INVESTIGATING COMPLEXITY MANAGEMENT IN PRODUCT SERVICE SYSTEMS: A CYBERNETICS PERSPECTIVE

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Doctor of Philosophy

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July 2020

Abstract

This research examines complexity management in the context of Product Service Systems. Product Service Systems are a configuration of product, service, technologies, human actors, and facilities to create value. The delivery of outcomes through a Product Service System is fraught with complexity. Current studies on complexity management in the context of Product Service System are fragmented; context specific, industry specific and address specific aspects of the delivery system.

This research explores complexity management in Product Service Systems using the Viable System Model (VSM) as an epistemological lens. Principles and concepts underlying the VSM were applied, including Stafford Beer's Variety Engineering and Ashby's Law of Requisite Variety, to develop a VSM-Based Complexity Management framework.

Using multiple case study research strategy, the research found three mechanisms underlying complexity management in Product Service System context. These mechanisms are connectivity, collaboration, and flexibility. Further analysis shows that these three mechanisms are anchored on a knowledge management strategy designed and implemented by PSS companies to develop requisite variety and drive viability.

Identifying a relationship between knowledge, organisational learning, and complexity management permits the integration of concepts and models from both literature and fields to understand survival strategy in firms offering PSS.

Complexity Management, Product Service System, Viable System Model, Knowledge Management

Acknowledgements

I want to acknowledge the support, encouragement, advice and guidance of my supervisors, Dr Andrew Greasley, and Professor Pavel Albores. Dr Greasley, you were patient with me, frank, and candid in your conversation with me. This thesis would not have been possible without you. Your insightful feedback and advice were timely and useful over the course of writing this thesis.

My acknowledgements go to the wider administration and support team at the Post Graduate Research Office – Ms Brocklebank, Ms Ara, Dr Crawshaw, Dr Schofield, whose support, directly and indirectly, facilitated the completion of this thesis.

My gratitude goes to my family and my sponsors for their patience, financial and moral support throughout the course of the research. Your help was invaluable.

Last but not least, I want to offer my thanks and appreciation to organisations and people in these organisations who decided to participate in my research. Your input is invaluable.

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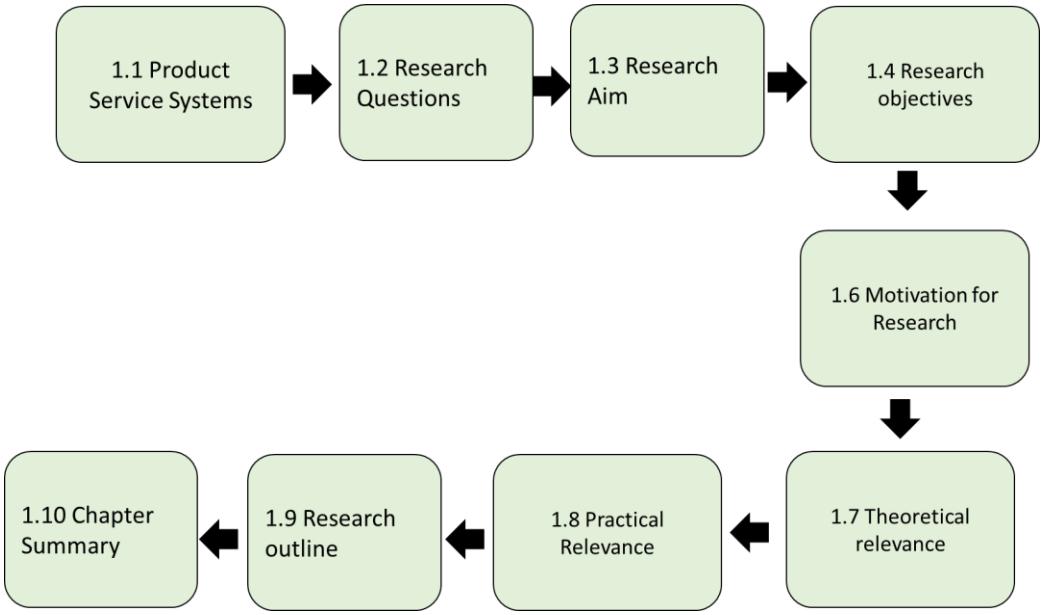
List of Abbreviations

CAQDAS	Computer Aided Qualitative Data Analysis Software
CAS	Complex Adaptive Systems
PSS	Product Service Systems
SAST	Strategic Assumption Surfacing and Testing
SDL	Service Dominant Logic
SODA	Strategic Option Development Analysis
SSM	Soft Systems Methodology
VSM	Viable Systems Model

1. Introduction

In this introductory section of this thesis, the context of the research is introduced. In section 1.1, the concept of product service systems (PSS) is introduced. This is followed by a clear delineation of the context of this research in section 1.2 and complexity section 1.3. The research questions, research scope and the research objectives follow in sections 1.5 to 1.8. The full content of this chapter can be found in the diagram below.

Figure 1: Structure of this chapter



1.1 Product Service Systems

The need to increase competitive advantage has resulted in manufacturing companies exploiting services to increase revenue, boost growth and deliver more value to their customers (Baines *et al.* 2007). The result is the emergence of Product Service Systems (commonly known as PSS). A PSS is a "marketable set of products and services capable of jointly fulfilling a user's need" (Goedkoop *et al.* 1999, p. 18).

Authors like Goedkoop *et al.* (1999), Mont (2002), Vasantha *et al.* (2012), Baines and Lightfoot (2013), Pezzotta *et al.* (2015), (West *et al.* (2018) acknowledge that a PSS is a

system; defined as the collection of elements, interacting to fulfil a purpose. The relationship and interaction of these elements is designed to achieve specific outcomes for the consumer. The components within a PSS range from products, service, operations, (Vasantha *et al.* 2012, Zaki and Neely 2014, Sandborn *et al.* 2017), software, digital technologies (Parikshit *et al.* 2017, West, Gaiardelli, Resta, *et al.* 2018, Gebauer, Paiola, *et al.* 2020),service stations and support facilities (Kyosti *et al.* 2011, Kyosti 2015, Settanni *et al.* 2017), and human actors (Bastl *et al.* 2012, Datta and Roy 2013, Datta *et al.* 2013, Ng *et al.* 2013, Zhang and Zhang 2014, Kreye 2017a, 2018). Whether the outcomes delivered via a PSS assume the form of a capability (Vasantha *et al.* 2013, Rönnberg Sjödin *et al.* 2016, Grubic and Jennions 2018, Huikkola and Kohtamäki 2018, Kohtamäki *et al.* 2018), product condition (Smith *et al.* 2012, Redding and Tjahjono 2018) or product provision (Gaiardelli *et al.* 2014, Wibowo *et al.* 2017), it requires the configuration of multiple and diverse range of components, whose quantity, nature and behaviour is uncertain as a result of variability and dynamicity.

1.2 Product Service System, Complexity and Viability

The concept of viability connotes different meanings in a variety of contexts. In systems science, viability is ability of a system to maintain an independent existence (Beer 1984). In a social system (i.e. an organisation), viability means survivability (Schwaninger 2006a, Barile *et al.* 2016) and maintaining an identity or a collective purpose (Lassl 2019a)

In the service literature, viability is described as the ability to maintain financial profitability (Neely 2009, Ng and Briscoe 2012, Eggert *et al.* 2014), or an increase in value co-created by a network of interacting agents (Vargo *et al.* 2017, Polese *et al.* 2020). In a PSS perspective, what constitutes value outcomes encapsulate a variety of performance areas such economic benefits, customer satisfaction and relationship, knowledge, learning, innovation, legitimacy (Garcia Martin *et al.* 2019). Some of these areas are considered as building blocks of a viable PSS. This is consistent with the extant literature that viability transcends outcomes and output of a system to incorporate the essential conditions in the system environment essential to its survival (Vargo and Akaka 2012, Lassl 2019a, Polese *et al.* 2020).

Although the concept of a PSS promises immense benefits to manufacturing firms and their customers (Vandermerwe and Rada 1988, Oliva and Kallenberg 2003, Baines and Lightfoot 2013), the PSS literature acknowledges the complexities associated with the successful adoption and operation of a PSS (Ng and Yip 2009, Benedettini *et al.* 2015, Martinez *et al.* 2017). In fact, empirical studies suggest that the adoption of services provided through a PSS can affect organisational performance negatively (Eggert *et al.* 2014, Böhm *et al.* 2016,

Benedettini *et al.* 2017). In other words, the proliferation of service content in a PSS engenders a greater number of risks and complexity to its viability (Kreye 2019, Zhang *et al.* 2019). Studies by Benedettini *et al.* (2015) established a link between providing a service through a PSS and bankruptcy cost in manufacturing companies. Bankruptcy risk stems from the increasing amount of complexity and risks (external and internal) associated with service provision. In an earlier study conducted A Bain and Co, only 21% of servitized companies succeeded with a service strategy (Baveja *et al.* 2004a). In a review of data on 10,208 firms from 25 different countries Neely (2009) found that manufacturing firms delivering services through a PSS generated lower profit than traditional firms. Few examples include the failed service business of Intel' web services, Siemen Business Services and Durr's outsourcing service (Sawhney *et al.* 2004, Fischer *et al.* 2010). In fact, the academic literature coined a term known as "service paradox", which describes a situation where manufacturers transitioning to services incur high investment costs but fail to generate the returns that these companies expect (Gebauer *et al.* 2005). Evidence from the literature indicates that some firms have started to reduce their PSS (via process known as deservitization) due to rising cost and poor business performance (viability) (Kowalkowski, Gebauer, Kamp, *et al.* 2017, Valtakoski 2017).

1.2.1 Product-Service Systems and Complexity

In this study, complexity relates to the structure and dynamics of a system. This includes the number of components, the relationship between these components and the dynamics of their interactions (Richardson *et al.* 2000, Jackson 2001, 2020). A variety of terms and characteristics are used in the PSS literature to denote complexity. These include uncertainty, dynamicity and variability (Zou *et al.* 2018). The PSS literature is replete with studies on PSS complexity. Zou *et al.* (2018) provide a systematic review of the PSS literature and highlight a set of characteristics and features of PSS offerings. The authors explored the "nature and content of complexity" and mapping these features into a four-dimension framework consisting of diversity, independence, variability, and multiplicity. The multiplicity and diversity of components increases as more advanced variants of PSS offering (result-oriented PSS), known by such terms such as availability-based contracts and performance- based contracts (Essig *et al.* 2016), outcome-based services (Böhm *et al.* 2016, O'Hare 2016), and advanced services (Baines *et al.* 2019), is adopted.

Complexity increases in advanced variants of PSS offerings due to value being co-created with a network of actors and stakeholders (Meier *et al.* 2010, Gebauer *et al.* 2013, Hakanen 2014, Barile *et al.* 2016). Achieving outcomes through a PSS involves a much closer provider-

consumer relationship and partnership (Batista *et al.* 2017, Raddats *et al.* 2019), which requires pooling and integration of resources and capabilities of actors across outside the boundaries of the main provider (Mills *et al.* 2013, Settanni *et al.* 2017). Service output and outcomes become uncertain as service providers rely on the inputs and contributions of other actors in the network as well as the customer' structures and operations to deliver contractually agreed benefits (Kreye 2019).

In the PSS literature, complexity and uncertainty are terms that are intrinsically linked (Kreye 2019). Uncertainty relates to the inability to predict the effects of decisions due to lack of sufficient or inadequate knowledge about future events. With complex systems, outcomes are unpredictable due to the constantly changing nature of interaction between the components of a system (Daniel and Daniel 2018). Since events are difficult to predict, uncertainty sets in (Kauffman 1995). The complexity of PSS also assumes the form of uncertain product performance, technological uncertainty, environmental uncertainty, organisational uncertainty and relational uncertainty (Erkoyuncu *et al.* 2013, Reim *et al.* 2013, Kreye 2017a, 2019, Zhang *et al.* 2019). The constant need to adapt to a dynamic context and conditions makes the promise and a guarantee of desired outcomes difficult and challenging.

Furthermore, adopting services provided through a PSS may increase coordination and adjustment costs, drawing from task interdependencies among a large network of actors and the need for synergy (Zhou 2011, Zhang *et al.* 2019). Cohesion becomes a challenge due to culture change and the heterogeneity of stakeholder view/needs and shared activities, thus increasing the pressure and requirement for information processing and robust and joint decision making across multiple interfaces (Baines *et al.* 2017).

Like in all organisations, a PSS is an open system. An open system exchanges materials, resources, and energy with its environment. Being an open system, a PSS interacts with its environment and exchanges materials. The implication of this is that a PSS is affected by events in its environment. Events such as perturbation and turbulence in the environment have the capacity to affect the ability of a PSS to deliver outcomes effectively and efficiently. Technological advances can lead to product or product component obsolescence, resulting in the non-availability of materials and tools (Hypko *et al.* 2010a, 2010b, Nullmeier *et al.* 2016). Market fluctuations may occur, standards and legislation may change, which would all affect the ability of a PSS to deliver its benefits or goals (Phumbua and Tjahjono 2012, Kreye 2019). High technological turbulence may deliver a superior customer value through access to innovative products, however it might result in high business costs (Cusumano *et al.* 2015) and erode gains as existing products fall below the customer threshold. The

effectiveness of a PSS business model is ensuring a fit between strategy and the environment (Zhang *et al.* 2019).

Despite the proliferation of studies on PSS complexity, the management of complexity in the context of PSS performance and viability unexplored. Existing studies relating to the management of complexity are fragmented, prescriptive and often specific to a complexity dimension or to a context. For example, Ng and Briscoe (2012) investigated the effect of contextual variety and variability in customer demand (complexity) on value co-creation in complex engineering services. The study considered 'viability' within the context of value-in-use (Tuli *et al.* 2007, Lusch and Vargo 2014, Smith *et al.* 2014). The study found complexity management strategies like direct (relational) and indirect (asset-based) engagement with the customer to influence customer behaviour and generate emotional value. However, what constitutes indirect and direct engagement is not elaborated upon.

Batista *et al.* (2017) developed a structuration of an outcome-based contract, "revealing the operational, managerial and governance structures necessary to preserve the functional viability of the system"(p.133). The study revealed critical relationships and mechanisms underlying the development of synergy and co-creation of value. Like Ng and Briscoe (2012), the study adopted a relational-process view, while exploring complexity generated within the system. However, the study was context-specific as the researchers focused on an outcome-based contract in the defence sector; a case that more of a monopsony and may not reflect the majority of all outcome-based contract. Settanni *et al.* (2017) provides a comprehensive mapping of a system delivering avionic availability as an outcome. However, the study highlighted and accentuated the large-scale coordination and cohesion challenges associated with availability-based contracts, Besides, the study focused on a single case in the defence industry. While some interesting insight has been developed from these cases, there is no holistic/generic framework regarding management strategies, which guides companies offering services through a PSS, taking into consideration the nature and context of their offerings.

This research examines complexity management through a cybernetics lens. Its core model, the Viable System Model (VSM) is applied to facilitate the exploration and understanding of complexity management strategies in the context of a Product Service Systems. The VSM is a formalised theoretical framework based on systems thinking and comprises well-established principles and concepts that explains the conditions underlying the viability of organisations. The VSM provides both exploratory and explanator power for organisational diagnosis and design and is used widely in research across multiple fields and disciplines.

1.3 Research questions

1. How can a PSS be steered and governed to maintain viability against the backdrop of complexity in its internal and external environment?
2. What are the mechanisms underlying the viability of a PSS?

1.4 Research Aim

To investigate complexity management strategies and mechanisms in the context of a PSS

1.5 Research Objectives

1. To *gain insight into the mechanisms underlying the viability and survivability of a PSS.*
2. *To explore complexity management strategies in the context of a PSS.*

1.6 Defining the Scope of this Research

The researcher uses the term “product service systems” to encompass only result-oriented PSS (Oliva and Kallenberg 2003, Tukker 2004) It is acknowledged in the servitization literature that the level of complexity is higher in result-oriented PSS types like performance-based services, availability-based services, outcome-based services, due to the multiplicity, variety and diversity of components and performed tasks (Kreye 2019) and the high interdependencies between customer and provider operations (Baines *et al.* 2011, Ferreira *et al.* 2015).

1.7 Motivation for this Research

Businesses face an increasing amount of complexity. With advances in technology and increasing level of consumption, old tools and strategies no longer work. As the problem faced by businesses change, it is important that new tools are explored to manage complexity.
This research looks at complexity management strategies in companies delivering product service systems. The research presents an opportunity explore what has worked and how it can be transferred to other companies.

1.8 Theoretical Relevance of this Research

This research makes several theoretical contributions to servitization.

The research proposes a complexity management framework that outlines complexity management structure, variety operators and functional mechanisms underlying the viability of service solutions delivered through a product service system.

By drawing on cybernetics principles, the research conceptualizes complexity management in the context of communication and control. The research looks at complexity management beyond the confines of operations only but encapsulates the whole system. In other words, a holistic perspective is undertaken.

It extends the conversation on service paradox and complexity associated with service solution delivered through a product service system. Specifically, it provides a holistic perspective of complexity management strategies in firms offering service solutions. By exploring complexity strategies through the viable system model, the research identifies specific mechanisms by which firm attenuate, absorb, and amplify their response capacity to achieve equilibrium between organisation and its environment.

Furthermore, the research provides detailed insight into variety operators deployed and utilized by service firms as part of the organisational structure to manage complexity.

1.9 Practical Importance of this Research

The business landscape is getting more complex. Advances in technology opens a legion of opportunities for businesses to transform and adopt to new business models. However, this comes with an increasing amount of complexity.

This research examines complexity. For managers, this research is important because it identifies the critical operators for managing complexity effectively. Findings would provide managers with knowledge essential to navigating the waves of turbulence in their environment. This includes how to steer and govern their organisations.

With the growing level of complexity, the viability of firm occupies the centre stage.

1.10 Research Outline and Structure

Part I Introduction - This section presents the background and scope for this research. The research questions are identified, and the objectives of the research are defined. Furthermore, the theoretical and practical implications and relevance of this research are outlined

Part II Literature Review - In this section, a critical review of complexity in generic and in the context of a PSS is provided. These include the dimensions and forms of complexity as well as the modelling of complex systems. Gaps in the literature are outlined and a summary of the chapter is presented.

Part* III *Research Methodology – This section covers the philosophical standpoint taken to answer the research questions, collect data and analyse results in this research.

Part IV Case Studies -The selected systems approach is applied to three case studies

Part V Results - This section describes the evaluation of the framework through multiple case studies. The aim is to test and validate the framework rather than deriving cost estimates for the case studies/scenarios analysed.

***Part VI* Analysis** – The cases are analysed, and themes are presented

Part VII *Discussion* - This section discusses the research findings.

***Part VII*I Contributions, Limitations and Conclusion** - In this section, a summary of the finding vis-a-vis the research question, research aim, and objectives is provided. Direction for future research is also identified.

Part IX - References

Part X – Appendices

1.11 Chapter Summary

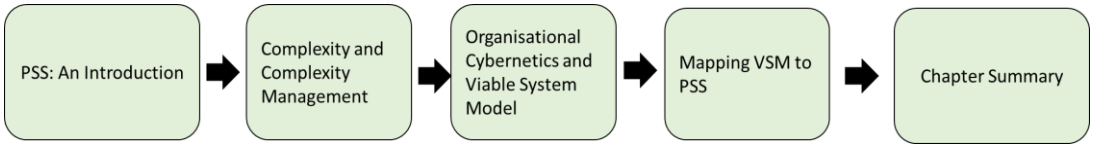
In this chapter, a background to the research is presented. It identifies the context, objectives, research questions and motivation underpinning the research. The research questions and breakdown of the research has been presented.

2 Literature Review

2.1 Introduction

This chapter provides review of the literature. First, complexity in the context of the PSS is described (section 1.2). This is followed by a review of the literature on complexity management in section 1.3. Managing complexity in organisations based on organisational cybernetics the VSM are introduced in section 1.4. In Section 1.5. the principles of the VSM are mapped to complexity management of the PSS. The chapter summary follows in section 1.6.

Figure 2. Structure of this Chapter



2.2 Product Service Systems

Product Service Systems encapsulate the combination of product and service components with the aim of delivering outcomes. Here, product service systems are considered in the context of servitization; which denotes the transformation of a manufacturing company's capabilities to deliver outcomes using a combination of product and service components (Goedkoop *et al.* 1999, Baines *et al.* 2009, Gaiardelli *et al.* 2014, Agrawal and Bellos 2015, Lee *et al.* 2015). In this research, the focus is on the system, hence the choice of the term Product Service System, which is defined as "*a mix of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling final customer needs*" (Tukker and Tischner 2006, p. 1225), as opposed to the transformation process, which is known as servitization (Baines *et al.* 2009).

Multiple classification and topology of a PSS have been presented in the PSS literature, resulting in a range of variants. These include classification based on PSS orientation (Tukker 2004) – product-oriented PSS, use-oriented PSS and result-oriented PSS; based on content of service (Baines and Lightfoot 2013) – base services, intermediate services and advanced

services; and based on the object of the service (Oliva and Kallenberg 2003), consisting of service supporting the product and service supporting the customer. The latter type of service (which supports the customer) are often known in industry as “integrated solutions” (Baines *et al.* 2009, Kreye *et al.* 2015, Annarelli *et al.* 2016, Fliess and Lexutt 2019) or advanced services (Baines *et al.* 2017, Gebauer, Paiola, *et al.* 2020).

Advanced services constitute the most advanced form of PSS (Baines *et al.* 2019). Advanced services are end-to-end offerings that are developed around a customer’s operations and processes and the provider assumes full responsibility of achieving a mutually agreed outcomes (Gaiardelli *et al.* 2014, Garcia Martin *et al.* 2019). The content and sophistication of advanced services engenders a higher degree complexity and risks for the provider, arising from a variety of influencing factors underlying the delivery of outcomes, such as the need for a unique set of capabilities required to deliver services; operational risks, uncertainty associated with lifecycle costs, profitability and contract performance, multiplicity of customer demands and dealing with customer expectations (Reim *et al.* 2013). These complexity drivers drive up service delivery costs while leaving the provider with little profit, a situation known as the service paradox (Gebauer *et al.* 2005, Kohtamäki *et al.* 2020), which holds serious implications for the viability of service solutions delivered through a PSS.

