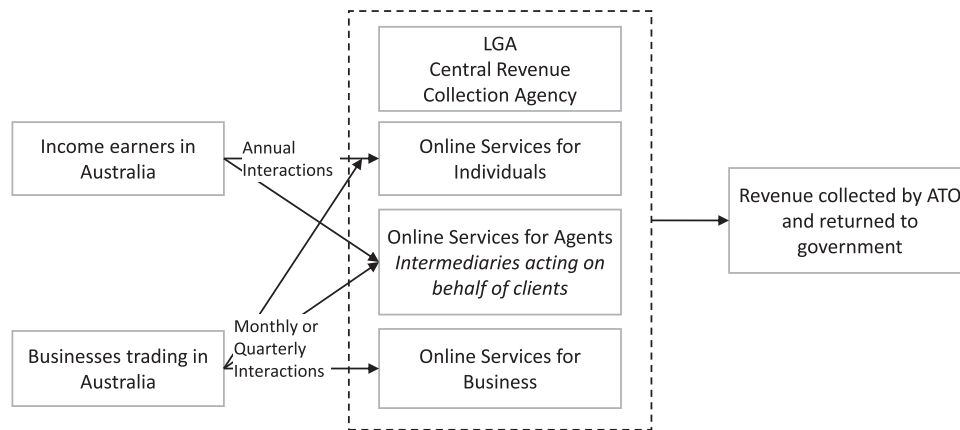**FIGURE 2** Application of the SoSE framework for effective digital transformation.[103]



**FIGURE 3** How the LGA operates.

one of the largest government agencies in Australia in both number of clients and employees. The services were historically completed using legacy systems (e.g., paper, phone and intermediary), thus requiring an improvement.

The LGA is the central revenue collection agency in Australia and as such, it is responsible for the collection of income and business taxes from entities registered in Australia. There are multiple different entity types under the law. However, for simplicity, in this paper they will be referred to as business or individual (income earners). The system is outlined in figure 3. Income earners are required to interact annually with the LGA to complete their income tax returns. These returns can be completed via online services (digitally) for individuals or through an intermediary on their behalf via online services for Agents. Businesses, however, have monthly or quarterly interaction requirements, in addition to their annual income tax requirements. These interactions can be completed through business online services or through an interme-

diary. As Australia has a self-assessment tax authority, individuals are responsible for ensuring their reporting is correct, and the LGA utilizes data and models to assess all interactions. All the revenue collected is returned to the government for distribution to key agencies.

The LGA developed the 2015 Reinvention Program, which outlined significant changes to the operations of the agency.[106] Starting with a shift to client experience, requiring developing a greater understanding of the needs and expectations of the various clients, including skills, access to infrastructure and willingness to participate. In addition, the use of data to support decision-making and advance modelling was increased.[106] This provided more information about the histories of clients, trends across locations (e.g., states, postcodes, Local Government Areas), occupations and business market segment. Through the use of data, more accurate profiling was enabled, which provided faster responses to disasters or adverse events, supporting clients better during COVID-19 and Bushfires. Another key component of this

**TABLE 2** Definitions of constituent systems and SoS.

| System | Description |
|---|---|
| Cognitive | Individual taxpayers (who are income earners in Australia). In 2020–21, this population comprised 11.8 million clients.[107] |
| Social | Social system consists of 1 million employers, 209,000 not for profit organizations and 37,000 registered tax agents.[107] |
| Digital | Online/digital service interfaces provided to clients to interact with the LGA:<br>Online services for individuals<br>Online services for agents<br>Online services for businesses<br>Alex Virtual Assistant<br>ATO.gov.au |
| Infrastructure | Infrastructure supporting the LGA's digital transformation:<br>Single Touch payroll—enabling streamlined reporting for employers.<br>Australian Business Registry service<br>MyGovID<br>MyGov online platform<br>National Broadband Network |
| Business | Business system includes 4.3 million small businesses, 201,000 privately owned groups and 39,000 public and multinational businesses across multiple industries and locations.[107] |
| Policy | The LGA is responsible for the administration of the Income Tax Assessment Act 1936 (ITAA 1936) and the Income Tax Assessment Act 1997 (ITAA 1997). The Agency is operating under the Public Governance, Performance and Accountability Act 2013, within the Treasury portfolio, and is accountable under the Public Service Act 1999 |