2.3 PSS, Complexity and Viability

The PSS literature presents success stories of firms adopting a service-based model and becoming a solution provider (Baines *et al.* 2011, Hakanen 2014, Ziaee Bigdeli *et al.* 2018), including more stable revenue streams, improved customer loyalty and satisfaction, and profitability (Vandermerwe and Rada 1988, Mathieu 2001, Oliva and Kallenberg 2003). Despite these success stories and rewards of offering a PSS (Lee *et al.* 2016, Kamp and Parry 2017), many manufacturing firms fail to realize the benefits associated with transforming from a manufacturer to a service provider, resulting in what has been described as a service paradox (Gebauer and Friedli 2005, Paiola *et al.* 2013, Green *et al.* 2017, Herterich *et al.* 2017) or servitization failure (Brax 2005, Martinez *et al.* 2010, Benedettini *et al.* 2015). Service paradox refers to a situation where a manufacturing firm fails to realize the performance benefits (lower profitability) despite the huge investment in service offerings.

Contributions from empirical studies show many firms struggle to realize the benefits of transitioning to a service-based model (Neely 2009, Valtakoski 2017). In a Bain and Co study, it was found that only a tiny 21% of companies succeeded with service strategies (Baveja *et al.* 2004b, Benedettini *et al.* 2015). In another study, service accounted for an insignificant

portion of the total revenue for servitizing German and Swiss companies in the capital goods industry (Fischer *et al.* 2010). The case of Siemens Business Services and Intel web-based services are further examples of servitization failures (Benedettini *et al.* 2015). These empirical cases show that adopting services as a manufacturer does not guarantee success and benefits. In other words, its ***viability*** is not guaranteed.

Drawing evidence from in the literature, the relationship between adopting a service-based model and performance is not linear but complex. Examining the performance of 464 software firms based in the United States, Suarez *et al.* (2013), found a U-shaped trajectory in the relationship between revenue from services and profit margin. This is consistent with other studies conducted by Visnjic Kastalli and Van Looy (2013), which found complex relationship between sales and performance as service increment increased; by Visnjic *et al.* (2012), which found a negative effect on profitability and margins with increasing service breath; and Tenucci and Supino (2020) on the inverse relationship between advanced service solutions delivered through a PSS and company profitability.

Although some of these studies indicate a positive yet complex relationship, with increase service content, it can easily be inferred that maintaining the viability of a PSS is a path that is fraught with risks (Hou and Neely 2017, Fliess and Lexutt 2019), complexity (Neely *et al.* 2011, Benedettini and Neely 2012, Kreye *et al.* 2015) and uncertainty (Erkoyuncu *et al.* 2009, Kreye *et al.* 2014, Kreye 2019). For these reasons, many firms do not achieve the benefits and gains they expect from integrating service into their offerings. These complexity factor increase cost and lower profitability. Zhang *et al.* (2019) argue that coordination and absorption costs tend to increase and are higher as the content and sophistication of service content increases. This is corroborated by findings from studies relating to PSS life cycle cost (Kyosti 2015), financial profitability and consequences of a PSS strategy (Neely 2009, Eggert *et al.* 2014), and resource consumption (Settanni *et al.* 2014, 2015). Evaluating over 70 bankrupt manufacturers and over 100 non-bankrupt competitors, Benedettini *et al.* (2017) found that the expansion of service portfolio increases bankruptcy risks. Although prior studies reported an increase in repeated sales and reduction in volatility of future cashflows, the authors found that offering more service increases survival risks.

2.3.1 Complexity in the Context of a PSS: A Problem of Optimization, Adaptation, Coordination and Cohesion

There are plenty of claims in the PSS and servitization literatures about the potential of digitalization and advances in digital technologies to drive new business models, whether they

are focused on product, services, and solutions; all with the goal of enhancing the value created and delivered (Barabba and Mitroff 2013, Anke 2017, Sala *et al.* 2017, Kowalkowski, Gebauer, and Oliva 2017, Chowdhury *et al.* 2018, Grubic and Jennions 2018, Sklyar *et al.* 2019, Fliess and Lexutt 2019, Kohtamäki, Parida, *et al.* 2019, Harris and Wonglimpiyarat 2020, Manser Payne *et al.* 2021, Ranta *et al.* 2021). The growth of digital technologies has created new channels, and opportunities for collaboration, connection, communication, and production. Technologies like cyber-physical systems that connect multiple devices, IoT-enabled devices that transmit huge volumes of data, and digital platforms that facilitate the creation and development of customized offerings and the emergence of new markets.

Digital technologies have permeated all aspects of the PSS business model; from value creation to value delivery and then value capture. Although, these technologies drive the proliferation of new opportunities and service-based solutions, they increase the degree of complexity service firms must confront. For example, the blurring of boundaries (facilitated by new digital technologies) allows PSS providers to design new offerings, leverage capabilities from multiple actors and extend their reach far beyond their traditional markets. However, it introduces variability in customer demands, and increases the need for coordination, both of which have implications for costs (Jakieła *et al.* 2016, Zhang *et al.* 2019). Operational problems associated with the management of information, product performance, organisation ethos and the design and provision of the PSS offerings, could intertwine to increase complexity for a PSS provider (Fliess and Lexutt 2019).

According to Anderson (1999), complexity is defined as non-simple interactions between multiple interdependent components, resulting in variability and dynamicity of behaviour. Johnson (2009) defined it as the phenomena that emerges from a collection of interacting.

In this research, complexity is defined as multiple and diverse components interacting in a dynamic way. Here, the features and characteristics of a complex object is used as the basis to define complexity. This is consistent with the characteristics ascribed to a Product Service System in the literature. Zou *et al.* (2018), following a review of the PSS literature grouped the characteristics and nature of complexity into dimensions: multiplicity, diversity, variability, and interdependence. According to the authors, multiplicity refers to the number of resources, actors, service components, technology and interactions involved in the delivery of outcomes. Parts and components are diverse as well as the requirements of users/customers; thus, driving the need for disparate and diverse service components. Variability over product performance, resource utilization, customer requirements and relationships increase the degree of complexity, faced by PSS suppliers.

Benedettini and Neely (2012), who explored the characteristics of service complexity identified four categories of service complexity based on the source of complexity (general complexity, individual complexity) and nature of complexity (complicatedness and difficulty). The four categories include the multiplicity of service function, diversity of service components, service with unpredictable or uncertain outcomes, service requiring a diversity and multiplicity of resources. Parry, Purchase and Mills (2011), investigated availability-type contract in the defence sector, and identified six groups of complexity factors: ***product groups*** - The product group relates to the number of variants of the product, fleets, diversity of parts, cross platform characteristics, resource needs, multiple parts, different failure behaviour; ***process*** – refers to the security of process, resource needs, stochasticity, governance and dependency; ***contracting*** - the challenge of governance, affordability, risk, regulations; organisation – multiple actors and boundaries each, stakeholders' policies multiple objective; ***finance*** – financial regulation, cost and report*ing;* ***people*** - culture, norms, beliefs, leadership, learning, change management. Erkoyuncu et al (2011) and Erkoyuncu et al (2011) identified factors such as supply network, customer demand, delivery process, resource availability, service delivery management, cost, affordability, technology, customer values as drivers of complexity in a PSS.

Neely, Mcfarlane and Visnjic, (2011) and Benedettini and Neely (2012b) categorized service complexity factors into classes: market and products production process, technology, administration and management, ecosystem. In investigating risk factors in outcome-based service contract Hou and Neely (2017), identified complexity as one of the risk factors. The authors further identified factors driving complexity in OBC, which include involvement of multiple stakeholders, diversified customer demand, unclear customer demands, complex contracts, and complex environment.

These classifications of complexity reveal the multi-dimensional and multi-faceted nature of complexity across the PSS life cycle. To structure the discussion on complexity associated with advanced services delivered through a PSS, the three aspects of the value architecture (business model) (Garcia Martin *et al.* 2019), - value creation, value delivery and value capture is used. Across these aspects, complexity manifest in the form of structural complexity, technical complexity, organisational complexity, environmental complexity, operational and human-based/relational complexity (Kreye 2019, Jackson 2020).

2.3.1.1 *Organizational Complexity associated with Internal configuration of resources and capabilities*.

Adopting service introduces the need for greater resource commitments in service-specific resources, infrastructure, and capabilities (Visnjic Kastalli and Van Looy 2013). The need to organise multiple and diverse resources, processes and capabilities that are new to the firm, into new organisational structures, with the likely aggravation in organisation and control costs (Zhang *et al.* 2019). In addition to technical skills and product knowledge, a service culture is essential as well as the capabilities for service provision (Martinez *et al.* 2010, Kohtamäki, Henneberg, *et al.* 2019). In some cases, a restructuring of the organisation may be required depending on the strategic importance of services as a vehicle for attaining competitive advantage (Fliess and Lexutt 2019). A lack of management and strategic buy-in may inhibit the creation of a common language and unity of purpose; a recipe for internal complexity (Oliva and Kallenberg 2003, Gebauer *et al.* 2008). Besides the transformation of mindset and culture, acquiring operational capabilities relating the integration product and service components, service design, solution customization, requirement evaluation encapsulate the breath of complexity inherent in the successful delivery of a PSS (Ceci and Prencipe 2008, Schuh *et al.* 2017, Shen *et al.* 2017, Song and Sakao 2017).

2.3.1.2 **Technical and Structural Complexity relating to the Development of PSS Offering**

According to Jackson (2020) structural complexity is associated with the collection of system elements and the interconnection/interrelationships between them. Technical complexity refers to the design of objects requiring multiple and a variety of technical building blocks. In the concept of a PSS, structural and technical complexity manifest in the form of

1. The design and development of a new PSS. At the design stage, the configuration of PSS components that would deliver on expected outcomes may not be known. Hence, the provider experiments with multiple combinations of product and service elements and test their efficacy and effectiveness (Schuh *et al.* 2017, Shen *et al.* 2017). Configurations comprising multiple and diverse product combinations can engender enormous amount of complexity either in their design or maintenance(Afshar and Wang 2011). Over the in-service phase, the provider might test new configurations of PSS as new information becomes available (Garetti *et al.* 2012, Rodríguez *et al.* 2019). As new information becomes available, previous design proposals and decisions have to be revisited and the design changed to reflect new information.

2. Configuring the network of actors and facilities for optimal performance (Kyösti *et al.* 2014). Offering advanced services may involve setting up service stations, facilities, and stations. Getting the location and distance between location right is important to the success of a PSS. Complexity may arise from as a result of the number of locations and travel distance between stations (Jazouli and Sandborn 2010, Sandborn *et al.* 2017).

2.3.1.3 **Operational Complexity in PSS**

In a PSS context, operational complexity is underpinned by uncertainty relating to the 'demands' on the underlying delivery system (services) as the product is put into use by the customer to realize its objectives (Erkoyuncu, Roy, Shehab, *et al.* 2011, Erkoyuncu, Durugbo, and Roy 2013, Kreye 2017b). It relates to managing the uncertainty of information and material requirements required to achieve mutually beneficial outcomes, given the level of turbulence within and outside the company (Reim *et al.* 2013, Maiwald *et al.* 2014).

Operational complexity is acknowledged in the PSS literature as well (Chalal *et al.* 2015, Hou and Neely 2017). As already stated, operational complexity is the type of complexity associated with dynamic processes and configuration of tasks (Cheng *et al.* 2014). Central to operational complexity is uncertainty regarding the amount, intensity and quantity of variables required to generate or achieve required outcomes (Briscoe *et al.* 2011). These demands on the PSS are stochastic and dynamic (Erkoyuncu, Durugbo, Shehab, *et al.* 2013, Schwabe *et al.* 2015). The nature, frequency, and timing of these demands on the system might not be known with certainty at the beginning of a contract, bidding stage or over the life cycle of the offering (Erkoyuncu, Roy, Datta, et al., 2011, Kreye, Newnes and Goh, 2011, 2014a). This is invariably due to the interaction of interdependent and interconnected variables and entities across time and space within the system (Phumbua and Tjahjono 2010). The uncertainty of these events within the system over time underscores the unpredictability of a future state or behaviour of the system underlying a PSS solution.

With the growth of digital technologies, the generation of huge influx of data increases the degree of complexity. Huge data volumes collected from multiple ports and IoT-enabled devices create data complexity for managers who must analyse these data to gain insight into the behaviour and use of devices and equipment.

2.3.1.4 **Relational Complexity associated with Inter-Organizational Networks.**

To offer service solutions through a PSS, firms may not possess all necessary resources and capabilities, triggering the need to integrate resources from outside the firm (Windahl and Lakemond 2010). Integrating resources and capabilities through service-driven relationship and inter-organisational networks allow firms access to diverse and superior structures and systems to orchestrate service outcomes (Cantù *et al.* 2012, Frow *et al.* 2014, Randall *et al.* 2015). Although this allows the firm to access specialized skills and technical know-how, however, the heterogeneity of stakeholders and their different interests exposes the firm to coordination challenges (Kreye 2017b, 2017a). Mills *et al.* (2013) and Parry (2018), modelled the complexity of service solutions delivered through a PSS using an enterprise image and highlight the multiplicity and diversity of actors and the huge challenge intrinsic to the integration of large volumes of resources and materials across multiple interfaces. Batista *et al.* (2013, 2017) investigated the development of co-capability in outcome-based contracts and identify the role of relational processes since the boundaries between the customer-business and the network of suppliers and provider become fuzzy. Kreye (2017, 2018), while exploring maintenance services found that as providers increase their service content by shifting from product-oriented services to result-oriented service find that relational complexity increases. This is consistent with the findings of Hockley *et al.* (2011), Smith *et al.* (2012, 2014) and (Gaiardelli *et al.* 2014). Ng *et al.* (2013), who explored the role of partnership and relational assts in contract performance, find that relational asset and aligning expectations ranked higher than equipment and information alignments in the achievement of outcomes.

Collaborating with multiple actors involves managing a variety of attitudes, preferences, interests, worldviews, and behaviour to deliver outcomes (Datta and Roy 2013). To control performance amidst variability in context, preferences and demands requires flexibility and adaptation to evolving situations. Furthermore, closer relationships between actors across the service network creates interdependency on issues like resources, information, materials (Karatzas *et al.* 2016, Reypens *et al.* 2016, Raddats *et al.* 2017).

2.3.1.5 **Contextual Complexity associated with Customer Variety of Use**

The relational nature of service engenders the co-creation of value with the customer (Maglio and Spohrer 2008, Lusch and Vargo 2014). In product manufacture, the customer is exogenous to the production system. However, in services, the consumer and user are participants in the service production process (Spohrer *et al.* 2008, Ng, Smith, *et al.* 2012, Vargo and Lusch 2018). In the context of service solutions delivered though a PSS, this implies that the service provider relies on the customer's resources for the generation of co-

capability to realize value (Ng *et al.* 2013, Sandin 2015, Batista *et al.* 2017). Here, the engagement with the customer transitions from value embedded in goods and services exchanged to value realised in use (Alves *et al.* 2016, Green *et al.* 2017). In this perspective, the place of customer relationship assumes a prominent and important position. Ng and Briscoe (2012) and (Ng *et al.* 2011) argue that complexity are driven largely from the customer‘s contextual variety of use. Contextual variety relates to the context of use; the variety of situations in which the solution or capability delivered to the customer is used (Green *et al.* 2017). It is an example of “unknowns” of customer requirements described in Parnaby (1988) and Godsiff 2010).

As context-of-use changes, the need for a functionality that was not previously anticipated arises (Ng and Briscoe 2012). This has implications for product design and supply chain. Since the product architecture and functionality is fixed, alterations and changes to the product might be difficult and the product supply chain might not be able to respond as quickly as customer’s context changes, therefore, flexibility diminishes, economies of scale vanishes, resulting in the loss of efficiency (Ng, Parry, *et al.* 2012, Green *et al.* 2017). Contextual variety drives variability in resource utilization and service processes as new resources or existing resources would need to be organized or re-organised to cope with changes in customer demands (Davies *et al.* 2007, Kreye *et al.* 2015, Zhang and Banerji 2017, Zou *et al.* 2018), and variability in customer perception and satisfaction (Green *et al.* 2017). Contextual variety engender uncertainty in the design and delivery of contractual outcomes. Furthermore, misunderstanding of customer’s requirements and demands may occur, creating non-aligned expectations between the customer and the provider and further implication for contract specification and contract cost (Kreye *et al.* 2009, Martinez *et al.* 2010, Kreye 2017a).

2.3.1.6 **Complexity driven by a Turbulence in the Environment.**

In addition to the problems of coordination and cohesion, a PSS must manage complexity stemming from the external environment. A PSS is an open system. This means it exchanges materials with its environment. As an open system, it is embedded within an environment and is affected by the perturbations in the environment.

The adoption of PSS solutions changes the nature of the interaction between the firm and its environment. Here, the customer assumes the role of co-producer and co-creator of value, hence, moves from an exogenous role to an endogenous role (Benedettini *et al.* 2015). Changes in technology, market rates, government regulations, social, legal and ecological changes have the potential to affect the affordability of the customer, trigger obsolescence,

create uncertainty in customer demands, as well as the constitution of the solution offered by the provider (Hypko *et al.* 2010b).

2.3.1.7 **Complexity and Advances in Technology**

Technology is a major driver of environmental-induced complexity. For assets that are contracted for a long period of time, changes in technology induces the need for a replacement of existing and legacy hardware, increasing the costs for the provider (Kreye 2018). The cost of obsolescence of a hardware could increase as new technologies are developed to replace existing ones (Prabhakar and Sandborn 2012b, Kessler and Brendel 2016). Furthermore, political events can affect the supply of services, causing a disruption for the customer (Kreye 2017a).

Advances in technology is driving more complexity in the provision of PSS enabled solutions. The growth of connected devices which connects, collects, and stores data from a variety of locations adds to the level of complexity and variety solution providers have to manage. More connected devices mean huge volumes of data is generated, which must be stored, processed, and analysed for insight.

2.3.1.8 **Complexity Exacerbates Risks and Uncertainty, and Threatens the Viability of PSS Business Models**

Dimensions of complexity highlighted in the above section account for the proliferation of risks and uncertainty of outcomes, leading to higher service costs and lower profit gains (Newnes, Mileham, Rees, *et al.* 2011, Parry *et al.* 2011, Zhang *et al.* 2014). Risk is the probability of loss/gain arising from an event. Uncertainty refers to the difficulty in predicting an event or the result of an event. Risks and uncertainty are associated with decision-making in complex situations. Risks and uncertainty are features of complexity. The dynamic interaction of components within a system makes it difficult to predict outcomes with or without probability.

Complexity threatens the viability of PSS strategy (Zou *et al.* 2018), and exacerbates the risk of bankruptcy (Benedettini *et al.* 2017). In exploring business failures and bankruptcy among

servitized firms using the Ooghe and Waeyaert (2004) framework, Benedettini *et al.* (2015) identify “internal risks are more salient” (p. 968) in manufacturing firms offering services and services amplify uncertainties and bankruptcy risks. Reim *et al.* (2013) identified three risk classes in the delivery of functional products: contractual risks, technical risks, and organisational structural risks. This is consistent with customers perceived risks highlighted by Maiwald *et al.* (2014), who found that uncertainty associated with customers’ requirements, difficulty in evaluating performance, variety in customer context of use, relational complexity and the loss of control increases the level of risk.

PSS providers also face uncertainty relating to product behaviour and product performance, which is driven by the behaviour of the technical system (failure and repair times are variable and random, technologies changes), usage behaviour and context, uncertainty of outcomes (Kreye *et al.* 2012, Nullmeier *et al.* 2016, Estrada *et al.* 2017); uncertainty relating to product reliability and availability (Ghodrati *et al.* 2010, Jazouli and Sandborn 2010, Newnes, Mileham, Rees, *et al.* 2011, Phumbua and Tjahjono 2011, Löfstrand *et al.* 2012, Narayana *et al.* 2012, Kyosti 2015, Erkoyuncu *et al.* 2017, Rodrigues *et al.* 2017, Settanni *et al.* 2017, Lindström 2017, Rijsdijk 2017)

Risks and uncertainty increase the potential of loss-events for PSS suppliers (Neely 2009, Kwak and Kim 2016, Qu *et al.* 2016). The riskier a PSS offering is or the higher the uncertainty associated with a PSS, the heightened chance of a loss-event happening. The elevated level of risk and uncertainty associated with the provision of a PSS explains the number of studies on cost estimation, life cycle costing and economic performance of a PSS (Roy and Kerr 2003, Newnes, Mileham, Cheung, *et al.* 2011, Waghmode and Sahasrabudhe 2012, Mannweiler *et al.* 2012, Marten and Gatzen 2014, Goh *et al.* 2015, Lindstrom 2015, Bonetti *et al.* 2016, Estrada and Romero 2016, Seiringer and Bauer 2016, Saccani *et al.* 2017, Zhang *et al.* 2017, Estrada *et al.* 2017, Rodríguez *et al.* 2019).

2.4 Complexity Management

The review of the PSS literature above reveals a variety of complexity drivers across four dimensions: organization dimension, network dimension, customer dimension and environmental dimension. These complexity drivers provide strong evidence regarding the variety of challenges and pitfalls manufacturing companies encounter when extending their activities into services (Benedettini *et al.* 2015, Valtakoski 2017).

According to Benedettini *et al.* (2015), the adoption of integrated solutions and services by manufacturing companies presents a challenge on two fronts: managing complexity associated with the change in the relationship between the company and its environment on the one hand (adaptation) and dealing with the problem of integration associated with the internal environment. The external environment comprises the current and future environment. The current environment is concerned with how the company implements its service-based business model while the future environment consists of changes in the external environment which could disrupt or alter the value creating activities of the company. In the internal environmental, the company must establish and sustain a new form of organisational arrangement and capacity (comprising processes, resources, technologies, competencies, capabilities and values) that allows it to create, deliver and capture value (Visnjic *et al.* 2017). The challenge in the internal environment is exacerbated due to the endogenous role of the customer and other actors across the supply chain, With advances in digital technology, the boundaries become blurred as loosely-coupled independent actors interact with each other (including the firm) to create value.

A less than holistic approach to managing complexity in the context of a PSS might serve as a recipe for financial loss and the service paradox (Kharlamov and Parry 2021)

Revisiting the research questions:

1. How can a PSS be steered and governed to maintain viability against the backdrop of complexity in its internal and external environment?
2. What are the conditions underlying the viability of a PSS? What conditions must PSS providers maintain to drive its viability?

Several qualitative and quantitative studies have attempted to answer to these questions (Gebauer *et al.* 2005, Settanni *et al.* 2014, Gebauer, Fleisch, *et al.* 2020). However, qualitative research findings are fragmented and often specific to an aspect of the underlying PSS delivery system. According to Settanni *et al.* (2017), the plethora of quantitative studies focus on the technical system of the PSS and producing product-centric formulations of PSS performance (viability), where specific measurable variables associated with the technical system assume the object of interest while ignoring the social elements of a PSS (for example Richardson and Jacopino 2006, Eggert *et al.* 2011, and Su and Cheng 2018). Often, these studies adopt a narrow definition of a system that focuses largely on measurable variables via the use of quantitative techniques (Thenent *et al.* 2012, 2013, Settanni *et al.* 2014). Thenent *et al.* (2013) argue whether technical knowledge is sufficient to link performance and cost. Rephrasing that argument, does managing technical and operational complexities sufficient for maintaining the viability of a PSS? Thenent *et al.* (2012) points to the role of technological

knowledge; the knowledge that drives the design and development of products and service as well as their delivery. Presenting empirical evidence from a case study of a outcome-based contract Settanni *et al.* (2017) found that availability (outcome) is a function of a complex interaction between the social and technical aspects of a PSS.

There is a lack of a holistic framework on managing complexity, which underpins the viability of a PSS business model.

2.4.1 Complexity Management: Strategies and Approaches

The extant literature on complexity acknowledges the lack of a single, and a generally accepted definition for the concept of complexity (Cohen and Axelrod 1999, Schwaninger 2000, Maguire *et al.* 2006, Heylighen *et al.* 2007, Alhadeff-Jones 2008, Terrazas *et al.* 2015, Eloranta and Turunen 2016, Allen *et al.* 2018, Yolles 2019a). Complexity as a concept, is multi-disciplinary, hence the management of complexity is conceptualized differently across different disciplines.

2.4.1.1 Organizational and Management Studies Perspective

Drawing from the organizational science literature, Burns and Stalker (1961) outlined several types of models of organizations, including the ***Mechanistic Organisation,***
which conceptualizes the organisation as a machine was proposed by Tom Burns and G.M. Stalker (Burns and Stalker 1961, Burns *et al.* 2011). The mechanistic organisation is known for its characteristic bureaucratic structure, specialization of tasks, lack of flexibility and hierarchy. The flow of information and communication is top down, and vertical. Mechanistic organisations have centralized decision making and standardized controlled systems. The inflexibility in mechanistic organisation could undermine its ability to respond to changes in the environment (Griffin and Moorhead 2010). According to Burns and Stalker (1961), the mechanistic organisation is suited to stable conditions, a description that far from the reality of today's organisations.
Burns and Stalker (1961) also identified another type of organisat***ion, the Organismic***
The organismic or organic organization contrast with the mechanistic organisation in characteristics: it has a flexible structure and information flow, and communication is horizontal. It lacks rigid processes and procedure. Organic organization have the ability to respond quickly to perturbation in the environment. Organic organisations respond to changes

in the environment quickly and the needs of all members are recognised. Decision is by consensus with autonomy and power shared among members.

A fundamental focus of the management studies literature regarding the management of complexity in organisations is the emphasis on **STUCTURE**. Structure refers to the architecture and anatomy of an organisation, how the roles and responsibilities are distributed, and functions are organized. Structure provides the mechanism in which control and integration are achieved and maintained (Chandler Jr 1962, Burns *et al.* 2011). The element of control is expressed through the degree of decentralization and the distribution of power and authority and operationalized through information systems and corporate code of conduct, which serves as channels to control and regulate behaviour of employees . With the current state of the today's environment, the organic organisation is better suited to survive.

In extending the discourse on organisational structure, the contingency theory argues that there is no 'one best way' to organise an organisation. There are multiple contingency theories, however, Fiedler's contingency theory (Fiedler 1978) of leadership relates to **leadership styles** and approach to problem situations. In structural contingency theory (Donaldson 2014, 2015), the emphasis is on organisational structure – the way an organisation is organized is contingent on its environmental contingencies- the uncertainties and complexities the organisation faces. A more stable environment might suit a higher specialization and decentralized organization/structure while it a high-uncertainty environment would command a lowly specialized and centralized structure. For structural contingency theory, the goal of any structure is to achieve effectiveness and efficiency.

2.4.1.2 **Strategic Management Perspective**

Drawing from corporate strategy perspective, complexity management involves achieving a fit between the organisation (structure) and its environment. It encompasses "making the right choice" at the right time to survive. Here, survival refers to the achievement of competitive advantage (Porter 1998) as well as satisfying the needs of stakeholders. According to Eisenhardt and Henning (2012), organisations as complex adaptive system manage complexity through essential organisational processes and practices. Practices and processes in the parlance of strategic management involves the configuration of resources, competences and capabilities including collaborations in other to compete. Here structure also plays a part in the execution of organisation strategies (Miles *et al.* 1978, Hall and Saias 1980, Mishra *et*

al. 2018). The debate over whether structure follows strategy or strategy follows structure is outside the scope of this research (Chandler Jr 1962, Mintzberg 1987). For a strategy to succeed, structure must be adapted to facilitate the execution and implementation of strategy (Johnson *et al.* 2007)

Two commonly-cited theories in the strategic management literature are the resource-based view and the dynamic capabilities.

Resource-Based View

The resource-based view of the firm, originally proposed by Birger Wernerfelt (1984) and later refined by Barney (1991) espouses that a firm can achieve competitive advantages by accumulating strategic assets that are valuable, rare, hard to imitate, and non-substitutable (Barney 1991). These assets include capabilities, resources, knowledge, attributes, and organisational processes. that are controlled or accessed by the firm to obtain a competitive advantage.

A number of studies have explored the transition to PSS solutions by manufacturing firms, using RBV. These includes Raddats *et al.* (2015), who examined resources and capabilities required by manufacturers to develop services; Ulaga and Reinartz (2011) who identified key success factors for combining products and services; Baines *et al.* (2013), who explored human resource skills and capabilities in the delivery of advanced services. Others include Gebauer *et al.* (2017), Lenka *et al.* (2017), and Gebauer, Paiola, *et al.* (2020). However, RBV is a strategic management theory and does not explain the mechanism by which resources are configured to manage complexity in service firms. It has been criticized as static, takes no account of context and possess limited prescriptive implications (Eisenhardt and Martin 2000, Barney 2001). Furthermore, as Teece (2018) argues, although, VRIN resources offer some protection against in road by competitors, at some point, VRIN assets and resources will eventually be imitated to some extent.

Dynamic Capabilities

Due to the limitations of the resource-based view, dynamic capabilities perspective (Teece 2009): was developed to acknowledge the changing environments which organisations are

embedded. and the dynamic markets they serve (Eisenhardt and Martin 2000). Dynamic capabilities are more robust than resources since they involve the integration of a firm's processes, internal and external competences, routines, and practices to addressing rapidly evolving environments (Teece *et al.* 1997, Teece 2018). The core of the dynamic capability theory/framework espouses how firms orchestrate, "create, modify and transform" their resource set to achieve competitive advantage in times of rapid change (Helfat *et al.* 2007, p. 4). Dynamic capability manifest through a sense-seize-and transform process, involving resource-allocation processes, asset base positions and the path taken by the firm (Teece *et al.* 1997, Teece 2018). Dynamic capabilities perspective can be used to explain mechanisms such as absorptive capacity of firms, coordination, learning (Eisenhardt and Martin 2000, Majuri and Halonen 2019, Souza and Takahashi 2019), knowledge management and adaptation in complex systems (Espejo 2018).

Dynamic capabilities have been referenced in PSS studies (Fischer *et al.* 2010, Zhang and Zhang 2014, Gebauer *et al.* 2017, Raddats *et al.* 2017, Nenonen *et al.* 2018, Coreynen *et al.* 2020), particularly in the context of business model design and implementation (Ng *et al.* 2013), including capabilities relating to the design and delivery of services (Storbacka 2011, Ulaga and Reinartz 2011, Visintin 2012, Visnjic and Van Looy 2013, Sandin 2015, Batista *et al.* 2017, Raddats *et al.* 2017), building relationships (Aarikka-Stenroos and Jaakkola 2012, Raddats *et al.* 2017), and collaborating with a network of actors (Storbacka 2011, Vasantha *et al.* 2012, Gebauer *et al.* 2017).

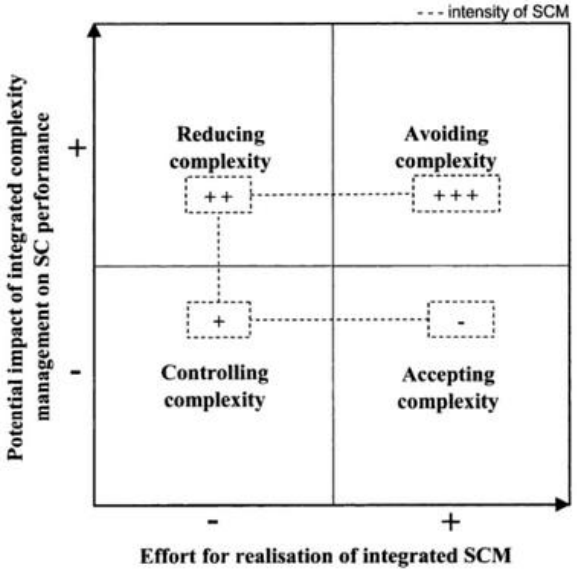
2.4.1.3 **Operations and Supply Chain Management**

Kaluza *et al.* (2006) developed the complexity strategy matrix, identifying four complexity management strategies: controlling, avoiding, reducing, and accepting. The authors pointed to managerial decisions and the intricacies of organisational systems in supply chains. This is consistent with the classification proposed by (Wildemann 1999), who reviewed complexity management strategies in logistics systems.

The ***accepting complexity strategy*** involves a passive and reactive approach, where the organisation simple adapts to the complexity. Organisations develop coping mechanism as a means of adaptation to the complexity requirements. For the ***controlling complexity strategy***, the organisation aims to control complexity by managing it. It involves monitoring the parameters and adjusting them accordingly. The ***reducing complexity approach*** is a proactive approach that seeks to decrease the size, level and degree of the complexity. To reduce complexity, the organisation optimizes the parameters. Any item, object, relationship,

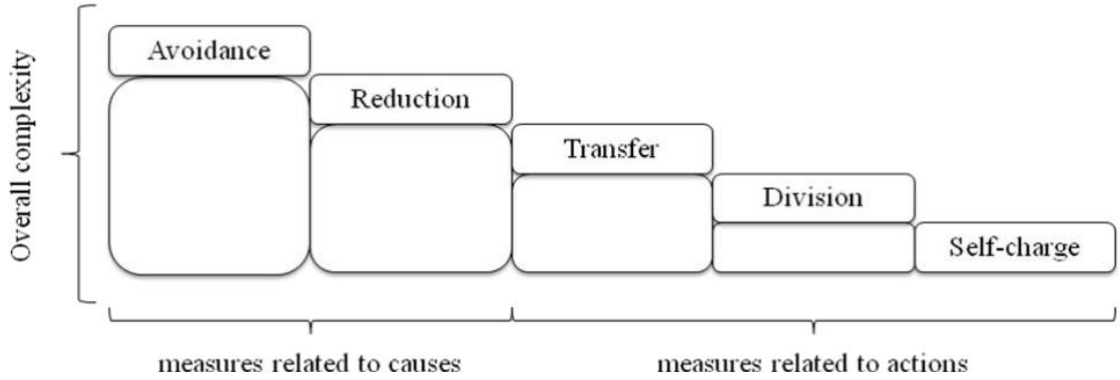
entity that adds no value is removed to reduce complexity and fastens information and resource flow. The last is the avoiding complexity strategy, which involves strategic redesign and evaluation of options to avoid complexity.

Figure 3: Complexity Strategy Matrix (Kaluza et al. 2006)



Kersten *et al.* (2012) extended the matrix to create complexity management strategies. The extended matrix consists of complexity avoidance, complexity reduction, complexity transfer., complexity division and self-charge. Complexity transfer and division are complexity regulation strategies suited for complex systems. By complexity transfer, that means the organisation outsources the complexity and complexity division means , the organisation divides the level of complexity into bits that can be handled by different parties.

Figure 4: Complexity Management strategies (Kersten et al. 2012)



Other complexity management strategies found in the operations management literature include smart complexity developed by (Mahler and Bahulkar 2009), modularity (Ulrich and Tung 1991, Wildemann 1999, Hornby 2007), platform strategies (Eisenmann *et al.* 2011, Prabhakar and Sandborn 2012, Bertoni and Bertoni 2018), standardization (Brownell and Merchant 1990, Wilson 2012, Hasegawa 2017, Moroni *et al.* 2020, Vendra *et al.* 2020) and simulation (Richardson and Jacopino 2006, Wong *et al.* 2008, Erkoyuncu *et al.* 2016).

These strategies can be categorised within one of the groups developed by (Kersten *et al.* 2012). For example standardization and modularity can be referred to as avoiding complexity strategy since it involves a proactive use of instrument to prevent the emergence of complexity (Jäger *et al.* 2014). In general, the focus of complexity management in operations management is the optimization of processes, resources and outputs.

The review of the extant literature reveals a variety of complexity management strategies. However, these complexity management methods, strategies and theories address specific aspect of the organisation or industry. A product service system consists of both product and service systems and require the configuration of a variety of resources to deliver on its purpose. A PSS does not conform to the tradition product-only context; hence, a complexity management strategy or model must capture a holistic depth and breadth of its structure and processes, including its interaction with environment.

2.4.2 Managing Complexity: A System-thinking Approach

The advent of the general system theory (Bertalanffy 1969) was a breakthrough for complexity science researchers as general system theory provides a prism to think about the world or structure our thoughts about the world (Jackson 2002, 2007). According to Reynolds and Holwell (2010), systems are social constructs of real-world entities, objects, and phenomena. This is consistent with the definition offered by Flood and Jackson (1991), who described a 'system' as not an entity out there in the world but a particular way of seeing the world.

Systems-thinking is a way of engaging with real world objects. According to Jackson (2007) citing Churchman (1968), systems approach is a way of seeing the world, that is, worldviews. Systems-thinking acknowledges the existence of objects not as isolated entities but in relations to other objects. Systems-thinking reinforces relationships and the whole rather than isolated entities. It highlights contexts and provides insight about the world.

Senge (2006) argues that systems-thinking is a discipline for seeing wholes. It is a framework for seeing interrelationships rather than things, for seeing patterns of change rather than static snapshots. Systems thinking is a sensibility – for the subtle interconnectedness that gives living systems their unique character." (p.68). Senge emphasizes the essence of systems thinking that focus on **interrelationships** rather than **a linear cause and effect** relationships, processes rather than snapshots, feedbacks as communication mechanism, participants as active agents in shaping reality (pp. 69-73)

Systems thinking is a holistic approach to analysis and it focuses on the way parts (multiplicity and diversity) and components interact and interrelate (interaction and interdependency) and work together over time (dynamism) and within a larger system context. A system thinking approach contrast with reductionist approach, which is characterized by the belief that system behaviour can be understood based on the characteristics and properties of its parts. According to Merali and Allen (2011), systems thinking is characterized by the following properties.

A. The existence of a distinct entity that can be identified and explicitly defined as "the system" or "the whole".
B. the composition of "the whole" from a number of *inter-connected* parts
C. the existence of distinctive properties that can be ascribed to "the whole" but not to any of the individual parts that constitute the whole (i.e., the whole is more than the sum of its parts

The whole is not predetermined but is selected based on a given purpose.

2.4.3 Systems-Thinking Approaches and Complexity

In some systems such as dynamical systems and complex adaptive systems, relationship and interaction between components give rise to global or whole behaviour that cannot be linked to the behaviour of the individual components(Holland 1995). These systems are complex systems (Cilliers 1998). According to Arthur (2015, p.182) “Common to all studies of complexity are systems with multiple elements adapting … to the world – the aggregate pattern – they create”. The interactions of actions by individual components create aggregate patterns that are unpredictable (Stacey 1995, Dooley 1996)

Complex systems display patterns of behaviours that are, unlike complicated and simple systems, unpredictable. Emergent phenomena, arising from densely interacting events and variables, self-organisation, co-evolution, path dependency constitutes some of the properties of complex systems. In social systems (for example organisations), the presence of human beings with multiple beliefs, values and knowledge and interpretations that inform their responses and govern their behaviour imposes more complexity in organization and highlights the difficulty in the management of organisations (Checkland 1981, Jackson 2002).The management of organisations is the object of interest in this research.

Since Bertalanffy (1969), proposed the general system theory, with its premise that complex **systems** share organizing principles which can be extended to explain all **systems**, a variety of formulations and system approaches have emerged or developed to provide ontological or epistemological devices or models to explore, gain insight about the world or explain phenomena in organisations and explore the effects of interventions that are geared toward the control, steering and governance of systems/organisation (Gare 2000, Merali and Allen 2011).

These system-based approaches include cybernetics, systems analysis, operations research, systems engineering, soft systems and complex system (Checkland 1982, Cilliers 2000, Phelan 2001, Heylighen *et al.* 2007, Jackson 2007, Ryan 2008). Attempts have been made to group these approaches into categories; objective worldview vs inter-subjective knowledge, soft versus hard systems approaches (von Foerster 1979, Checkland 1981, 1983); exploratory and explanatory systems approaches (Phelan 1999); the nature of the problem: pluralist vs monist (Checkland 1981); complex systems versus systems theories (Phelan 1999), functionalist versus interpretivists versus emancipatory approaches (Flood and Jackson 1991a, Jackson 2002); complexity as a function of the number of components and interaction between them versus complexity as something that emerges hen several agents follow simple rules (Phelan 1999).

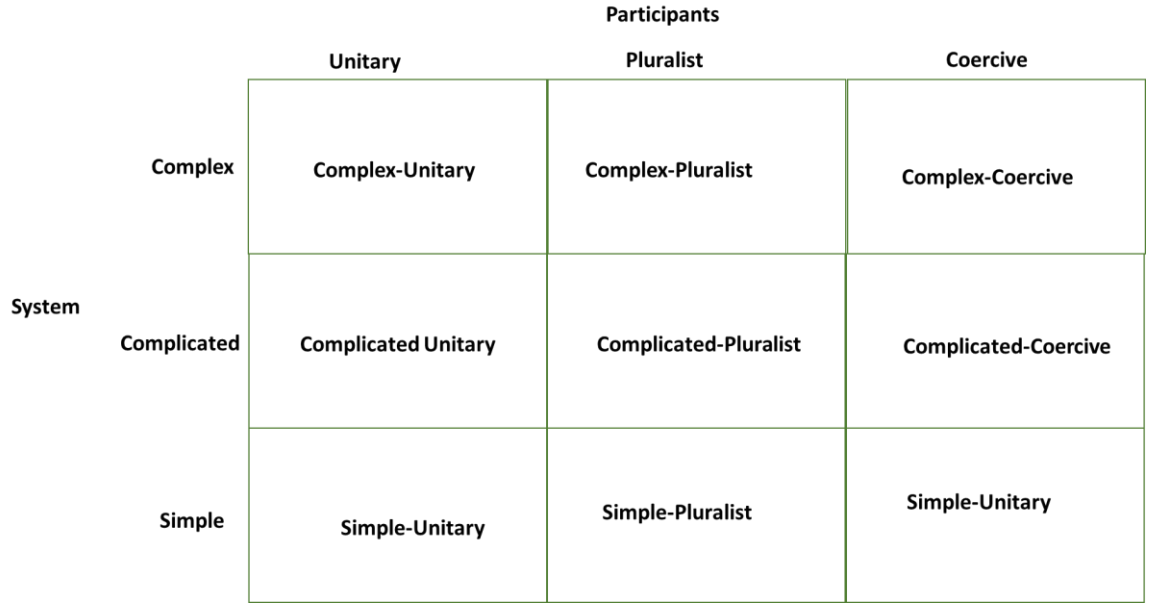
While these attempts at categorization of system approaches expands the discourse around complexity, they denote the lack of a monolithic stance about complexity. Ryan (2008) argues that differences between system approaches do not "relate to the questions asked but the way in which they are answered" (p. 25). However, the nature of the answers provide by these approaches is determined by the different view on the nature of complexity. This stance is consistent with the contributions from Cilliers (1998, 2005).

2.4.4 Systems Approaches and Problem Contexts: Jackson's System of Systems Methodologies

Contributions from Michael Jackson (Jackson and Keys 1984, Jackson 2006b, 2007, 2008, 2019, 2020, 1988, 1991a, 1994, 1999, 2001, 2002, 2003, 2006a, Flood and Jackson 1991a, 1991b), focused on the application of system-approaches to management of organisations. Jackson (2020) argues that different understanding of complexity influences and underpin the selection and choice of approaches and response. In an earlier article, Jackson and Keys (1984) developed a system of systems methodology matrix which relates systems approaches/methodology to problem situation context. Jackson and Keys (1984, p. 473) define problem context as "the individual or group of individuals who are the would-be problem solvers, the system(s) within which the problem lies and the set of relevant decision makers. This set contains all of the elements which can make decisions which may affect the behaviour of the system(s)." The authors used system type and decision makers/participants later changed to stakeholders (Jackson 2020) as contextual elements – consisting of nature of the system, (ranging from simple to complex system) and participants (unitary, pluralist and coercive/radical with respect to some objectives). The matrix was expanded in (Jackson 1991b) and (Jackson 2019).