Reinvention was building of community confidence using insights and tailored engagement techniques. This required the combination of data and modelling, along with client experience requirements to develop clear engagement strategies to support and encourage participation within the system. The process examined and addressed the needs and expectations of clients, by seeking feedback, responding to complaints, measuring use of services provided, and offering support to clients who required it.

The Reinvention Program was not only focused on clients, but an additional focus was on the future requirements of the workforce and employees. This included a staff experience lens, which aimed to improve the available tools and process offered to staff (both responding to clients and completing operational work), responding to issues raised, implementing staff innovations, and providing greater opportunities for development and growth within the organisation.[106] By using this approach as the starting point for undertaking their digital transformation, there were already considerations for the constituent factors outlined within the framework. The framework was based on the insights observed and documented as part of the ongoing digital transformation cycles within the LGA and lessons learned. Due to the exponential growth in technology and engineering, the LGA has had to transition quickly in order to keep up with the paradigm shift, to ensure the Agency remained effective and continued providing quality services. This called for new approaches to understanding and responding to a variety of challenges. One of the major obstacles for all organizations undergoing digital transformation is effectively transitioning to advanced technology making sure it is supported by systems. As new interfaces are developed, organizations need to be confident that the various constituent systems' views and needs are integrated. As a result, although much of the transformation is driven by technological advances, there is still a need to effectively manage the integration of systems' developing views and needs.

In addition, digital transformation efforts rarely begin from scratch. Often efforts focus on improvements to existing platforms (or legacy systems) and the progressive introduction of the evolving technology into the organization. A comprehensive framework is thus required, which allows digital transformation to occur, including managing and leveraging both benefits and rising challenges. The framework applied within this case study demonstrates how the interpretation of constituents as autonomous decentralized systems as part of SoS was necessary. To support the digital transformation effort, it is interesting to note that each constituent system chooses to be part of the SoS, in order to achieve the shared goal of effective transformation efforts.

## 5.2 | Framework application

The application was made during the initial Reinvention state of digital transformation and supported the development of new services and improvements to existing legacy services. The LGA applied the framework by identifying the purpose of the overarching digital transformation initiative and the impacts it may have on different stakeholder groups (e.g., employees, users, and policy makers) (Figure 3). Using this framework, the organization was able to identify and interpret the relationships between the constituent systems. This view supported improvements to the historic approach that was utilized to implement new services, which focused on the individual systems rather than the relationships between. In order for the LGA to properly support digital engineering, it needs to understand the constituent systems beyond technology, including people involved, supporting factors and policy. This paper will focus on the external client facing framework application.

The digital transformation SoS at the LGA consists of a number of constituent systems outlined in Table 2. These presented definitions