The three types of systems and three types of participants are combined to form a 3x3 matrix of nine cells, with each representing a contextual category (Jackson 2019). See figure 5

Figure 5: Grid of problem contexts and associated systems approaches or methodologies (Jackson 2003)



Each contextual category (problem context) presents characteristics that determine or describes the nature of the real world problem (Jackson 1991b) (Jackson and Keys 1984, Flood and Jackson 1991b). According to Jackson, it is important that decision makers consider both the system and stakeholder complexity prior to deciding the intervention. 10 system methodologies were classified in the matrix based on the problem context (system-stakeholder combination)(Jackson 2020)

Table 1:System of systems methodologies

Problem context	System Approaches	
Simple-Unitary	Systems engineering Cybernetics	There are agreed objectives for the system. Problem is well-defined. Scientific method preferred. The focus is optimising processes, resources and sub-systems in the most efficient way to achieve the objectives using quantitative methods (Vasconcelos and Ramirez 2011). ***Concerned about technical complexity.***

Complicated-Unitary	System dynamics	Problem context is fluid due to the dynamic, nature/number of interaction of components in the system. SD is used to Identify the most important variables and the interaction between them to understand system behaviour ***Focused on structural complexity***
Complex-Unitary	Organisational cybernetics Viable system model Complexity theory	Problem context is considered as driven by dynamic interaction between components in the organisation and between the organisation and its turbulent environment. The objective is the viability of the system and the ability of the system to reconfigure itself to take advantage of new opportunities. ***Focused on managing organizational complexity***
Simple-pluralist	Strategic assumption surfacing and testing approach (Mason & Mitroff, 1981). Social systems methodology,(Churchman 1971) Interactive planning (Ackoff 2001) Soft system methodology (Checkland and Winter 2006)	Purpose is to address the pluralism arising multiple and diverse purposes of humans and how they see the world. The approaches seek to bring about improvement by exploring multiple perspectives to build consensus that allows action to be taken. ***Focused on people complexity***
Complicated - pluralist		
Complex-pluralist		
Simple-coercive	Emancipatory Critical system heuristics	The problem of injustice arising from unfair and coerces treatment of participants. The purpose of the approach is to ensure fairness by allowing participants to decide what is good for them. Focus on the coercive complexity
Complicated-coercive		To ensure fairness
Complex-coercive	Post modernism	Promote diversity

The matrix is comprehensive in that it captures both ontological complexity and cognitive complexity (Rescher 1998). ontological complexity (functionalism) and cognitive complexity (interpretivism). Ontological complexity is “the complexity that exists in the real world. It derives from the quantity and variety of the elements of a system and the elaborateness of their interrelationships. It seems all the time to be increasing” (Jackson 2020, p. 2). Cognitive complexity is concerned with the way observers view the world. It is a constructivist view of complexity.

2.5 Managing Complexity in Organisations

It is apparent that each of the systems approaches outlined in the previous section maintains a different view regarding the nature of complexity and are designed to address complexity in different ways. Following the review of the systems methodologies, cybernetics as the grid shows, is designed to address organisational complexity. Organisational complexity is driven by dynamic interaction between the components/parts within an organisation and between the organisation and its environment. Cybernetics is designed to address problem context that are Complex-Unitary. It is COMPLEX because the interaction between the components and between the organisation and its turbulent environment is dynamic and UNITARY because the objective of the system is to maintain a separate existence – viability.

Cybernetics as a systems approach suited for the addressing organisational complexity is corroborated by Bohórquez Arévalo and Espinosa (2015), who reviewed three parallel theoretical approaches for managing complexity in organisations (organisational cybernetics, complex adaptive systems and complexity science). The authors argue that organisational cybernetics is the most suited to addressing organisational complexity since its focus of interest is the viability of the organization. The authors added that organisational cybernetics presents some well-developed and formalized principles and concepts for describing self-organisation and survival - recursion, requisite variety, homeostasis, redundant potential command (RPC), autonomy and coherence. The latter concept of dependent potential command (McCulloch 2016) and autonomy are fundamental to Viable System Model (VSM) as they represent a means to distribute command capability through an organization (or system of organisation), hence facilitating the management of complexity.

Furthermore, Jackson (2020), while reviewing the response of the UK government to the complexity associated with managing the Covid-19 pandemic, points to the concepts of decentralization and autonomy (both concepts in the VSM) - empowering local teams and sub-systems with power to solve problems at sites closest to the centre of problem, as an effective approach to managing variety. Autonomy and decentralization drive flexibility and empower subsystems with necessary information, which increases their capacity to intervene in problem situation at the local level.

There are plenty of examples of studies that have employed the organisational cybernetics through the VSM for the diagnosis and design of organisations and for the management of complexity in organisations and enterprises. These include in information processing (Hutchinson and Warren 2002, Preece *et al.* 2013), supply chain management (Hildbrand and Bodhanya 2014), multi-organisational setting (Tavella and Papadopoulos 2015), knowledge and learning (Espejo 1997, Leonard 2000), IT governance (Huygh and De Haes 2018),

information processing in disaster management (Preece *et al.* 2013), and infirmation security governance (Alqurashi *et al.* 2013)

To develop a framework on complexity management in the context of a PSS, a review of the PSS literature is undertaken. The review is aimed at unearthing, identifying, and collating the set of actions, mechanisms, structures, practices, and processes associated with managing complexity in the context of a PSS. To guide the review of the PSS literature, this research adopts an organisational cybernetics perspective, precisely the viable system model as a theoretical lens to guide the navigation of the PSS literature.

2.5.1 Organisational Cybernetics

The Viable System Model is rooted in systems-thinking and cybernetic principles (control and communication) and represents a holistic view of the essential processes and functions underlying the viability of systems. The VSM is also based on cybernetics principles. Cybernetics comes from the Greek word *kybernetes* meaning 'stateman' or 'governor'. In ancient Greece, the term was used in the context of ***steering*** and ***coordinating*** a ship and its crew in a wide variety of conditions at sea. Wiener (1961) defined cybernetics as the science of control and communication in animals and machines. Wiener observed that mechanical and biological systems operated in a circular manner. Simply put, these systems regulate themselves through information flow and communication between the components of the system and its environment to maintain stability.

Cybernetics explores purposeful systems and the mechanisms, processes, structures and constraints underlying the maintenance and sustainment of a system's purpose. These processes assume the form of circular causal chains and feedback loops, which move from action to sensing and action depending on the nature of information received by the system of interest. In complex systems, information (in the external or internal environment) act as stimuli, which triggers the system to act via a sequence of actions (denoted as control - each action having an output, which serves an input in an action) aimed at adapting the behaviour of the system in response to the stimuli from the environment.

Early works on cybernetics had focused on the control of artificial systems, physical system, machines, and engineering systems. These works focused on how systems could be modelled and controlled In applying the natural laws of cybernetics to organisations, Stafford Beer defined cybernetics as the "science of effective organisation". . Stafford Beer was inspired by functions and processes underlying the human neurological system discovered an isomorphism; that these functions and processes were shared by both the nervous system

and the management systems of a viable organisation. Beer referred to these functions as system functions and they are necessary for the functioning of any organisation. The VSM functions are described below.

2.5.1.1 Organisations, Environment and Variety (Complexity)

The conceptualization of an organisation in management cybernetics differs from the traditional image of hierarchical aggregation of roles and ranks, organisational chart, or an organogram. Beer conceptualizes an organisation as the relations between processes, whose unity gives the organisation its closure (Vidgen 1998). This is opposed to the term “structure” which depicts the number and relationship between components; commonly represented by organizational charts and organigrams. Two features characterise the description of organisations: identity and relations with the environment.

2.5.1.2 Organisation as a System with Purpose and Identity

One main feature of an organisation is its purpose. According to Stafford Beer (Beer 2002, p. 217)

> *“The purpose of a system is what it does”.*

In cybernetics, the pattern of organisation and relationship between processes encapsulates the purpose of that system; what the organisation does (Harnden 1989, Espejo 2015b). The purpose of an organisation may include the production of goods and/or service, the delivery of some social outcomes or solving societal problems. Another associated term is identity. While purpose relates to what an organisation does, identity is what the organisation is (what it represents). Identity represents a set of stable relationship, a pattern of norms, meanings and values which defines some form of closure (Harnden 1989, Espejo *et al.* 1999a, Espejo and Reyes 2011).

Product Service systems (PSS) are systems of organisations and can be referred to as purposeful systems since they are created or designed to achieve specific purpose (the delivery of mutually benefiting outcomes) (Ackoff and Emery 1972, Reynolds and Holwell 2010). The identity of a PSS can be described using the business model – value proposition, value creation, and value delivery (Pawar *et al.* 2009, Garcia Martin *et al.* 2019).

2.5.1.3 Organisations, Environment and Variety (Complexity)

The pattern in which resources, processes and activities are organised reflect the value an organisation creates for its environment (Lassl 2019a). These configurations and

organisations of processes reflects how an organisation intends to implement its purpose. Purpose as already described in the previous section, is what an organisation does; its primary activities, which is the production of goods and services or some outcomes. Other activities and processes are designed to support the implementation of its identity.

Stafford Beer (1995) argues that an organisation as a unity, is separate from its environment, which it interacts (Beer 1995a). Through the configuration of processes, an organisation establishes a relationship between itself and the environment. Through its primary activities, an organisation produces goods and services that benefit the environment. The interaction between an organisation and its environment is bidirectional (Lassl 2019a). This means that the organisation is influenced by its environment and in turn, the organisation influences its environment. However, the environment is not static but complex. Therefore, the organisation is in a constant flux of continuously balancing relations between system functions as well as between itself and the environment (Lassl 2019a)

This is related to the concept of autopoiesis developed by Maturana and Varela (1980), which describes living systems (applied to organisations) as self-reproducing in terms of internal organisation. It was further developed by von Foerster (von Foerster 1979). Luhmann (1984) extended the concept to social systems (organisations) to explain the maintenance of identity through information and communication flow. Stafford Beers agreed with this position. (Maturana and Varela 1975, p. 70, cited by Mingers 1995)

"For I am quite sure of the answer: yes, human societies are biological systems. ... any cohesive social institution is an autopoietic system—because it survives, because its methods of survival answer the autopoietic criteria, and because it may well change its entire appearance and its apparent purpose in the process. As examples I list: firms and industries, schools and universities, clinics and hospitals, professional bodies, departments of state and whole countries"

For managers in organisations, the business environment is characterized by uncertainty, instability, and chaos. Complexity in the external environment relates to the nature of relationships the organisation has with a variety of stakeholders who hold different views about an organisation's interaction with them. These interactions may involve the impression of the customer about the product or service offered by the organisation; the supply of goods/service delivered by a supplier; relationship between the organisation and the government or the activities of a competitor. Organisations also encounter internal complexity, i.e., complexity in the internal environment. Within an organisation are human actors (referred to as employees) working in a variety of functions and roles to achieve the purpose of the organisation. These human actors have individual worldviews and beliefs (individual identity and purpose), from

which they ascribe purpose to the task they carry out. The presence of individual perspectives creates complexity for managers who are saddled with challenge of aligning the interest of these human actors towards achieving the collective purpose of the organisation.

2.5.1.4 **Variety**

Ashby (1956), the cybernetician, conceptualized complexity using the notion of 'variety'. Ashby describes variety as the number of possible states of a system. Elaborating on the concept of variety, Espejo and Reyes (2011a) differentiates variety and complexity and argue that while a situation can have multiple states (variety), actors in that situation can only make a finite distinctions of states within in a context. The number of distinctions an actor could makes describes the complexity. As variety increases, it becomes exceedingly difficult to make distinctions between or sense of the possible states available. The stance taken by the authors represents an interpretivist view of complexity: that complexity is not an objective attribute of a system but a feature that is domain or context specific and indicates the ability of an observer to make distinctions about the situation or object of interest. Distinctions about a situation can change over time as new information is absorbed about that situation. New information shapes further distinctions made by the observer.

Elaborating on variety in the context of organisational complexity, Espejo and Reyes, (2011) identified the differences between individual complexity and situational complexity. Individual complexity denotes the distinctions an observer can identify relative to a situation. Situational complexity reflects the current state of a situation and the practices or actions the observer can deploy to deal with the situation. A gap or mismatch between individual complexity (the distinctions an observer can make) and situational complexity (available practices or actions that can be deployed by the observer to manage or cope with the situation) reflects the level or degree of complexity.

Like individuals, organisations have their own identity. The ability of organisations to make distinctions about their environment within specific contexts influences their purpose and identity as well as the manner in which resources, relationships and processes are organized (Espejo 2018). Organisations make distinctions across the operational and information domains. The former constitutes the domain of interaction and actions, where organisation make distinctions, learn and develop knowledge about a situation while the later refers to distinctions made about information received even when no action has been taken (Espejo 2007, 2015a, Kidd 2014). Events in the two domains are not fixed but are characterized by a dynamic stream of events, changes, and turbulence, resulting in the need

for managers in organisations to make more distinctions. As the number of distinctions grows, the degree of complexity increases as the organisation is challenged with the need to devise a decision and a point of action for each scenario identified. The effect of situational context is important (Yolles 2000, Espejo 2015b). Different contexts may require different number of distinctions to be made about a situation and the points of action an organisation can deploy. Therefore, since the environment an organisation is embedded is characterized by constant change, it is essential that organisations possess the capabilities for making distinctions. This involves a dynamic process of constitution and reconstitution, in which new distinctions and parts are made, replaced, and discarded (Lassl 2019a).

Following the review of some underlying concepts relating to organisational cybernetics, the viable system model is introduced and discussed next.

2.5.2 The Viable System Model

The Viable System Model (VSM) was developed by Stafford Beer (1979, 1981, 1984, 1985). The VSM describes the conditions essential for a system to maintain separate and independent existence, that is to be viable. This implies that the system is able to adapt to a changing environment, while maintaining its internal identity and its purpose. Stafford Beer (1979, 1985) acknowledge that organisations face perturbation and turbulence in their environment, hence, to survive, organisations require structures and functions sufficient for their long-term viability. The Viable System Model provides the language to describe, diagnose and design the management of organisations in terms their viability or a lack of it.

Central to the VSM, is the concept of Viability. The Viable System Model demonstrates and illustrates the necessary and sufficient conditions for the viability of an organization (system). In other words, a system is viable, if it can maintain its own existence and survive perturbations in its environment. Beer (1979, 1984) argues that the fundamental problem of management in organisation is the problem of ***complexity,*** which he referred to as ‘variety’. He acknowledges that organisations face perturbations, driven by forces in the environment. These perturbations and jolts could prevent on organization from maintaining its own existence. To this end, Beer (1984) defined viability as the ability and capacity of an organization or a system to maintain its own existence and identity.

VSM provides a methodological framework for a variety of purposes relating to system inquiry– functionalist (Espejo 1988, 1992a, Bowling and Espejo 1992), interpretivist (Espejo, Gill, *et al.* 1997, Tavella and Papadopoulos 2015), problem structuring (Lowe *et al.* 2016) and system diagnosis (Hildbr and Bodhanya 2015). It is mainly a system diagnosis and design tool.

Relating to complex situation and complexity, VSM has been used to understand and manage complexity engendered by the multiplicity of stakeholders' views and perspectives (Hutchinson and Warren 2002, Hoverstadt and Bowling 2005).

It is important to emphasise that the Viable System Model is underpinned by second-order cybernetics, which assumes that objective perception of the external world is impossible. By being a model of the system being regulated, the regulating system inserts itself into the model in a self-referent way that allows the agent (regulating system) to keep learning. This self-referent behaviour is the core of the second-order cybernetics, where the observing entity is subsumed within the observed (Espejo 1992).

Social agent sees the world using a model that is developed through perception and interpretation (Julia 2000, Yolles 2019b). This created world is what an agent interacts with. Applying this to complexity management, complexity is considered not as an objective feature or characteristic of a complex system but a feature of our constructed world (Julia 2000, Umpleby 2016).

In the following sub-sections, the main concepts, and principles of the Viable System Model (VSM) are described. The VSM is made up of five functions and six communication channels.

2.5.2.1 System 1- Operations (Implementation)

This consist of operating units which perform the primary activities of the organisation (Espejo 1992, 2003, Espejo *et al.* 1999b, Lowe *et al.* 2020). These operating units implement the purpose of the organisation and produces the products and services of the system.(Beer 1985, Lowe *et al.* 2020). System 1 is autonomous and has its own local environment (Lassl 2019b).

2.5.2.2 System 2 – Coordination

System 2 is responsible for coordinating the interfaces between the operating units (System 1). This includes resolving disputes, oscillations and conflicts and ensuring stability (Espejo 2013). System 2 ensures harmony among the operating units by providing a common language and standards for communication and information. Examples of coordination activities include the use of timetables, schedule, rosters, and manuals (Ríos 2012).

2.5.2.3 System 3 – Control

The main function of System 3 is cohesion and synergy (Beer 1985, Espejo and Harnden 1989a), by keeping all autonomy of system 1 while maintaining cohesion of the whole systems(Espejo and Reyes 2011). System 3 achieves this via three means.

- Resource allocation - System 3 allocate resources to operating units (system 1). It optimises the distribution of resources by creating synergy among the operating units.
- Resource accountability

System 3 plays an important role in the adaptation of an organisation via the vertical homeostasis process. The vertical homeostatic process integrates the future (outside then) and the present (here and now). System 3 communicates with system 4 and 5 to develop strategy and shape policy and communicates with Systems 1 and 2 to create cohesion and synergy via the interpretation of policy and implementation of strategy. In fact, System 3 balances control, planning and policy in a way that helps the organisation and enterprise to achieve cohesion (Hoverstadt 2010).

2.5.2.4 System 3* - Audit Function

This provides a channel for monitoring the performance of the operating units through formal and informal audit sessions. It sends performance reports to senior management (Reyes 2001).

2.5.2.5 System 4 – Intelligence and Strategy

System 4 interfaces with the wider environment. It collects, process, produce, and disseminate information about the future environment (Hoverstadt 2020). It collects information form the environment and makes predictions and forecasts about the environment as well the future demand of the system. Information collected is processed and translated into strategies necessary to adapt to the future environment and passed to System 3 (Espejo and Harnden 1989a). Some information is passed to system 5 for policy formulation, which is then passed on to system 3 (Espejo 2013). Therefore, system 4 serve as the 'brain' and 'sense' of the VSM. System 4 plays an essential role in integrating the future (strategy development and innovation) with the now (operational control function). Beer referred to the exchange between System 4 and System 3 the "organ of adaption" (Beer 1995. p. 120).

2.5.2.6 System 5 – Policy

System 5 provides directives and formulate policies and guidelines, which define the mission, identity, and values of the whole organisation (Beer 1995b). System 5 represents the normative management as it sets the overall direction of the organisation (Beer 1994).

2.5.2.7 **Communication Channels**

In addition to the functions, the VSM also consist of communication channels for information flow. The relationship between the systems within VSM is represented by communication channels and information loops, which provide a medium for interaction between the systems . These interactions support specific mechanisms and processes essential to the ability of the system to maintain viability. There are six communication channels in VSM. Each information channel serves as a communication medium between components within a VSM (Ríos 2006)

Channel 1 - Corporate Intervention channel (S1–S2–S3) – This is the corporate intervention channel (Espinosa and Walker 2013). It communicates task and responsibilities from system 3 to system 1. The assignment of tasks and responsibilities increases the eigne-variety of system 1 (Lassl 2019a)

Channel 2 - Resource Bargaining (S3–S1): This forms the central command channel between system 3 and system 1 (Beer 1995b). The channel allocate resources (time, knowledge, people), demands accountability for resource use and negotiates expected results.

Channel 3 - The inter-operational units channel: This is the squiggly line. It facilitates communication between the operational units. Strategy Development Processes (S4–S3) – Combining internal and external perspectives on feasible and desirable future developments, to support strategy development for the organisation.

Channel 4 - The Operational unit- environment channel: This is responsible for the communication between the operational units and their local environment. Horizontal homeostasis occurs here.

Channel 5 – The Coordination channel: It supports the coordination function (system 2) by connecting systems 1,2 and 3.

Channel 6 – This provides access to System 3* to conduct performance monitoring and audit.

Figure 6: The six communication channels (Lassl 2019a)

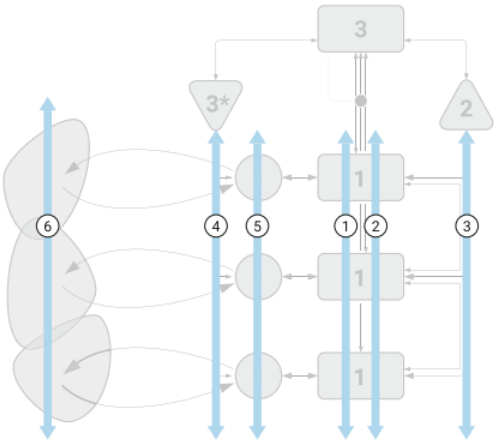
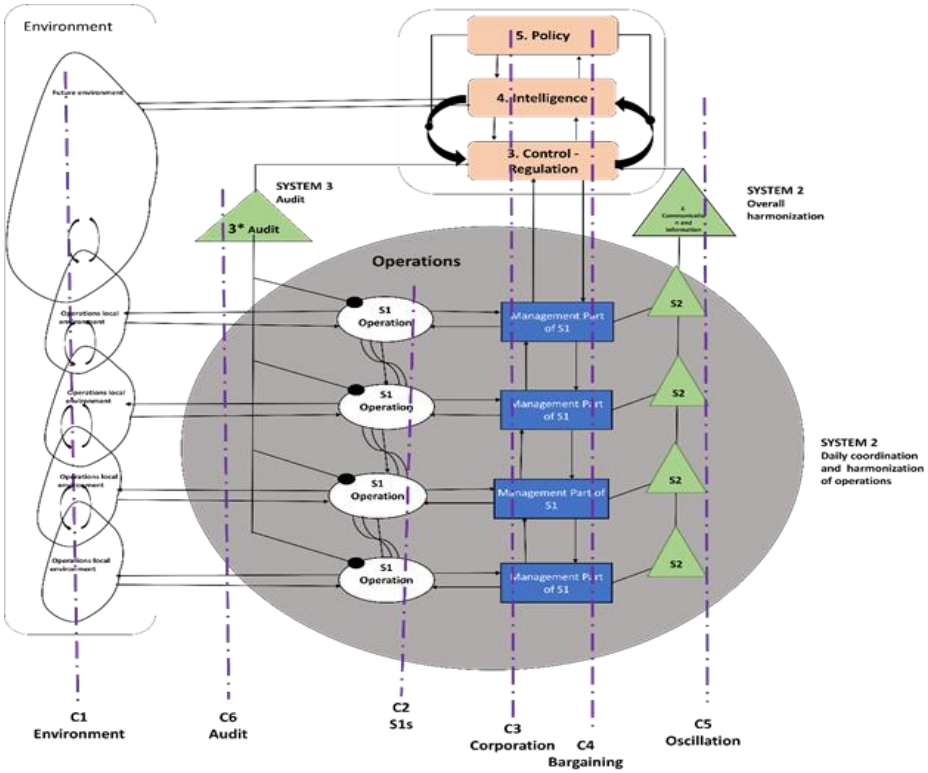


Figure 7: A Viable System Model showing Systems 1-5 and Channels 1-6



2.5.3 The Viable System Model and Complexity Management

Having described the structure of the Viable System Model, in this section, the focus shifts to the mechanism by which the VSM manages complexity (variety). The VSM integrates the five system functions and communication channels to achieve viability. The communications between the functions within the VSM play important role in driving viability. Any dysfunctionality or omission of function or communication channels would result in the system of interest unable to process variety. Hence, the VSM provides a means to observe the context in which communication occurs among individual and participants in organisations as they experience problem situations (Lassl 2019a).

The Viable System Model (Beer 1979, 1981a, 1985) is a "model for recursive organizations that balances autonomy and cohesion" (Espejo and Reyes 2011, p. 87). The concepts of recursion, autonomy and cohesion are central to the ability of viable system to self-regulate and self-organise itself by enhancing ***connectivity and*** leveraging ***structure*** to foster ***relationships*** and boost performance. These concepts alongside principles such as the Ashby's Law of Requisite Variety and variety engineering provide deeper insight into mechanisms by which viable systems are able to maintain a sperate existence, adapt to changing environment (Ríos 2012).

2.5.3.1 **Structural Recursion**

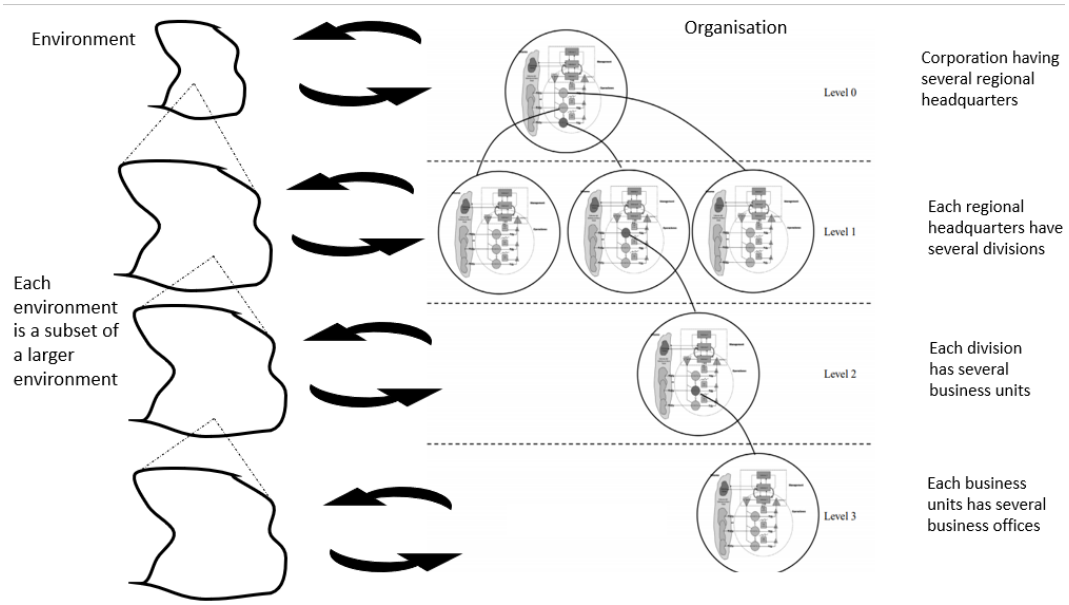
Recursive structures are viable systems within viable systems. This is akin to a Russian doll, where the removal of the outer doll reveals an inner dol, which possess the same features and properties as the outer doll. The removal of the inner doll reveals another doll, possessing the same features and properties.

Organizations are systems of multiple autonomous units, with each being a viable system (Lassl 2019b). These autonomous units carry out specific aspects of the organisation purpose by performing its primary activities. These primary activities define the organisation's performing complexity, that is, its capacity to solve a specific problem; meaning that each autonomous unit is mapped to a chunk of complexity in the environment. The chunks of environmental complexity can be defined based on customer market, product lines, technology or demographic groups (Espejo *et al.* 1999a, Espejo and Reyes 2011, Espejo 2015b, 2020). An evidence of this conceptualization of organisation at multiple recursive is the multinational cooperation that is made of division based on customer segment or regions.

Each of these divisions can be broken down further to reveal subdivisions. Each unit in this hierarchy of divisions is design to process environmental complexity.

The concept of a recursive organization suggests that a viable system is contained another viable system and each viable system possess the structure, mechanisms, and sub-system essential for its viability (Ríos 2012, Smith and Shaw 2019). Each recursive entity is maintaining its own autonomy relative to its environment and contributes to the viability of the larger viable system.

Figure 8: complex organizational structure – autonomous units at different recursive levels (adapted from Beer 1995).



Being recursive, these autonomous units are layered within another autonomous unit (see fig 8), with itself enclosing another (or multiple) autonomous unit (s), creating multiple layers and a hierarchy of viable systems (Harnden 1989, Ríos 2012). That means, each autonomous unit have a structure that gives them the capacity for meaning creation (i.e., policy making), regulation (i.e., management and services) and meaning production (i.e., implementation) (Espejo *et al.* 1999b, Lassl 2019b). Autonomous units, to maintain a separate existence in their environment, need to create their own meanings (i.e., policies) as well as implement them. Each autonomous unit as a viable system possesses self-regulatory and self-organizing capabilities since they share structural and management functions and requirements to form

an invariant structure (Espejo 2015b). Recursion permits the management of complexity locally, leaving a small residual variety for higher level components (Espejo *et al.* 1999a). The exact number of autonomous units and the level of ***structural recursion*** is determined by a range of factor including knowledge about the environment and the technologies available to cope with the environmental complexity, realise its purpose and enhance its learning capabilities.

2.5.3.2 **Autonomy**

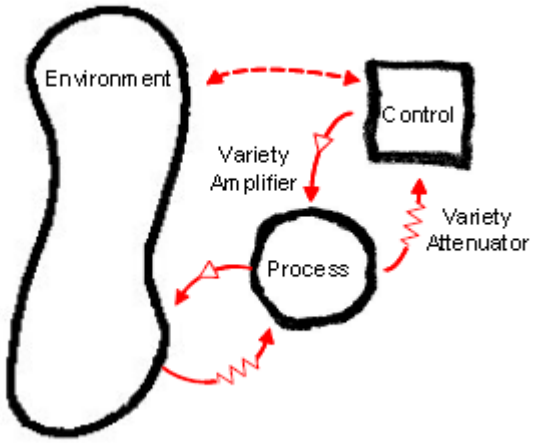
According to Beer (Beer 1984), each part of System 1, which is the operational subsystem needs to be autonomous so that it can absorb some of the variety from its local environment. By being recursive means, each subsystem exhibits the five functions of the whole system. This means, having a viable system located within each subsystem. The implication of this is each subsystem is able to take decision locally, retain their structure and coherently evolve together. Recursion fosters autonomy at local levels by granting lower levels decision-making powers, providing that the cohesion of the whole system is not undermined or compromised (Lowe *et al.* 2020). The distributed level of control within the system allows for self-organisation.

2.5.3.3 **Synergy and Cohesion**

In the event of multiple autonomous units, there is the need to achieve synergy and cohesion to achieve the collective purpose. The regulatory function is performed by the meta-system (management). To achieve viability, each autonomous unit need to achieve a balance between the primary activities and regulatory /support activities (Lassl 2019b). The primary activities are linked to the regulatory functions via communication channels and interactions . The purpose of the primary functions defines how the system does while the regulatory functions define what the system does and why it is done. The purpose for both functions must align to enable the achievement of viability. Any imbalance of purpose increases the amount and degree of variety in the system.

Achieving synergy requires regulatory capacity (Espejo and Reyes 2011). The regulatory functions must be able to determine the appropriate level and degree of regulatory capacity it wants to keep at the operating activities level (system1) or retain. Keeping too much regulatory capacity at the primary activities level leaves management (the regulatory

function) with little residual variety. The opposite leaves management with a large amount to variety to deal with.



For the autonomous unit, comprising a producing function and regulatory functions, its purpose is defined by the problem it intends to solve/address in its environment. These might include the production of products, delivering a service or delivering an outcome.

Complexity arises from the relations of the autonomous unit with its environment. Customers or suppliers in the local environment can stretch the capacity of the autonomous system via demands made on it, putting pressure on the need to come up with creative ways or adopting new capabilities to address the issues.

One way to address the increasing complexity from the environment is to match the complexity in the environment with the autonomous own variety through a process known as amplification. Granting autonomy to individual teams is one way to achieve amplification. Autonomy releases the flexibility, creativity to deal with local variety. In responding to variety in the environment, the autonomous unit might choose specific variety it would prefer to deal while ignoring other variety that bear no relations to its purpose, through a process known as attenuation. The dual process of amplification and attenuation form the basis for problem solving in the viable system model.

2.5.3.4 **The Law of Requisite Variety**

The VSM operationalizes the management of complexity through a number of mechanisms that complies with the Law of Requisite Variety. The Law of Requisite Variety was developed by Ross Ashby (1956. p. 207), which states that;

"only variety can destroy variety"

The Law of Requisite Variety was restated by Stafford Beer (1979, p. 283) to "variety absorbs variety". The Law of Requisite Variety proposes that to maintain viability, systems must be able to create a repertoire of responses, decision points and actions which match the distinctions they have created or made about the s situation (Espejo and Reyes 2011).

This is consistent with the Conant-Ashby theorem (1970), which states that

Every good regulator of a system must be a model of that system.

Both the Law of Requisite Variety and the Conant-Ashby theorem provide the underlying theories, which explain the ability of a viable system to process variety, adapt, learn and grow. In cybernetics terms, to be viable, a system has to absorb variety in its environment (Law of requisite variety). To achieve this successfully, the system (regulator) must be a model of that system being regulated (Ashby-Conant theorem). The concept of a model relates to understanding the practices and pattern of behaviour of the system being regulated.

The proliferation of variety in the external environment makes complexity in the external environment greater than variety an organisation can comprehend or control. Organisations do not know every aspect of the environment they operate in. In addition, managers do not know every aspect of their organisations as people within the organisation and their actions are unpredictable. If the organisation is to maintain viability within its environment, and the management is to steer the organisation, then as the Law of Requisite Variety suggests, the response from the organisation and its management should at least match the complexity in its environment and the variety of the management should at least match the complexity emerging from the organisation.

Against the backdrop of the above theories, the viability of an organisation is dependent on its ability to process variety (complexity). Fundamental to the ability of an organisation to process variety are the systemic functions that have been discussed in the previous section. Any deficiency or absence of any function or damage or dysfunctional information and communication channel would inhibit the ability of an organisation to process variety, balance variety across the system and impair the viability of the organisation (Espejo 2018)

To achieve viability, organisations need to possess variety (technically labelled as eigen-variety by (Schwaninger and Rios 2006)): a form of capacity to respond to complexity in their environment. The eigen-variety of an organisation may include its resources, capabilities, competences, and devices through which the system can exert regulatory control to keep output variables of the system (goals and performance of the system) within a desired range (Rosenkranz and Holten 2011). Therefore, a system embedded within a highly complex environment would require a high amount of flexibility (variety) to achieve its goals. Imbalances between the variety in a system and its environment could result in the collapse of the system (Lassl 2019a).

2.5.4 Variety Engineering: Attenuators and Amplifiers

The process of managing variety imbalance does not occur by default in organisations, they are designed through a process known as "variety engineering" (Beer pp). Variety engineering is concerned with the development of devices, mechanism and instruments known as attenuators and amplifiers, which help to regulate the equilibrium between an organisation and its environment.

Beer specified a number of strategies, comprising two processes ***attenuation***, which means to filter and reduce (attenuate) the complexity observed in the environment and ***amplification,*** which means to increase variety and response capacity to the filtered complexity in the environment.

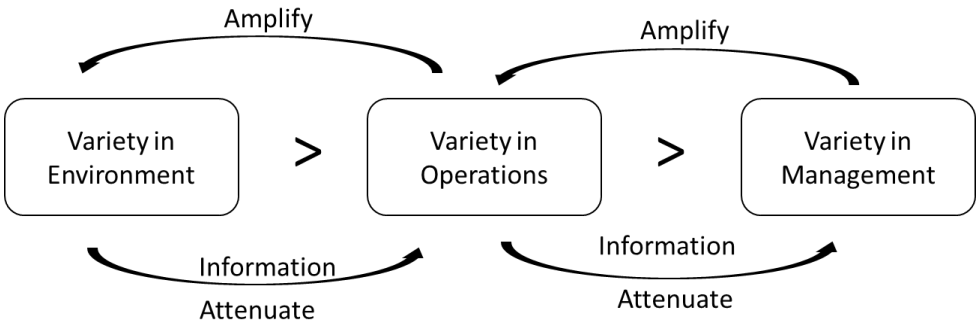
Attenuation refers to mechanisms that are designed to reduce the proliferation of complexity while amplification refers to mechanism which allows the organisation to expand its regulatory or response capacity to match the variety in the system it seeks to control(Espejo, Gill, *et al.* 1997, Schwaninger and Scheef 2016). The combination of attenuation and amplification ensures that an organisation filters and separates aspects of the environment (signals) that is essential to its purpose while ignoring aspects that are irrelevant to its identity. It allows the organisation to respond through appropriate actions to the filtered complexity in its environment. What an organisation chooses to filter and focus on is a function of its value and relevance of the aspect of the environment to the purpose of the organisation. Attenuation allows the organisation to make fewer distinctions and amplification allow organisations to amplify their own variety, through their action and response to increase their power over the environment (Rosenkranz and Holten 2011, O'Grady *et al.* 2015).

Examples of attenuators includes market research, question boards, market segmentation while amplifiers include actions such as advertisement and sales promotion. Attenuators and

amplifiers are not only essential, how they are deployed and the context and scenarios they are used are as well important. An improperly used amplifier used in an incorrect setting or way could undermine rather than boost the performance of the variables of interest.

The variety in the environment is greater than the variety of the operational systems. The variety of the operational units is greater than the variety of management. When the operational units are overwhelmed by variety, it processes the level its eigen-variety can muzzle and passes the rest as residual variety. Since the variety of management is lesser than the variety of the operational units, management must ensure that it is not overwhelmed by variety than its own eigen-variety can handle. The objective of variety engineering is to ensure the design and development of appropriate amplifiers and attenuators that can enable both management and operational units to process variety. When there is a balance of variety, equilibrium is achieved and homeostasis ensues(Rosenkranz and Holten 2011).

Figure 9: Attenuation and amplification in viable system model



Adaptation occurs when operations absorb the variety in its environment by attenuating the incoming variety and amplifies its own variety to the environment. The Management absorbs the variety from the operations by attenuating the incoming variety and amplifying its own variety in return. The attenuating and amplifying mechanisms allow the organization to process variety and achieve equilibrium relative to its environment.

This brings to fore the essential role of transducers. Transducers enable Systems sending a message (originating System) and Systems receiving messages to translate these messages into forms that can be understood. The variety of the transducers at the interface between the communication channel and System must be equal to the variety of the channel. Disparity in the variety of both entities could affect the functioning of the whole system. Time delays in the functioning of the system can be disastrous as it can lead to a system heading towards chaos and instability.

The Law of Requisite Variety recognises the place of purpose in the management of variety. The choice of attenuators, amplifiers and transducers are determined by the purpose of the system in focus. The purpose of a situation or system is expressed in some form of parameters and criteria dictates the degree and level of variety that must be muzzled to absorb or destroy variety from the environment.

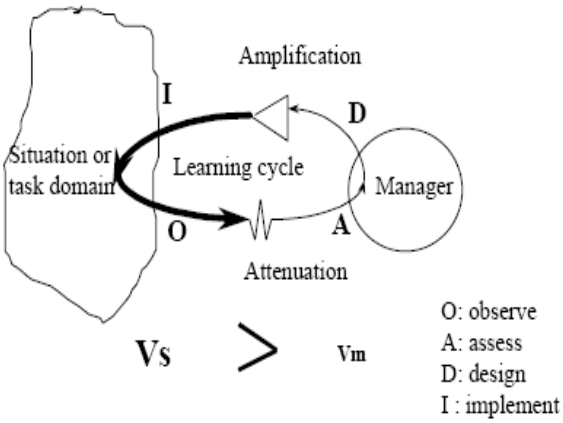
2.6 Mechanisms for Managing Complexity.

Managing complexity requires developing requisite variety that at least match the variety of the situation A system aims to control. A system is considered to possess requisite variety when its subsystems have the capabilities to amplify or attenuate variety in a way which enables it to absorb or generate as much variety it encounters (Rosenkranz and Holten 2011, O'Grady *et al.* 2015). These capabilities encapsulate its problem-solving capacity and ability to manage complexity.

Since the complexity in the environment changes, organisations do need to update its requisite variety to match the system it aims to control. Espejo (2007) argues that the management of complexity involves a learning process, where an organisation ***observes*** its environment or situation, ***assess*** the situation by making distinctions, then ***designs*** what needs to be done based on a set of performance values/purpose and then implement ***those*** decisions. In other words, managing complexity can be represented using a cybernetic model of a learning Loop between the organisation and its environment.

This is consistent with Lassl (2019) who argues that matching variety for variety to achieve equilibrium (Ashby's equilibrium) does not constitute a static process but a continuous balancing and learning process (p.16). Organisations find new balance positions as variety in the environment changes.

Figure 10: Observe-Assess-design and Implement(Espejo 2007)

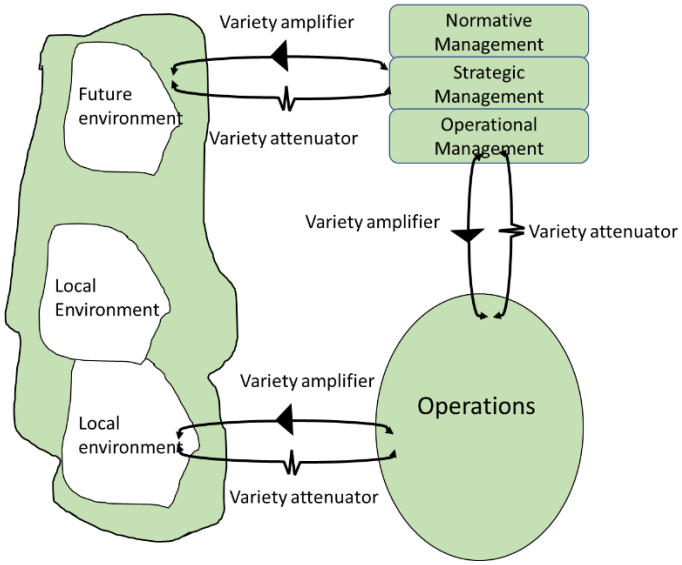


Variety engineering is essential to the achievement of homeostatic balance. Homeostasis relates to the process by which a viable system maintains a dynamic state of equilibrium. It involves the tendency of a system to resist change and maintain stability as changes in its environment occur. Homeostasis operates through negative feedback loops that counteracts changes, which alter the values of variables from their set points. Homeostasis involves identifying perturbances or changes in its environment and responding appropriately (Harnden 1989, Espinosa *et al.* 2008, Espejo 2020). Failure to achieve homeostasis results in instability of the system, which in turn would lead to system collapse. The purpose of homeostasis is not stagnation but stability, hence the need for a reference state or condition, which specifies how much change in terms of ***steering and governance*** is necessary.

Homeostasis can only occur when an organisation's variety balances with the filtered environmental variety. The matching of variety for variety as espoused by Ashby's Law of Requisite Variety does not connote a variety-for-variety match like a boxing match. Requisite variety simply denote actions and mechanisms, which help a system to self-regulate itself relative to its environment. It means processing the variety in the environment; adjusting and adapting the organisation's variety to environmental variety to maintain equilibrium or homeostasis. Attenuators and amplifiers reduce or increase organisation's eigen-variety (response capacity)

Aspects of the eigen-variety of the organisation could include knowledge, skills, resources, and routines. Examples of actions include solving a problem locally, creating a win-win situation, satisfying a requirement, providing information that is required, or modifying products, adopting new technologies, training salespeople, or boosting research and development. These actions enable the organisation to control the balance of variety between herself and the environment.

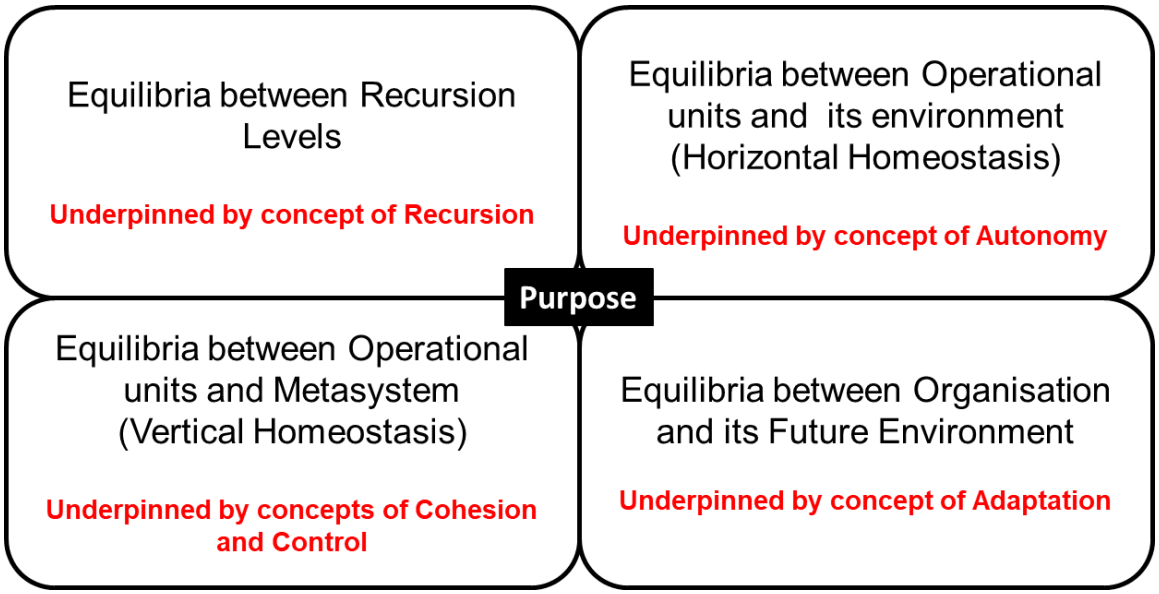
Figure 11: Variety balances between the Environment, Metasystem and Operations



In broad terms, there are four main equilibria sites within the VSM, all of which play very essential roles in complexity management. Through the mechanisms which occur at these equilibria sites, organisations can ***steer and govern*** in order to survive in constantly changing environments. Each mechanism is underpinned by a specific principle. These equilibria sites are:

- Equilibria between Recursion Levels – this is underpinned by the principle of the recursive structure of a viable organisation (Beer 1979).
- Equilibria between the operational units and its local environment – This is called Horizontal homeostasis (Ashby 1961). Horizontal Homeostasis is enhanced via the principle of autonomy.
- Equilibria between Management system and operational units – this involves balancing horizontal variety with vertical eigen-variety. This is known as the vertical homeostasis (Lassl 2019a). The mechanism is underpinned by the principle of control/cohesion.
- Equilibria between the future environment and the organisation – This is underpinned by the concept of adaptation.