**TABLE 3** What does the organization need to do to externally support the transformation (e.g., clients)?

| | Sub system | Considerations | Responses |
|---|---|---|---|
| **Cognitive system** | Ability | What skills are available? What skills need to be developed? Are clients technologically ready? | A simple interface required, with clear steps and explanatory descriptions. Skills development may need to be considered into the future. |
| | Attitudes | What are the attitudes clients have towards new services and changes to services? Are they comfortable learning new skills? | Some clients are change averse. Maintaining legacy systems for a duration and limiting their access. Allowing clients to progressively use new services and where necessary, continue to use legacy services. |
| | Willingness | The clients/user's willingness to participate in the system, both digitally and legacy services. | Incentivize the use of digital services by making interactions easier to use, while obtaining faster responses (e.g., faster refunds). |
| | Beliefs | What are the beliefs and concerns (e.g., security concerns) that would prevent adoption? | Provide assurances regarding the provision of assurance on security provided (e.g., two factor authentication). |
| **Social system** | Culture | What is the culture around adoption, use and supports? | The culture can be difficult to read, so ensuring that there are available supports for the different needs of cultural needs and expectations. |
| | Social norms | What are the societal expectations and norms around interaction with government services and completing mandatory interactions? | Sharing percentage details of those not completing their mandatory obligations. |
| | Human resources | What are the client contact services that the LGA provides to their clients? | Availability of volunteer tax help services (free service), telephony services and webchat. Outside of the LGA there are intermediaries that can complete interactions (paid service). |
| | Community | What are the impacts are of the tax and superannuation system on the community? | Provide clients with a receipt of where their tax dollars are spent within their community, including a breakdown of percentages. |
| **Digital system** | Supports | What supports are required to interact with the new and existing digital services provided? | Availability of volunteer tax help services (free service), and webchat. |
| | Interface | What feedback mechanisms are provided to clients? When are they responded to and how frequently? | The development of inbuilt feedback mechanisms (feedback and complaints). This allows clients to voice concerns and receive a response. |
| | Digital literacy | What is the proportion of the clients who have identified having high or low digital literacy? Are there specific Local Government Areas that require assistance or support? | Provision of additional mobile support to these areas through mobile teams to support digital literacy development. |
| | ICT technology | Have we considered what the requirements of the client ICT technology needs to be for interactions with digital services? | Provide low bandwidth services that can be used on older technology and operating systems. |
| **Infrastructure system** | Technology | What proportion of the population has access to the technology needed for interacting with digital services? | Utilizing Australian Bureau of statistics data to understand the access to technology, ownership and internet access/availability. |
| | Support | Do clients have access to support for their ICT technology where they are located? | ICT support is outside of the control of the organization, However, having knowledge of areas with limited access, the LGA can expand access to different services, where possible. |
| | Products | Are there specific products required? | Ensure the digital services provided do not require downloading or specific products and can be run through any web browser. |
| | Computing power | What are the minimum computing power levels required to interact with the digital services? | Provide access to digital services that account for varying computing powers. |
| | Bandwidth | What are the accesses to the internet? In some areas there are bandwidth and connection issues. How can we respond to this? | Availability of community ICT technology and access to non-digital services (e.g., legacy) where needed. |

(Continues)

**TABLE 3** (Continued)

| | Sub system | Considerations | Responses |
|---|---|---|---|
| **Business system** | Industry | What do industry clients require from the services provided? | Obtain data from different sectors to pre-fill into the digital services and simplify interactions. |
| | Innovations | How do we incorporate new innovative ideas/feedback provided by clients? | Implementation of client feedback and innovations. |
| | Private sector | What are the client expectations of services provided by the private sector? | The banking sector provides a benchmark for expected services. Providing similar services to banking (where possible), including mobile apps and webpages. |
| | Universities | What opportunities can be leveraged through universities to encourage participation and service creation? | Working with university students to develop new services and innovations and attending relevant events to share the importance of interacting with the LGA. |
| **Policy system** | Legislation | Do clients understand the legislation and how it affects their interactions? | Development of web pages, outlining in plain language how to read and respond to the legislative requirements. |
| | Government | Do clients understand the impacts of changing governments and new agencies/legislation on their interaction requirements? | Development of web pages outlining in plain language how to read and respond to the legislative requirements. |
| | National interest | How does taxation serve the national interests of the country? | Ensuring that clients are aware of the impact of their interactions with the taxation system (through above receipt of where money is spent). |
| | Mandatory services | As compliance to legislation is mandatory, services need to be accessible. | Maintain legacy service offers (e.g., paper and telephony) to support clients who need additional time or cannot digitally comply. |
| | Legacy services | What legacy services are required to maintain long term? Do clients like any specific elements? | |