Figure 12: A generic complexity management framework based on the PSS. The four main equilibria systems for steering and governing an organisation based on VSM principles.



2.6.1.1 Equilibria between Recursion Levels: Verticalization of an Organisation: Unfolding Complexity to create Recursive Units.

According to Beer (1979)

> *"every viable system contains and is contained in another viable system".*

Essential for the viability of organisation is the relationship between each recursive level and the local environment it is mapped to. Recursive organisational structure must mirror the environmental boundaries it serves, creating an interdependency that emboldens and operationalizes the strategic decision of the organization. If there is a mismatch between a recursive level and its local environmental boundaries, it would be difficult for the organisation to process variety efficiently. Recursion plays an important complexity management role through recursive problem solving (Beer 1972, Schiemenz 2002). To achieve this, there must be equilibrium across all recursion levels of the organisation (Lassl 2019a). Organisations have a far less complexity than their environments; resulting in an imbalance of variety between the organisation and its environment, if not processed would lead to instability and

then collapse. Recursion allows an organisation to bring complexity (external or internal) within its response range (Espejo *et al.* 1997). Recursion allows an organisations to map viable autonomous units to chunks of environmental complexity (Espejo and Reyes 2011, Espejo 2020).

Since the complexity in the environment is greater the complexity in an organisation, recursion ensures each viable unit (with its self-regulatory and self-organising capabilities) can deal with the complexity associated with its local environment. This way, an organisation can address the imbalance by leveraging strategies that can be employed at each recursive level to deal with complexity relevant to them and contributes to the adaptation of organisation (Schwaninger 2006b, Kontogiannis and Malakis 2012). The devolution of power across multiple recursive permits a distributed problem-solving approach to managing complexity. It encapsulates a more effective and efficient way to absorb complexity as local problems are solved locally, primary units are supported by regulatory and communication functions, operating unit at each level operate cohesively, leaving the metasystem at each level to deal with little residual variety (Espejo *et al.* 1997).

Autonomy and inter-recursive integration combine to enhance the problem-solving capacity of a recursive organisation. Autonomy allows teams to respond flexibly, and quickly without resorting to intervention from management. It drives innovative responses and creativity in solving problems associated with variety in the environment. Connections between recursive levels ensures that each level is mutually informed of activities through communication and interactions, so that varieties can be processed and balanced out. Lateral connection helps to limit bottlenecks and redundancy. Imbalances between recursive levels arising from asymmetry of information, insufficient communication and misunderstanding between recursive levels results in slow processing of varieties, delays, extra costs and poses a threat to cohesion within the organisation. Dysfunctionalities like misallocated system functions, where the metasystem of a higher recursive level performs the function of that of a lower-level results in increased costs, wastage of time and misunderstanding.

2.6.1.2 Equilibria between the Operational units and its local environment: Horizontal Homeostasis

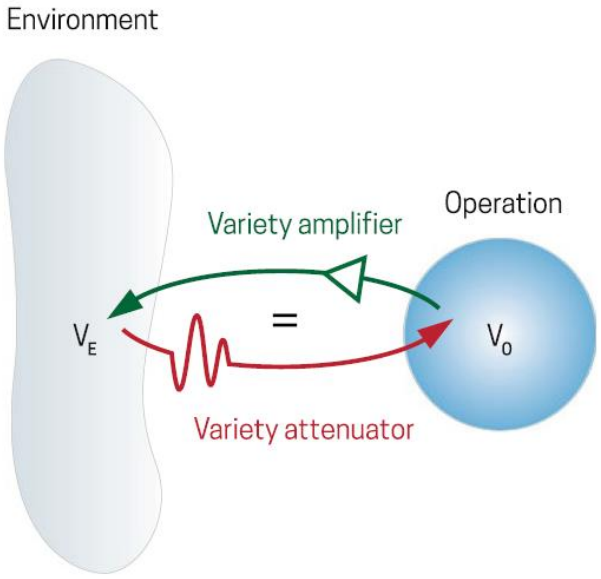
The horizontal homeostasis is the main equilibrium site for complexity management in the viable system model. At the heart of this equilibria is Ashby's Law of Requisite Variety. Horizontal homeostasis occurs when the eigen-variety of System 1 is in equilibrium with the variety of the local environment. For example, horizontal homeostasis can occur when System

1 (operating units) uses the resources, technologies, and processes to produce products that meets the requirement and quality expectation of customers/consumers.

Autonomy is pivotal to the ability of the operating systems to balancing the amount of variety between itself and its environment. System 1 interfaces with its local environment. The degree of autonomy granted to System 1 determines the flexibility at which it processes the variety in its local environment. A limited amount of flexibility might result in the creation of residual variety for the meta system to deal with. Overwhelming the metasystem with residual variety leaves them with little time to play their primary functions. The interaction between System 1 and its local environment is bi-directional. The primary market includes relevant product and customers markets. Competitors, suppliers may also be part of the market, but they do not serve as the main object of the organisation's purpose.

However, to achieve equilibrium, operations must have requisite variety – product, process and resources including skills, knowledge and competence, all capabilities required to process variety (Ríos 2010, 2012).

Figure 13:. Equilibrium between operations (system 1) and its local environment (adapted from(Beer 1995a, Lassl 2019b)



As already stated, the local environment for System 1 consists of product and consumer markets, technology, and competitors. The needs, activities and actions of these local market

participants and events in the environment influence the level and degree of complexity in the environment, which System 1 is required to deal with. In a similar fashion, System 1 can influence and shape its local environment by virtue of its actions and response.

Understanding the environment is important to achieving homeostasis. The Conant-Ashby (1970) theorem states that

> *A good regulator must be a model of what it seeks to regulate and control.*

This means that for operations to be able to regulate its local environmental variety, it must be structured and modelled in the form of its local environment. The operating units, its management and regulatory centre must have the eigen-variety to process variety. An understanding of the variety confronting the operating units allows its management to develop control model that can inform its response.

There is a bi-directional relationship between operations and the environment. The environment influences the organisation and the organisation in response or proactively shapes and influences its environment. Facing the variety from the environment, operations can raise/reduce its eigen-variety depending on the nature and size of the variety from the environment. This stance corroborates Beer's First Principle of the Organisation, which states that:

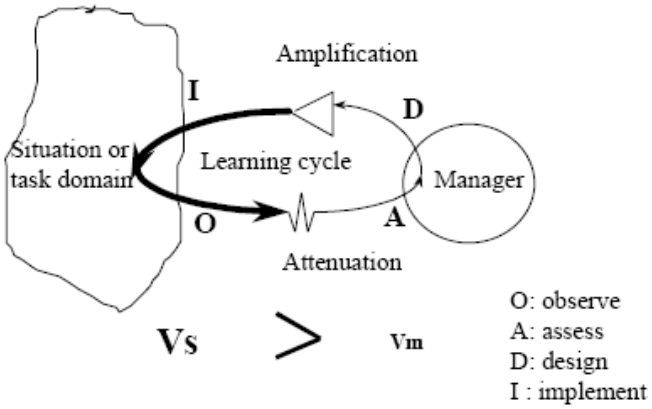
> *Managerial, operational, and environmental varieties diffusing through institutional system tend to equate (Beer 1995, p.97)*

The reciprocal relationship (adapting to each other cycle) takes place though an adjustment and equation process. Adjustment, meaning to change position relative to the environment and equate, meaning to match environmental variety to a level it can manage. The reciprocal relationship reinforces the dynamic nature of the equilibria between operations and the environment. The dynamic nature of environmental variety means the equilibrium position shift constantly; which means organisations would need to continuously adapt, learn, and acquire new competences to continuously monitor, adjust and equate (via the use of attenuators and amplifiers) the variety from its environment (Lassl 2019c, p. 46). This corroborates the fourth Principle of the Organisation, which states that:

> *The operation of the first three principles must be cyclically maintained throughout time and without hiatus or lags (Beer 1995, p.258).*

Adjustment can be described in terms of THE OADI process, meaning Observe, Assess, Design and Implement. At each stage of the OADI process, the organisation and the environment are locked in a ***mutual dynamic learning and adaptation process*** - through mutual search, sensing and learning.

Figure 14: Operations and Complexity(adapted from (Espejo 2007)



2.6.1.3 Equilibria between Management system and Operational units – Cohesion: Control, Governance, Relationship and Shared Purpose

While the autonomy of the operating units is essential to the management of complexity, the total capacity of the whole organisation to attenuate or amplify responses to complexity in its environment is a function of the synergistic communication of its multiple subsystems (Lassl 2019b). In other words, the autonomous units need to work together as a cohesive whole to ensure the collective purpose is fulfilled.

How much decentralization management wants is a function of political, social, cultural, and technological factors (Brown 1997). A centralized structure may be viable, but it could hamper the ability of the primary activities to respond flexibly to agents in their environment; hence leaving a higher amount of residual variety for management to deal with (Espejo 2020). On the opposite end, excessive autonomy threatens the realization of the collective purpose.

Hence, strategies to manage the linking of processes and functional units is vital to the viability of organisations.

Espejo and Reyes (2011) argues that to achieve cohesion, there needs to be alignment between operations (system 1) and the metasystem (management). Cohesion is aimed at aligning operating units' purpose/interest with the collective purpose. In the context of a viable system model (VSM), the term 'cohesion' does not suggest that the interests of both groups are the same but implies the implementation of the collective purpose of the organisation though the activities of the operating units, without compromising or violating the autonomy of the primary activities/operating units (ESPEJO and Raul 1989, Espejo and Reyes 2011, Lowe *et al.* 2020). It denotes the articulation of the collective purpose and organisation's purpose through the programmes and activities of the autonomous units/operating units.

According to Beer's (1995) First Axiom of Management:

> *"In a viable system the horizontal variety of the systems 1 must correspond to the vertical variety"* (Beer 1995b. Pp 217)

The horizontal variety refers to the variety of system 1, generated as system processes environmental variety. If horizontal variety is unabsorbed, it generates residual variety for management (the metasystem).

Achieving cohesion is a tough task the metasystem must manage carefully. Balancing the *control dilemma,* which involves system 3 specifying the extent of the adjustment system1 can undertake, while leaving sufficient freedom for system 1 to search, sense, learn and adapt to the environment, is a *delicate balance* that is central to the cohesion function.

The core of the complexity management process and absorbing internal complexity involves ***balancing horizontal variety and vertical eigen-variety*** to extract additional value from operation (Lassl, 2019c). In fact, as Espejo and Reyes (2011) argue, the metasystem (Systems 2-5) **encapsulate *resources and relations*** that "steers the implementation function in the direction of the collective purpose" (Espejo and Reyes 2011 p98). The regulation function includes a variety of mechanisms that ensure synergy and alignment of all operating units towards the collective purpose of the firm, through.

a. Minimising oscillation via coordination (System 2),
b. Negotiating resources and programmes to operational purpose consistent with organisational purpose.

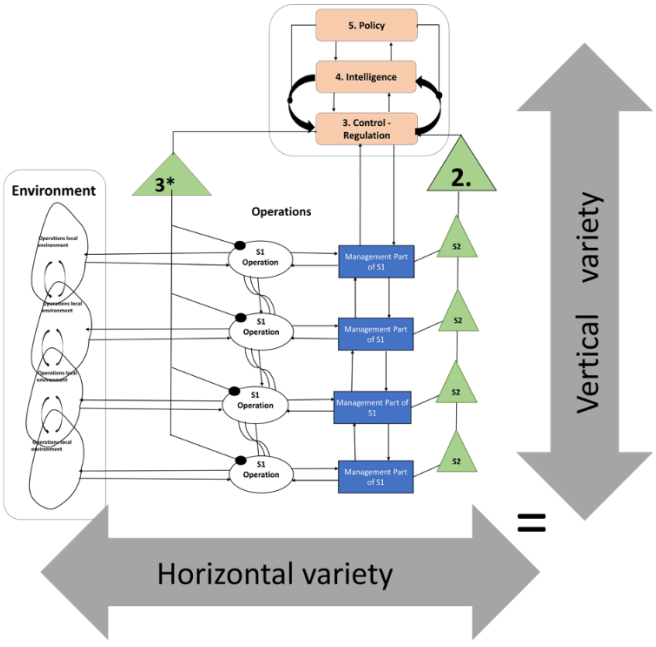
c. Monitoring and holding the operating functions accountable for resource and performance of programme in line with policy (System 1-3 and 3*) and
d. contributing to policy.

These mechanisms are designed to increase the ***flexibility*** of system 1, increase their ability (eigen-variety) to process variety from the environment, and ensure that system 1 (operations) is fully ***resourced*** (resource allocation), are ***accountable*** for resources utilized (reduces costs and enhances efficiency), are ***coordinated*** (coordinating relationship between systems, sharing resources), ***connected*** (through resources sharing which reduces costs) and protected against fluctuation in business cycles (Schwaninger 2000).

However, the metasystem must possess and provide sufficient eigen-variety ***to steer and coordinate*** to achieve the outcomes stated above. This includes possessing the appropriate level of competence, skills, knowledge, and experience of the metasystem as well as tools, instruments and resources required to balance, process and absorb variety.

If there is a mis-match between the levels of horizontal variety and vertical eigen variety, ***then cohesion and coordination problems*** will occur. In such situations, the metasystem will not be able to produce additional value and might even not keep the operational organization together. Here the viability of the organisation is threatened. On the opposite end, too much eigen-variety by the metasystem can lead to overcontrolling and overbearing system 1, which tends to undermine their responsiveness and increase conflicts.

Figure 15: The correspondence between horizontal variety and vertical eigen-variety. (adapted from Beer 1995)



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Two strategies can be exploited including reducing horizontal variety via actions such as standardizing offering (reducing customization), reducing product lines, divesting from a number of markets, limiting the number of technologies. Alternatively, management can increase its vertical requisite eigen-variety by acquiring up resources, boosting existing skills, competences, and resources within the meta system or acquiring new one in the form of consultants, experts to facilitate integration.

Specific actions are essential to maintaining the balance of variety between the operational units and the management. These include:

Establishing an Appropriate Level of Decentralization

Since the complexity in regulatory function is lower than the variety in the implementation function, the tendency for managers to be concerned about the information gap relating to the activities of the implementation function could drive the demands for information, close monitoring, and investigations. This is known as control games (Espejo and Reyes, 2011), where resource allocations are used as instruments for exercising control by managers and the asymmetry of information is used to manipulate senior management into making poor decisions. When this happens, it undermines the flexibility and capacity of the implementation function to deal with environmental demands and its internal complexity .

Management needs to find a design criterion that makes the complementarity between regulatory and primary activities effective to prevent discrepancies in purposes. Stable communication between the regulatory function and implementation function enhances the chances for articulating the activities of the implementation function with the organisation's identity. The question of the right degree of centralisation or decentralisation and synergies is a result of the organisation's intention expressed in its identity, purpose, values, and mission. It also depends on the environment the organisation is embedded in (Beer 1995)

Maximizing Coordination function

The coordination function exists to attenuate all oscillations (Beer 1995a). Oscillations occurs when operating units shares resources, serve overlapping environments, shares interfaces and connecting channels or are heterogenous. This can be achieved using rules, regulations and standards (Lassl 2019c). The coordination function (System 2) provides a

common language that facilitates lateral communications among the operating units (system 1) and thus enables local problem solving.

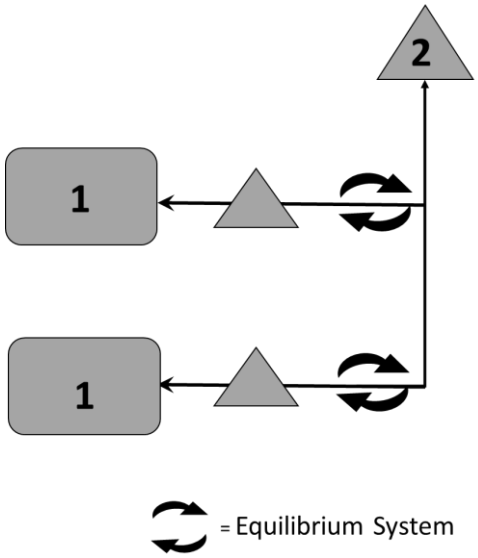
Rules limits uncertainty in behaviour and action, and hence increases autonomy. To avoid inconsistent responses from operating units, management can develop stabilizers and inter-communication structures between autonomous units. In addition, creating shared culture, sharing resources, and establishing common standards and procedures and promote mutual regulation. The stronger is the coordination function, the less residual variety is left for the attention of the cohesion function, and the more space primary activities have to assert their autonomy. Rules are not set on stones and can be amended reflect evolving situations. In the VSM, the local regulatory centres in System 2 are linked to the organisational regulatory centre through connecting channels. This is to ensure local rules align with organisational rules and they also provide spaces and processes for the revision and adaptation of the rules if necessary.

.

Preventing Conflict between Local Operational Rules and Organisational Rules (System 1-2)

Another complexity management site is the interaction between local regulatory centres in system 1 and the main coordination function at the management level. Equilibrium between these two regulatory centres must match to avoid local rules conflicting with organisational rules. Group-wide standards and rules can clash with local level rules and if not properly handled or managed could result in an increase in horizontal variety.

Figure 16: : Equilibrium between system 1 operational units (Lassl 2019a)



Equilibria between System 1 and System 3 while Negotiating Resource Allocation

The main task here is to govern the allocation, storage and use of the organisation's resources. Efficiency and effectiveness are important twin words for this function. This includes making the right investment in resources that the organisation needs, storing resources against rainy days and distributing resources were appropriately. System 3 must

- Possess sufficient eigen-variety (competent staff, technologies, effective decisions) to assess the resource needs of System 1 vis-a-vis with that of the organisation as a whole (Beer 1995b). This includes determining the right amount of eigen-variety System1 needs and in what form, and
- Able to balance the need to preserve the autonomy of system 1 while maintaining the coherence of the whole organisation. The use of exception reporting, reporting objectives and sporadic monitoring to avoid interference by management.
- Possess sufficient eigen-variety to demand responsibility and accountability on resource usage and apply appropriate penalty when non-compliance occurs. The accountability channel is important to ensure that resources are judiciously utilized, and operations take full accountability for meeting defined targets. The result is the reduction in waste and mismanagement of resources.

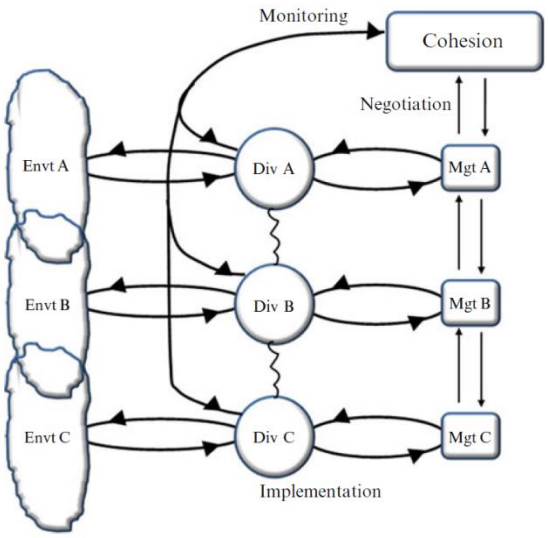
Sporadic monitoring with discretion – (System 1 and 3*)

Trust openness and transparency is essential (Espejo 2001). As part of ensuring synergy and cohesion, discretionary monitoring is needed. A way to confirm the autonomous units

assigns the same meaning to the information they have received is critical to the monitoring activity. Monitoring occurs thorough the algedonic channel that links system 1 with system 5 directly without passing through the operational management (Beer 1979). Monitoring also occurs through system 3*, the audit function, which employs a variety of transparent and open activities like unscheduled visits, collation of performance reports and informal conversations (Espejo and Reyes 2011). However, it is important that system 3 has the eigen-variety to review and assess the performance of system 1 following any of the activities stated above.

Trust is needed between the operations and regulatory functions is essential to the success of the resource allocation, accountability and monitoring activities (Espejo *et al.* 2001, Reyes 2001)

Figure 17: Monitoring mechanism (Espejo and Reyes 2011)



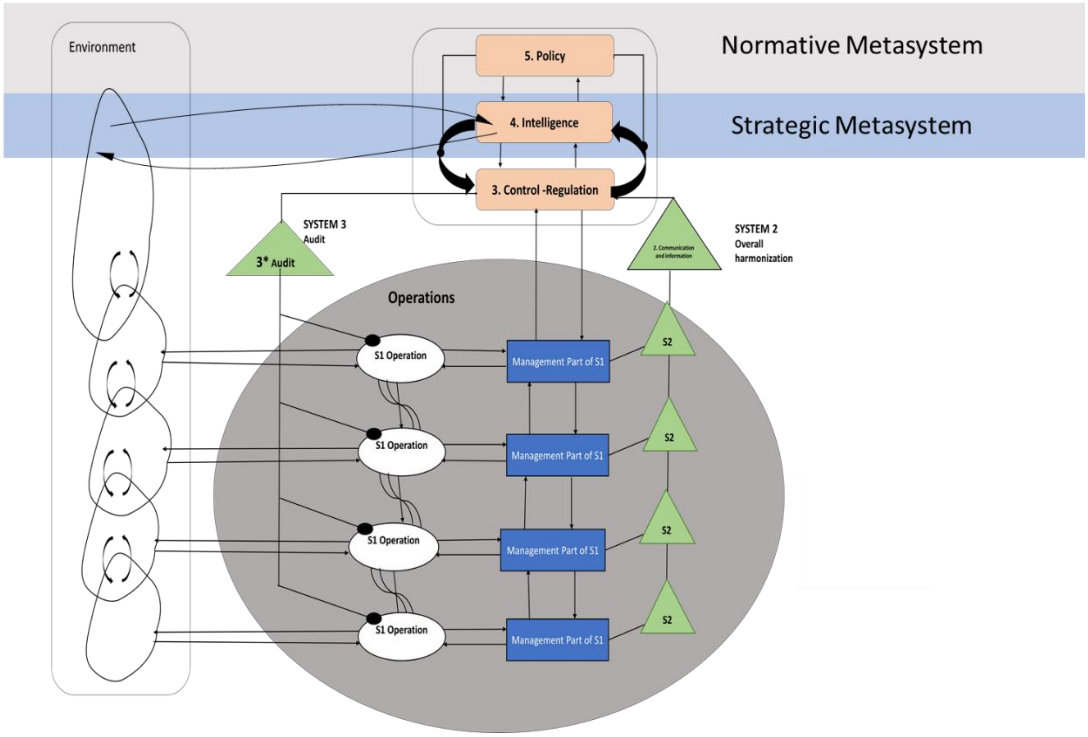
2.6.1.4 Equilibria between the Future Environment and the Organisation: Adapting and Transitioning Cohesively from Now to the Future

At the heart of this is the intelligence function (system 4), the heterotactic function, which deals with the "outside and then" (Harnden 1989). System 4 alongside system 3 and under the supervision of system 5 function manages the transition of the whole organisation from the current environment to the future environment while ensuring that the whole organization does

not get torn apart but remains sufficiently coherent, and yet, dynamic (Espjo *et al.* 1997, Hoverstadt and Bowling 2005).

In the Viable System Model (VSM), the strategic and normative metasystem (system 4 and system 5) constitute senior management functions of the metasystem (Harnden 1989, Espejo *et al.* 1997, Espejo 2015b). The strategic and normative metasystem make decisions and deliberations about the transitioning from the "now" to the "future", essentially about the future adaptation of the organisation.

Figure 18: The Strategic-Normative Metasystem



Central to the adaptation process is identifying and determining 'what to do' and having the capacity to do it against the backdrop of trends in the environment and potential changes in the environment. These activities encapsulate the adaptation processes

Adaptation Process – Equilibria Between the Operational Metasystem (Systems 3) and the Strategic-Normative meta (system 4 and system 5)

At the centre of the adaptation process are systems 3 (control and cohesion function), 4 (intelligence and strategy function) and 5 (policy, values, and norms function). System 3 connects the operational organisation and the strategic metasystem. System 3 has a double nature: involved in operational business as well as in strategic development. System 3 sees all aspects of the operational organisation, hence can help to **filter** data and information that are salient and relevant to strategy development and provides a **gateway** function to the strategic metasystem through the information it provides about the operational organisation.

System 4 (strategy and intelligence system) on the other hand scans the wider ***environment*** and the ***unknown environment***, which are the much broader environment than the local environment of system 1 (Beer 1995b). The wider environment is known and recognizable, however, the unknown environment is unpredictable and current tools and trends do not allow its prediction, as most model do not consider the trajectory of events involving human creativity, which has the potency to change the unknown future. For the ***wider future,*** simulation, scenario planning and forecasting may be useful but for the ***unknown environment,*** creativity and innovation represents the main instruments. For system 4, having the right tools and sensors is important. System 4 must have the eigen-variety to collect information, facts and ideas and identify areas of the environment to ***focus on.*** To maintain viability, organisations need to have the capacity to regularly monitor their wider environment including the future environment for any changes that could disrupt its viability.

System 5 plays an oversight role, ensuring debate are not lopsided and open debate is not stifled while contextualizing decisions within the boundaries of the norms, value, and principles of the organisation.

Since organisations are not static, but operate in time, a process of bridging the 'now' to the 'unknown and wider future' is needed to preserve the viability of the organisation (Beer 1995b). Making decisions about the future of the organisation follows an arduous process as decisions need to balance with existing capabilities, framework, identity, resources and future opportunities. Therefore, a different set of skills, competences, resources, capabilities and functions and processes are required. Stafford Beer argue that as part of processing information from the future environment, the system 4 constructs a model of what the organisation should focus on (Beer 1995b)

There are four systems involved in the adaptation process, for which specific resources and channels are essential.

1. Scanning the future environment

2. Equilibria between system 3 and 4
3. Equilibria between system 3,4 and 5
4. Equilibria between the metasystem and the operational organisation

Scanning the Environment and Creating a Model/Focus

Scanning the future and wider environment requires time and considerable effort. Fundamental to the process are ***sensors, interfaces and instruments*** used by system 4 for the collection of information and the ***simulation models*** , the mechanism system 4 uses to make sense of the information.

Lassl (2019. p.97) highlights some sensors including “memberships in trade associations, contacts to business and political networks, external consultants, trade fairs, or simply reading newspapers and the Internet”. Organisation do not only collect; they assess them to see whether they are relevant or not to the organisation. If the information is evaluated correctly and found to be relevant to the organisation, it is feedback to the organization to examine the changes that lie ahead and its possible impact on the organization.
Through the use of scenario modelling, the system 4 examines different images about the future to create a focus. Here, scenario models are instrument for increasing the eigen-variety of the organisation.

The environment in the organization needs to be palatable for new ideas and creativity; particularly when considering the unknown future. Increasing ***awareness among workers*** around spotting emerging trends and technologies, creating an environment that is conducive for different multiple ***cognitive*** perspectives, increasing proximity to spaces and hubs that promote creative thinking (research labs and universities) and ***promoting social processes*** that serve as incubation hub for innovation. The latter could be made of informal employee encounters, the formation of informal communities, formal structure within the organisations and outside organisation, online channels, and meeting platforms; all designed to minimize silo mentality.

Equilibria between Systems 3 and 4: Reconciling Now with the Future

The models and picture created by System 4 may be disparate, however, it is important that these models about the future of the organization takes into perspective the status of the operational organisation The model of the future and the relevance of the information about the future environment can only be useful when it is compared to the inside world (Lassl 2019).

By considering the internal status, the organisation can infer aspects of the model that is essential or irrelevant.

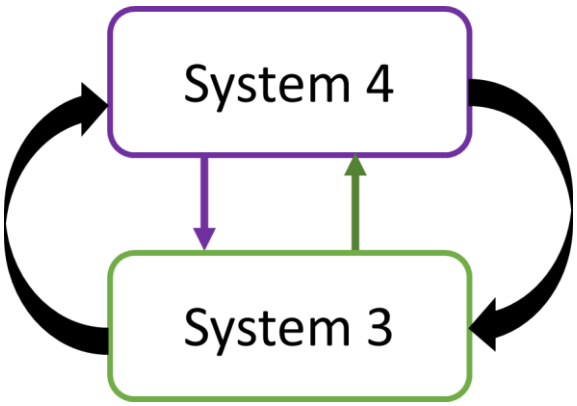
The integration of the 'outer eye' and the inner 'eye' involves a balancing act of reconciling current resources and capabilities with opportunities and threat in the future environment. It addresses the question relating to how to move from the present to the future. Stafford Beer refers to the exchange between systems 3 and 4 as

> *"the organ of adaption" (Beer 1995. p.120*)

Stafford Beer (1995) points to the importance of the interaction between system 3 and 4 in the ability of the organisation to adapt to a changing environment, hence added an additional loop with a higher capacity to manage and handle variety than the regular communication channel.

The equilibria between system 3 and system 4 is a high variety site. The balancing act between system 3 and 4 is a mutual adjustment process, which does not occur automatically. As part of the strategic change process, it requires finding the right course from a factual perspective, and where often opposing demands from different time horizons must be mediated (short term versus long-term considerations).

Figure 19: Higher variety loop between system 3 and 4



Equilibria between Systems 3, 4 and 5

To deal or manage the complexity in its environment, organisations need a balancing act; by balancing current policies with the future. Options are explored and perspectives are

reconciled. This includes having a balanced debate about strategies, debates about current capabilities, debates about opportunities in the environment, debates about matching current capabilities to opportunities in the environment. In some situations, system 3 and 4 may not have all the information to make decisions, a decision criteria and models are created to support decision making. In this sort of debate, a holistic view, anchored on a broad range of perspectives is embraced. This increases the eigen-variety of the decision-making process.

These debates are often framed within the general direction of the organisation: ***what it wants and what not, where it wants to be and what its values are.*** This is where system 5 comes in. System 5 is the highest decision-making function of the metasystem in a viable system model. It is concerned with policy, norms, and identity. System 5 provides clarity about the values, identity, and mission of the organisation. It shapes the future direction of As part of its function, system 5 develops policy: policy is fundamental and integral to the decision-making process. Since the debate between system 3 and 4 regarding the future adaptation relates to fundamental issues such as identity and purpose, system 5 is needed to give the decision-making process some sense of objectivity and independence. System 5 creates that vantage point, where all options are evaluated and explored with clarity about the goals objectives and purpose of the organisation.

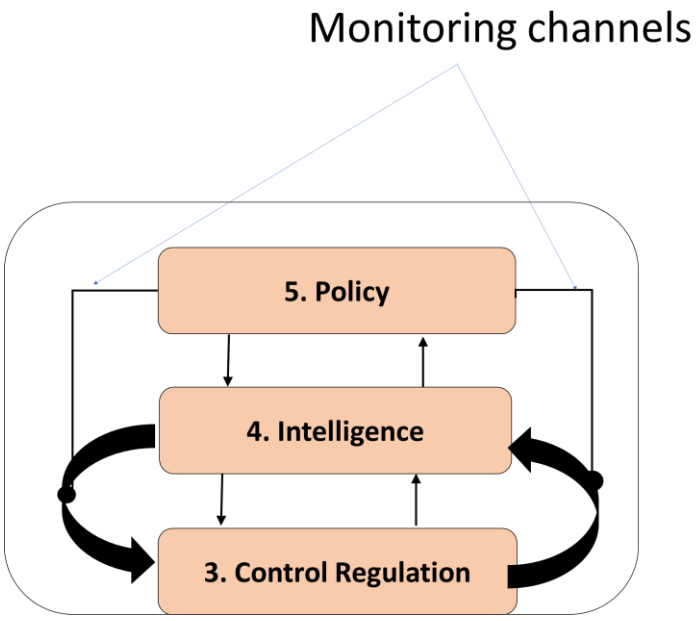
***System 5 plays a balancing role through the Communication Channels*.**

The role of the system is decision-making. In the perspective of VSM, decision criteria based on the identity, purpose and values of the organisation must be able to process the residual variety from other system. System 5 faces the challenge of finding a balance between a decision At the heart of these equilibria are communication channels, which help system 5 to

1. ensure **balance within the metasystem** by influencing system 3 and 4 through the command channels, and between itself, and the interaction between system 3 and 4. For the latter role, Stafford Beer refers to system 5 as gently guiding and promoting healthy and open debate between system 3 and 4 (Beer 1995b). Furthermore, Beer (1995b) depicted the ***oversight, simulation, advising and monitoring*** role of system 5 with the monitoring channel that interacts with the interaction between system 3 and 4. (See fig.
2. Ensure balance between the operational organisation and the metasystem. This is achieved by taking a holistic view of the organisation and its environment through information flow through the algedonic channel. Here, the objective is o respect the internal equilibria within the organisation.

3. ***Steering Open Debates through the Monitoring Channel-*** System 5 ensures that information received from system 3 and 4 are subject to open debate, objectively scrutinized, unveiling the truth, promoting a climate of debate, matching variety for variety, before they become decisions are made. System 5 entertains purposeful and balanced debates between the intelligence function system 4 (outside then) and control function system 3 (inside and now), and then steer their interaction along the lines of the organisation values. Steering is the hallmark of system 5. Steering should aim at accommodating a balanced contribution of cohesion and intelligence resources, that selecting among options gives closure to the organization. Extensive debates within the organization among different and opposing viewpoints should produce well-informed conclusions and improve the quality of policy making. Through these debates, **truth** emerges (Habermas 1995) and hidden **imbalances of varieties** is illuminated in line with Ashby's Law.

Figure 20: System 5 monitoring channel (adapted from Beer 1995b)



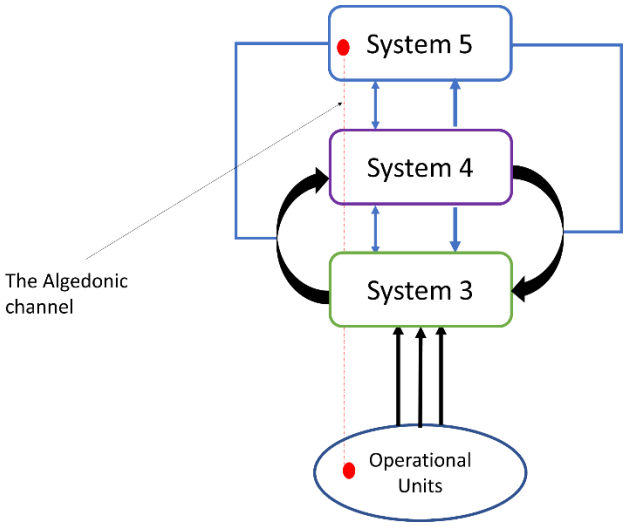
Through these channels, system 5 interacts with system 3 and 4 individuals and monitors the interactions between system 3 and 4. In the VSM perspective, system 5 does not dominate system 3 and 4 (Ríos 2012). Although, there is a central command channels from system 5 to system 3 and system 4 individually, according to Beer, system 5 serves as a guiding role,

stimulating a climate of open debates. System 5 does not have much information as available to other system function, therefore, receives information from system 3 and 4. The intelligence and cohesion functions offer alternative perspectives on shared adaptation problems.

Gaining a holistic View through the Algedonic Channel

Besides the command and monitoring channels, System 5 obtains information from system 1 through a channel known as **the Algedonic Channel**. The Algedonic channel does not take over the duties of system 3 as an information flow, reporting or command channel; rather it us used to only transmit warning signals from system 1 to 5 in case of imbalances. The channels transmit signals of pain or pleasure intermittently, without overburdening system 5 with residual-variety. Through the algedonic channel, system 5 is made aware of dangers or aspects as well as consequences or repercussions of decisions that were not foreseen or were overlooked in the decision-making process.; and advised to rethink or change them (Beer 1981a, 1995a). Dysfunctionality associated with the algedonic channel (failure to act on warning and pockets of concerns raised through the algedonic channel) results in explosive consequences in organisation; whereby generating unprocessed variety demanding for rebalancing and adjustment. Hence, the algedonic channel safeguards the organisation's viability.

Figure 21: The Algedonic channel in red(Beer 1995b)

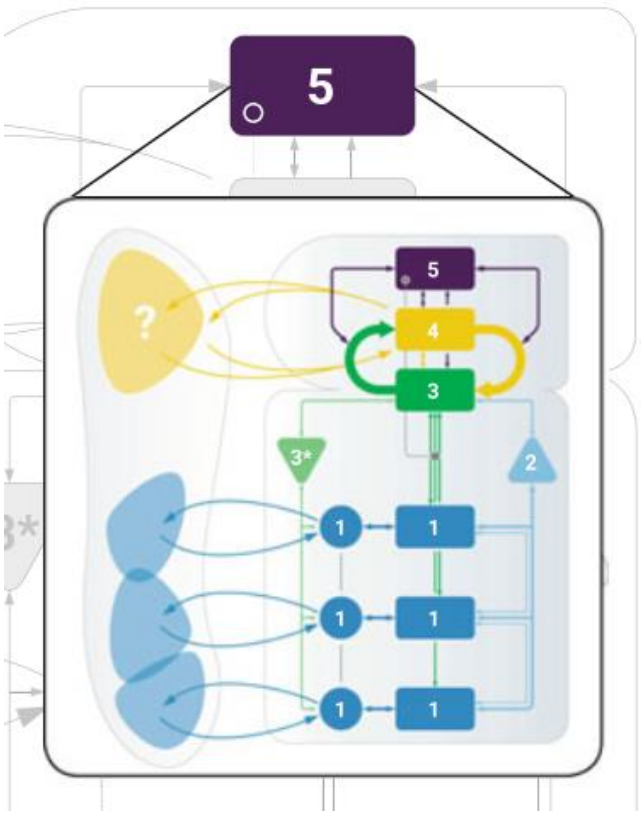


Closing the organisation

Monitoring debate between system 3 and system 4 and collecting information through the algedonic channel provides system 5 the potential to listen to and understand the organisation.

In other words, the organisation listening to itself. Listening is essential and key as a failure to listen weakens the algedonic channel, making it effective. By listening, system 5 keeps an eye on the ***stability and coherence of the organisation as well as decide factual issues in the organisation's strategy***. System 5 achieves these outcomes via its decision-making and mediation and reconciling function.

Figure 22: System 5 should be able to see the whole organisation(Beer 1995b)



2.7 Chapter Summary

The concepts of complexity and viability have been introduced and discussed. Complexity threatens the viability of a PSS. A systems-thinking approach to complexity management has been adopted as a theoretical lens to guide the exploration of complexity management strategies in companies transitioning to service-based model.

Organizational cybernetics is a systems-thinking approach. It is designed for exploring organisational complexity. The Viable System Model is based on organisational cybernetics

and systems-thinking. The principles, concepts and mechanisms underlying the viability of organisations have been explored.

These mechanisms have been mapped to a PSS using findings from the PSS literature.

Revisiting the research questions:

- How can a PSS be steered and governed to maintain viability against the backdrop of complexity in its internal and external environment?
- What are the mechanisms/conditions underlying the viability of a PSS?

Through the literature review, a research gap has been identified and a set of research questions have been formulated. Four complexity management sites in the viable system model has been developed and would be used to explore complexity management in Product Service Systems.

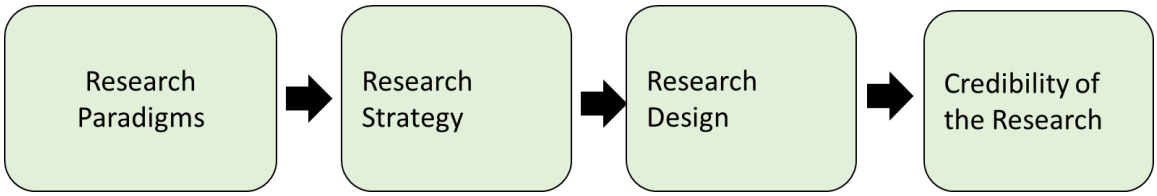
3 Chapter 3 - Methodology

3.1 Introduction

This chapter presents the methodology used to answer the research questions. Like in all research, this research is based on philosophical assumptions, beliefs, and values. These philosophical assumptions underpin the development of knowledge through the selection of appropriate methodology and methods. This section outlines the philosophical assumptions underpinning this research, the epistemological and ontological dimensions as well as the methodology and methods employed to realize the research objectives.

First, common research paradigms are reviewed and presented in section 3.2, with detail descriptions of its elements and types. Following this, the chosen paradigm, research strategy and data collection methods employed in this research are presented (section 3.3). This research employs an interpretivist paradigm, which is operationalized through an explanatory case study. Section 3.4 covers the research design. Summary chapter follows in section 3.5.

Figure 23: Research Methodology Steps



3.2 Research Paradigm: An Introduction

An important element of a research is the research paradigm (Creswell and Miller 2000, Bryman 2012). The concept of research paradigm was introduced by Kuhn (1977), who defined it as a generally accepted scientific knowledge framework, which provides scientists with problem raising and solving methods for a period. Paradigm, according to Kuhn (cited in Scott and Usher 1996, p. 15) refers to "the entire constellation of beliefs, values and techniques shared by members of a given scientific community". Lather, (1986) argues that paradigm reflects beliefs about the world we live in. The paradigm selected by a research informs the views held regarding the research as well as the choice of ontology, epistemology

and methodology (Saunders *et al.* 2012). Research paradigms consist of four elements: ontology and epistemology, methodology, and methods (Saunders *et al.* 2012).

3.2.1 Ontology

Ontological aspects of a research paradigm relate to assumptions relating to the researcher's worldview about reality (the world) and the nature of knowledge regarding reality. Ontology refers to the branch of paradigm concerned with belief about the nature of being, the world and existence (Crotty 1998). It specifies the form and nature of the world and what can be known about it. Ontology provides underlying assumptions of what constitutes reality, terms of *what it is* (Guba and Lincoln 1994). It seeks to understand "*how are things really are*" and "*how things really work*" about the phenomena or entity of interest.

There are two aspects of ontology (Saunders *et al.* 2012): objectivism and subjectivism. Objectivism is a philosophical assumption which asserts that there is a social reality, an existence that is independent of human conceptions an interpretation (Bryman 2012). Objectivism emphasizes the structural aspects of organizations. Subjectivism posit hat social phenomena are created from the subjective perceptions and experiences of social actors. Reality is the constructed through conditioning, views, interaction, and meanings (Saunders 2003).

3.2.2 Epistemology

Epistemology is concerned with the nature of knowledge (Saunders *et al.* 2012) and ways of enquiring into the social and natural worlds (Easterby-Smith *et al.* 2013)It is branch of paradigm that is concerned with how knowledge about a phenomenon (reality/existence) is created and communicated (Guba and Lincoln 1994). Epistemology brings to the fore the nature of the relationship between the researcher and what can be known about the phenomena of interest (Guba and Lincoln 1994). For example. If an ontological stance considers a real world that exist, epistemology is concerned about the means to understand and know that existence (Crotty 1998).

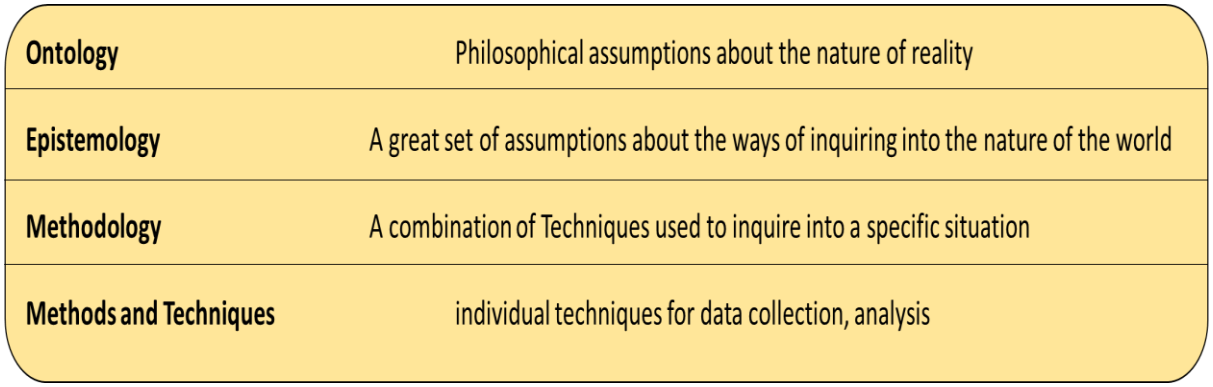
3.2.3 Research Methodology and Method

A research methodology is a systematic way of solving a research problem. It expresses the plan, strategy, actions, and decision behind the selection of methods used to inquire into a specific phenomenon of interest (Easterby-Smith *et al.* 2013). Research methodology comprises the means of linking methods to research objectives (Creswell 2003). It relates to what, where, from where and how data is collected and analysed. Methodology is the path taken to answer the questions of finding out what is believed to exist or known (Guba and Lincoln 1994, Crotty 1998). Research methodologies focus on the question of "why" – why the method? Why the technique, why sample size? Why the research problem has been designed the way it is? Why a data analysis tool has been chosen (Kothari 2004).