describe the inclusions for each of the constituent systems, identifying the stakeholders' needs and how they individually and collectively can impact ongoing digital transformation effectiveness. This highlights the need for a SoS view to integrate the multiple autonomous decentralized systems which are working together on a common goal. The key findings from the framework question "what the organization needs to do externally to support the successful digital transformation" with clients, is shown in Table 3. The table shows the constituent system and the subsystems within it, in addition to the considerations or questions that needed to be responded to in order to successfully transform digitally. The table outlines the importance of interacting with clients to understand their needs and expectations, considering how to incorporate their needs and feedback into the development of new services and improvements to existing/legacy services. Through the application of the SoS framework, the LGA was able to provide improved client experience and expand their digital service offering to suit the needs and expectations of the various constituent systems.

Table 4 demonstrates the outcomes of having an overarching and end-to-end understanding of the services being provided, with required updates to technology and skills developments. The table shows the implementation of a number of solutions developed in response to the application of the framework. As a result of the implementation of the framework and these solutions, the overall organization saw an increase in the number of interactions from 91% to 98.2%, for individual tax return lodgements.[107] For all client groups, 94% of the overall inbound transactions were completed digitally

(in 2020–21). Finally, fewer complaints associated with digital services (20% decrease in the number of complaints from clients) were recorded.

## 5.3 | Lessons learned

Through the application of the framework, and the resulting interpretability and integration of the constituent systems and SoS, significant improvements were identified in the long-term digital service offer. Key Performance Indicators for Australian Public Sector Agency Service Provision are made public every year, outlining the performance of each agency on specific performance expectations. Table 5 outlines the results for the 2015–16 financial year in which the digital transformation began and the most recent data from the 2020–21 financial year. The results demonstrate an increase in the number of key service interactions occurring digitally between the 2015–16 to 2020–21. A similar trend can be identified with the increase in the percentage of individuals lodging their tax return digitally. A significant increase from 2015–16 to 2020–21 was demonstrated in the decision point at time of online interaction. Furthermore, a progressive decrease of the median cost of compliance has been identified, having a positive impact on client experience. Additional improvements to digital service offerings have been identified with the increased availability of prefill data to simplify client interactions and ongoing improvements to overall digital system availability. In 2015–16, progressive

**TABLE 4** Outlines examples of the application of the framework and outcomes.

| Constituent system | Examples of application |
|---|---|
| Cognitive | In 2018 programs for teaching and learning about tax at schools reached more than 20,000 students.[108] Decreased cost of compliance with managing tax affairs by 3% from 2020 to 2021.[107] |
| Social | All clients are provided a receipt of where their tax money was used across different community services.[109] Expansion of the Tax Help volunteer program run at community centers, libraries, and schools to support taxpayers complete their tax return. These services can now be used for both non-digital and digital services.[110] |
| Digital | The implementation of Alex Virtual Assistant through the LGA website has more than 2 million conversations a year, leading to an 8%–10% reduction in calls for support and an 88% first time contact resolution for issues raised.[111] More than 85 million pieces of prefill data were obtained to support the completion of digital tax returns.[107] The implementation of prompts within digital income tax provides support for more than 360,000 transactions by highlighting when information is missing or incorrect within a return.[107] |
| Infrastructure | The cost of printing and postage (decreasing to between 1.2% and 3.6% of the operating budget).[107] Development of online chat functions (webchat) to support clients in their preferred format.[110] |
| Business | Feedback provided by 56% of the survey respondents indicated that they believe the tax system unfairly advantages big business and wealthy people.[113] In response the LGA broadened their sharing of corporate tax collections data outlining whether big business is paying their taxes.[114] The National Tax Clinic Program has been developed in collaboration with universities across Australia, providing a free service for tax help and support.[115] |
| Policy | The LGA has 100's of webpages and supporting documents outlining and explaining policy and legislation in language that is an easy-to-understand language, across multiple common languages spoken in Australia. |

**TABLE 5** Key performance indicators LGA 2015/16 to 2020/21.[108,112]

| Key performance indicator | 2015–16 | 2020–21 |
|---|---|---|
| Proportion of key service interactions occurring digitally | 85% | 94% |
| Individual digital tax return lodgment | 91% | 98.2% |
| Decision at point of online application | 73.5% | 96% |
| Proportion of items that use prefill data | N/A | 89.5% |
| Digital system availability *Excluding planned outages* | N/A | 99.9% |
| Proportion of self-preparing clients lodging digitally | 25.3% | 31.1% |
| Median cost of compliance | 7.2% decrease from 2015 to 2021 | |

implementation of new services across and in addition to legacy systems was underway.

A number of lessons were learned from the application of the framework to the internal and external stakeholders to support successful digital transformation. The responses to the various questions within the framework and the relevant constituent systems demonstrate how different approaches are required to respond to the different sys-

tems. Through a system of system engineering approach, it is easier to identify various roles and interactions. Understanding the systems separately and as a whole, supports improvement to the overall transformation and risk management, assisting skills development and driving interactions with one-time and ongoing services.

By utilizing the SoSE approach to understand the whole system, organizations can understand the different autonomous constituent systems individually along with the goals and requirements of the system as a whole. Therefore, the framework creates value for digital transformation through identifying and integrating multiple autonomous decentralized systems to bring about effective digital transformation. Many of the emergent properties that occur as the by-product of the systems' interactions can be captured within the whole system through the framework. The framework offers organizations, digital service designers, and policy makers the ability to obtain more knowledge on how different systems influence digital transformation, allowing them to create more dynamic services and generate higher levels of productivity and preparedness in responding to unforeseen circumstances. However, further research is suggested in different digital transformation settings to validate the framework across various sectors.

## 5.4 | Best practices

The importance of understanding the various constituent system needs and a holistic system of systems lens. As a result, feedback loops are needed to ensure that clients and staff are empowered to provide positive and negative feedback to support innovation and participation. Stakeholder engagement is a key part of this and can be achieved by understanding the constituent systems, addressing client and staff needs, and encouraging the use of feedback loops. Best practices within the case study show the importance of strong leadership to promote transformation culture within an organization while supporting skills development. At the same time, incorporating check in points, to assure quality of the process and related requirements for the delivery of the transformation. Therefore, best practices indicate the importance of

a supportive culture, which is based on innovation and measuring risk taking (whereby risks can be taken in a safe space), while also providing a broader understanding of stakeholder needs and expectations (both internal and external) to support client experience.

## 6 | CONCLUSION

In summary, this paper provides a contribution to the current body of knowledge in the field of systems engineering by introducing a SoSE governance framework to support effective digital transformation and engineering efforts. Through the presented framework, organizations can consider all the autonomous and decentralized constituent systems involved and how they interact within the SoS. By applying the framework and asking specific questions in order to better document the various interactions, needs and requirements of each system, organizations can develop a more comprehensive understanding of the different systems involved. The questions raised outline different elements that will support digital engineering and transformation within and outside the organization. Lessons learned from the case study highlight the importance of understanding those systems and the impact that can have on the overall digital transformation experience. In addition, best practices reveal that successful digital transformations require more than just technological and infrastructure improvements. Organizations also need to consider internal and external processes, procedures, practices, and people. The findings and insights gained from this research have broad applications across domains and industries.

## 6.1 | Future research

Future research is recommended in exploring the role of organizational culture as a supportive mechanism to effective digital transformation. This includes examining the importance of a continuous lifecycle as part of digital transformation projects in order to improve developments on an ongoing basis. In addition, further research can be valuable in testing the in-depth application of this framework across industries in order to assess its generalizability. Finally, it would be beneficial to investigate the use of artificial intelligence in the development and application of modelling and simulation to automate the framework application.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available from https://www.ato.gov.au/About-ATO/Research-and-statistics/.

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