Methodology does not exist on its own, it stems from ontological and epistemology choices. For example, an **ontology** that considers reality as "real" and non-subjective, would consider an **epistemological** stance that considers knowledge via an objective standpoint. This then informs a methodology that is characterized by methods (whether qualitative or quantitative) that are objective, verifiable, generalizable in order to get closer to that real reality (Guba and Lincoln 1994). Holden and Lynch (2006) argue that the choice of methodology and methods should be related and linked to the philosophical position of the researcher, the latter being determined by the research questions the researcher seeks to answer.

A research method is a research tool, technique used in research. They refer to specific individual techniques for data collection, data analysis (Creswell 2003, Easterby-Smith *et al.* 2013). Research methods include interviews, questionnaire, survey.

Figure 24: 26 Ontology, epistemology, methodology and methods(Easterby-Smith et al. 2013)



Guba and Lincoln (1994) differentiated between three paradigms: positivist, post-positivist, and critical theory. Gephardt (1999) categorized research paradigm into three distinct classes: positivism, interpretivism and critical postmodernism. Saunders, (2003) distinguishes between positivism, realism, interpretivism and pragmatism. These are explained below:

3.2.3.1 **Positivism:**

Positivism is often considered as the scientific or natural science approach; however, positivism is also applied in the social sciences in the study of social entities and phenomena (Creswell and Poth 2017). Creswell (2003) argues that positivism is referred to by different names: positivist research, the scientific approach or post-positivism.

Positivism in terms of ontology, assumes the physical/social world is “real” (Crotty 1998). It holds the view that objects have an existence independent of the inquirer (Cohen 2002); that is, reality exist independent of the values and opinions of the researcher, who acts as an objective analyst (Žukauskas *et al.* 2018). Positivism believes reality can be measured through objective methods rather than been subjectively inferred through values, sensation, and intuition (Easterby-Smith *et al.* 2013).

In terms of epistemology, positivism believes that knowledge is significant if it is based on objective observation of the external reality. When positivism is applied to social sciences, it assumes that social structures are governed by natural laws, which are observable, measurable and are value neutral (Burbules and Philips 2000). According to Burrell and Morgan (2001), to understand those laws or patterns of regularities, a researcher observes objectively the phenomenon of interest to identify causal forces underlying the behaviour of the social phenomena. By testing, verification and experimentation, the researcher can understand those laws or regularities (Bryman 2012).

Positivism stems from the natural sciences and when applied to the social science, they are designed to confirm or refute hypothesis through experimentation (Saunders 2003). Here the observed entity or object is separate and independent of the researcher (observer) (Bryman 2012). In practice, positivism approach to research can begin with a theory, followed by the collection of data to test supports or refutes the theory and then makes revisions before res-testing is done (Ortiz, DanielGreene 2007, Saunders *et al.* 2012).

Methods commonly used in the positivist approach include experiments, observations, standardized tests, close ended questionnaire that seeks predictions and generalisations. (Saunders *et al.* 2012). Analysis techniques include descriptive and inferential statistics. Since

positivists uncover truth through empirical means, data collection and analysis methods are designed to systematize knowledge generation through an objective quantification of variables that is detached from the researcher's but aimed at enhancing the description of parameters and their relationships.

According to the positivist approach, if reality is objective and independent of social construction, then epistemologically, knowledge is either false or true, yes, or no, right or wrong (Creswell 2007). Hence, the absoluteness of the knowledge emerging from a positivist claim to knowledge has been questioned and criticized. Creswell (2007) argues that the positivist approach is reductionist; it reduces every phenomenon of interest into bits of variables and ideas to test, verify and experiment with. Furthermore, positivist approach assumes all social phenomena can be understood through a cause-and-effect lens, in essence deterministic. However, Berger and Luckmann (1991) criticised the use of the positivist approach in sociology. Johnson and Duberley (2011) argue that in explaining human behaviour, the positivist approach does not acknowledge the role of the metaphysical form of knowledge, the knowledge between phenomena and the observer. These criticisms alongside others made by other researchers in the social sciences such as (Bryman & Bell 2015), (Miles and Huberman 1994) and (Creswell 2003a) resulted in the emergence of the interpretivist paradigm.

3.2.3.2 **Interpretivism**

The interpretivist paradigms, also known as the constructivist paradigm, originated out of the paradigm of Edmund Husserl's phenomenology and Wilhelm Dilthey's study of hermeneutics (Mertens, 2005, p.12 citing Eichelberger, 1989). Interpretivist/constructivist approaches to research understand "the world of human experience" (Cohen & Manion, 1994, p.36), suggesting that "reality is socially constructed" (Mertens, 2005, p.12).

In terms of ontology, interpretivism assumes that there is no objective reality but a subjective one and the knowledge about reality reside within individuals, through a construction process that seek meanings around their own experiences about the world (Ortiz, DanielGreene 2007). In others, reality does not exist out there, but are created through experiences and their interaction with the world around them (Saunders 2003).

These experiences are formed through socio-interaction with the environment, others around us and cultural and historical norms (Creswell 2003a). Access to the world is through social

constructions and human interpretations assigned to events or phenomena (Bryman 2012). Therefore, in terms of epistemology, interpretivism argues there is no single or correct route to knowledge and advances a plurality of worldviews as opposed to a single objective view inherent in positivism (Myers 2009).

According to Walsham (1993), in the worldview of interpretivists, theories are not judged based on how right or wrong they are but rather based on how interesting they are to the researcher. The place of context is essential as meanings attached to reality is positioned within the context where the experience occurs. Creswell (1998) contends that a phenomenological study describes the meaning of the lived experiences for several individuals about a concept or the phenomenon (p. 51). In the human sphere, this normally translates into gathering "deep" information and perceptions through inductive qualitative research methods such as interviews and observation, representing this information and these perceptions from the perspective of the research participants (Lester, 1999). Guba and Lincoln (1994) argues that the interpretivist approach does not seek for objectivity like the positivist philosophy; rather they attempt to unwrap the participant's or individual's value system, belief system and the subjectivity in the construction of the individual world.

Walsham (1995b) presents three different uses of theory in interpretive case studies: theory guiding the design and collection of data; theory as an iterative process of data collection and analysis; and theory as an outcome of a case study.

Interpretivists use meaning-oriented methodologies (as opposed to measurement-oriented methodologies commonly used by the positivists) such as interviewing, workshops and focal groups that are underpinned by subjective relations between the researcher and participants in the research (Saunders *et al.* 2012). The goal is to capture and explain the constructed reality expressed reality constructed through language and identify subjective meanings and factors driving social action. Inductive research approaches are heavily used in research underpinned by interpretivist paradigm, due to their ability to develop new theories from meanings, patterns identified in data collected. Research method commonly used include observation of phenomena of interest and draw inferences (Miles and Huberman 1994).

Table 2: Difference between interpretivism and positivism

Assumptions	Interpretivism	Positivism
Ontology	Reality and existence is subjective and interpreted by the researcher	There is an objective reality and existence devoid of researcher's views
Epistemology	Knowledge is assumed via construction of person live experience	Knowledge is assumed as objective and independent of the researcher
Focus of research	Subjective meaning is sought	Objectivity in measurement
View on causality	Multiple simultaneous causes	Real cause exist
Type of data	Qualitative	Quantitative and qualitative
Data collection method	Observation, interviewing, focal group	Observation, interview, survey
Data Analysis	Hermeneutics, phenomenology	Content analysis, statistics
Validity	Defensive knowledge claims	Certainty, knowledge claims
Subject/researcher relationship	Interactive and cooperative	Separation
Knowledge generated	Idiographic, time bound, context dependent	Time free, context –independent

3.2.3.3 **Realism:**

The philosophical position of realism proposes a reality that is independent of the human mind, a reality that exist but our grasp of that reality is subject to what is captured by our senses (Bhaskar 2013). Realism is categorised into direct realism and critical realism. The former states that what the human mind perceives and experience through the senses portrays the world, while the latter describes the sensations and images as what the human mind perceives and not the real world directly. According to critical theorist like Bhaskar (2013), humans can only understand reality when we understand the social structures that underlie the phenomenon of interest, which they are trying to understand. Therefore, Dobson (1999) argued that knowledge of reality is a product of social conditioning and cannot be understood independently of social actors involved in the knowledge derivation process.

3.2.3.4 **Pragmatism**

Pragmatism derives from the work of Peirce, James, Mead and Dewey (Saunders *et al.* 2012) Pragmatism is not committed to any of the paradigms discussed above. Pragmatism focuses on the problem rather than antecedent condition. It emphasizes "what works i.e. solution, method, action, consequences (Easterby-Smith *et al.* 2012). Since the problem situation takes a centre stage, researchers use all kinds of approach to understand the problem. Howe (1988) argues that pragmatism helped to answer the debate around the incompatibility between qualitative and quantitative methods. Pragmatism allows researchers to study what interest them and in different ways they find appropriate using mixed methods and pluralistic approaches to obtain knowledge about a problem. Pragmatist researchers employ both qualitative and quantitative assumptions and methods when they engage with research (Ortiz, DanielGreene 2007). They choose multiple techniques and methods to collecting and analysing data. Their aim is to understand and obtain the best answer to a given problem rather than subscribing to the dual ontology of mind and reality (Saunders et al. 2012).

A diagrammatic sphere depicting all four elements of research paradigm are shown in the ring below.

Table 3: Comparison of the four-research paradigm(Saunders et al. 2012)

	Positivism	Realism	Interpretivism	Pragmatism
Ontology: *the researcher's view of the nature of reality or being*	External, objective and independent of social actors	Is objective. Exists independently of human thoughts and beliefs or knowledge of their existence (realist), but is interpreted through social conditioning (critical realist)	Socially constructed, subjective, may change, multiple	External, multiple, view chosen to best enable answering of research question
Epistemology: *the researcher's view regarding what constitutes acceptable knowledge*	Only observable phenomena can provide credible data, facts. Focus on causality and law like generalisations, reducing phenomena to simplest elements	Observable phenomena provide credible data, facts. Insufficient data means inaccuracies in sensations (direct realism). Alternatively, phenomena create sensations which are open to misinterpretation (critical realism). Focus on explaining within a context or contexts	Subjective meanings and social phenomena. Focus upon the details of situation, a reality behind these details, subjective meanings motivating actions	Either or both observable phenomena and subjective meanings can provide acceptable knowledge dependent upon the research question. Focus on practical applied research, integrating different perspectives to help interpret the data
Axiology: *the researcher's view of the role of values in research*	Research is undertaken in a value-free way, the researcher is independent of the data and maintains an objective stance	Research is value laden; the researcher is biased by world views, cultural experiences and upbringing. These will impact on the research	Research is value bound, the researcher is part of what is being researched, cannot be separated and so will be subjective	Values play a large role in interpreting results, the researcher adopting both objective and subjective points of view
Data collection techniques most often used	Highly structured, large samples, measurement, quantitative, but can use qualitative	Methods chosen must fit the subject matter, quantitative or qualitative	Small samples, in-depth investigations, qualitative	Mixed or multiple method designs, quantitative and qualitative

3.2.4 Research Paradigm adopted in this Research.

Complexity science is associated with paradigm diversity (Cooksey 2001). That means multiple worldviews with its accompanying theoretical and methodological assumptions and associations are acceptable. Importantly, any choice of paradigm is determined by the context and problem of interest. According to Cooksey, (2001), what needs and must be done is to contextualize each paradigm and worldview into the wider scheme of things by asking which paradigm is fit for a particular problem rather "than forcing a problem to fit a paradigm" (p. 82)

In the management sciences, engineering and business and management disciplines, the positivist research tradition dominates (Guba and Lincoln 1994, Crotty 1998, Anderson *et al.* 2006). The system engineering school of thought considers complexity as a property of a system and an objective reality. To grasp reality, system engineering espouses positivism, where there is a clear demarcation between the subject and the object been observed. To this school of thought, there is only one finite state or behaviour.

The nature of knowledge is assumed to be true only and if only it is objective, obtained, and analysed via thoroughly verified scientific methods. To that end, the methodological stance associated with system engineering school of thought is characterized by mathematical formulations, algorithms, and procedure (including simulation techniques), aimed at quantifying complexity or/and uncertainty or gaining insight into the order underlying cause and effect relationships between quantitative variables. Typical algorithms would include stochastic/deterministic differential equations that allow "clear predictions to be made and optimization carried out" (Allen 2001, p. 24). Broadly, it involves a priori theorization and setting up hypothesis regarding the phenomenon of interest, deductive reasoning, statistical analysis and modelling, measurement and quantification, control and prediction or generalization of behaviour.

However, in the social sciences, where human actors, their relations, and heterogeneous behaviour within contexts are object of enquiry and study, understanding complexity through the perspective of people confronting a problem becomes the norm. In this perspective, the phenomenon of interest (reality) is subjective and socially negotiated from an interpretivist perspective using metaphors and words that conveys the subject's perspective about the phenomenon. Qualitative methods and inductive methods of analysis is common.

Supporting the subjective nature of complexity, Authors like Cilliers (Cilliers 1998, 2000, 2005, Richardson *et al.* 2000, Heylighen *et al.* 2007) point to the limitations of human observer to grasp the totality of a complex system or complex phenomena. The analogy of the map and territory is operative here. Models of a complex scenario or a problem (territory) are a mental image (map) of the territory. Therefore, attempts to simplify the world or reality through models represents a reduced representation of that reality. An interpretive epistemology would seek to build on the various account of realities gathered through interaction with or observation of participants.

3.2.5 Justification of Choice of Paradigm

In his system of systems methodologies, Jackson (Jackson and Keys 1984, Flood and Jackson 1991a, 1991b, Jackson 1991b, 1994, 2001, 2003) classified the viable system model has a functionalist approach; where systems appear as objective constructions of reality independent of observers (Jackson 2020), meaning a system of an organisation is assumed to be real world ontology (Hoverstadt and Bowling 2005, Hoverstadt 2010).

However, recent studies point to the possibility of taking an entirely interpretivist approach within a Viable System Model (Espinosa and Walker 2013, Preece *et al.* 2013, Lowe *et al.* 2020), In interpretivist approach within a viable system model (VSM) means regarding an organisation as system of multiple perceptions of reality (Jackson 2002). This view considers a system as epistemological constructs (knowledge vehicle) as opposed to real-world entities (Hoverstadt and Bowling 2005, Hoverstadt 2010).

This research follows an interpretivist paradigm. In this research, the Viable System Model developed by (Beer 1979, 1985) is used as a theoretical lens and a guiding framework to explore and analyse complexity management in PSS system (Batista *et al.* 2017). Beer (1981) acknowledges that complexity is an attribute of the observer; the relationship between an object or situation and the observer (Espejo and Reyes 2011).

As a model we are reminded that the VSM is "***neither true nor false: it is more or less useful***" (Beer, 1985, p. 2) offering "***a [...] set of abstractions as a working tool"*** (Beer, 1985, p. 11). Implicit in this statement is that in any situation the model has a user with a purpose behind it. Thus, the VSM is not an objective model of reality, but a model that reflects peoples' participation and perceptions of how the relevant organisational system of interest functions. Indeed, Beer (1985: 2) states "you are not determining absolute facts: you are establishing conventions… a model is neither true nor false: it is more or less useful". The VSM can be

viewed as a ‘generative mechanism’ (Harnden, 1989), an epistemological device (Espejo, 1996), a meta-language (Espinosa, 2015, Espinosa et al., 2008) and a boundary object (Harwood, 2009) to elicit, organise and communicate knowledge about the complexity of social organisation.

An interpretivist view of complexity and complexity management is rooted in the second order cybernetics famously termed “the cybernetics of observing systems” and attributed to the work of Von Foerster (von Foerster 1979) and Maturana and Verela (Maturana and Varela 1980). Second order cybernetics differ from first order cybernetics in that the observer is part of the system observed and the properties and features of the object of interest reside with the individual and expressed through language. While first order cybernetics focus on the observed object, second order cybernetics focus on the observing. Second order cybernetics recognises that models are not representation of a passive system separate from the observer (like in first order cybernetics) but cognitive constructs to capture aspects of the observed object relevant to the purpose for which model has been created. Therefore, knowledge of systems is mediated by individual subjective perception, and interaction with the observed object.

When we apply this concept to the social world, this viability is referencing organised human activity and conceptualisation of how collectives of lower level viable organisations produce (not serve) the organisations in which they are embedded (Espejo and Reyes 2011, Badinelli *et al.* 2012)

Therefore, organisational complexity is a function of cognition – the purpose and objective assigned to a situation, the ability of human actors to make distinctions in a specific domain in which they interact. The number of distinctions informs the mechanisms adopted to manage a situation. Like Espejo and Reyes (2011. p.47) argue, “understanding the self-organisation and self-regulating principles and using them to approach problem situation from the perspectives of individuals…. is at the core if managing complexity”.

In this research, human actors (participants) are treated like black boxes. Here, a black box is used as a cognitive instrument, which takes in input and releases output. We consider the participant as an observer within an organisation, but also producing the organisation through their patterns of interaction, perceptions, and conversation. Epistemologically, the perceptions, meanings, and subjective interpretations of different participants are regarded as

valid knowledge and version of reality (Saunders *et al.* 2012).These perceptions and shared meanings of experiences make up the system of interest; a cognitive and symbolic entity of interactions between different perceptions. The emergent system is different for every individual and participant over time since the subjective experiences of every participant and meaning each participant assign to those experiences changes over time .

Typical of interpretivist philosophy, reality is assumed from and influenced by the perspectives of the participants of this research (expressed through verbal narrative and written texts) as well as the interpretation of the researcher while assessing the cases. Examples of studies where interpretivist philosophy have been used for the diagnosis, design and description of a system based on the Viable System Model include the diagnosis of IT governance by (Huygh and De Haes 2018, 2019), exploring relationship mechanisms development of co-capability by actors involved in the delivery of outcomes in an outcome-based contract (Batista *et al.* 2017).

3.3 Research Approach

According to Saunders *et al.* (2012), a research approach describes the overall plan for a research. Research approach encapsulates both data collection and data analysis. Creswell and Creswell (2017) identify three research approaches: qualitative, quantitative, and mixed methods. Multiple scholars and researchers like Maxwell (2014), Corbetta (2003) and Saunders (2003) highlight the differences between qualitative and quantitative research by the nature of data collected.

3.3.1 Qualitative Research Approach

Qualitative research is characterised by the use of words using semi-structured or unstructured data collection methods like interviews, focal groups: data collected from the settings of the participants. Hence, qualitative research is associated with data analysis method include the use of content analysis, thematic analysis, sentimental analysis The aim of qualitative research is to derive meanings and interpretations individual assign to their experiences, problems interactions with the world and objects (Lawrence Neuman 2014, Maxwell 2014). As a result, qualitative research is commonly associated with inductive research approach, which involves the search for patterns from data, the generation of explanation for those patterns and developing theories from the explanation (Guba and Lincoln 1994, Corbetta 2003).

3.3.2 Quantitative Research Approach

Quantitative research approach is often employed to test theories (deductive research) using data collection methods like observation, experimentation, and survey (Saunders *et al.* 2012). The type of data used are hard, objective and standardized. Quantitative research tends to align with the positivist philosophy, which espouses that reality is objective and independent of the researcher's opinion of perception (Guba and Lincoln 1994) . Therefore, data collection and data analysis method employed in quantitative research must seem to be objective, devoid of bias and characterised by being able to be generalized and replicated (Creswell 2003a).

3.3.3 Mixed Research Approach

Mixed methods research approach combines both qualitative and quantitative research approaches. The core tenet of the mixed-method approach is that the combination of both quantitative and qualitative provides a complete image or generates deeper insight of the research problem than if either of the approaches were used alone. Mixed method approach is commonly associated with the pragmatic worldview and employed a wide variety of research methods in the collection and analysis of both quantitative and qualitative data (Creswell and Creswell 2017).

The differences between these research approaches are shown in the table below.

Table 4: Differences between research approaches

Tend to or Typically . . .	Qualitative Approaches	Quantitative Approaches	Mixed Methods Approaches
• Use these philosophical assumptions • Employ these strategies of inquiry	• Constructivist/ transformative knowledge claims • Phenomenology, grounded theory, ethnography, case study, and narrative	• Postpositivist knowledge claims • Surveys and experiments	• Pragmatic knowledge claims • Sequential, concurrent, and transformative
• Employ these methods	• Open-ended questions, emerging approaches, text or image data	• Closed-ended questions, predetermined approaches, numeric data	• Both open- and closed-ended questions, both emerging and predetermined approaches, and both quantitative and qualitative data and analysis
• Use these practices of research as the researcher	• Positions him- or herself • Collects participant meanings • Focuses on a single concept or phenomenon • Brings personal values into the study • Studies the context or setting of participants • Validates the accuracy of findings • Makes interpretations of the data • Creates an agenda for change or reform • Collaborates with the participants	• Tests or verifies theories or explanations • Identifies variables to study • Relates variables in questions or hypotheses • Uses standards of validity and reliability • Observes and measures information numerically • Uses unbiased approaches • Employs statistical procedures	• Collects both quantitative and qualitative data • Develops a rationale for mixing • Integrates the data at different stages of inquiry • Presents visual pictures of the procedures in the study • Employs the practices of both qualitative and quantitative research

3.3.4 Research Approach Selected in this Research.

In this research, an interpretivist perspective of complexity and viable system model is employed. This means, reality is assumed from the social construction and subjective meanings made by participants as they interact with the world, situation, objects and things (Crotty 1998, Creswell 2003a). Since this research seeks to understand complexity management through the views of participants expressed through language and words, a qualitative research approach is selected. A qualitative research approach allows the researcher to employ research methods such as case study, which allows the researcher to study the context of participants as they interact and engage with others actors within a PSS, collect rich and deep information necessary to identify the five systemic functions and communication channels, as well as underlying mechanisms and operators employed by PSS providers to manage complexity.

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3.4 Research Strategy

Research strategies provide specific direction in the design of the research and research approach. Saunders, Lewis and Thornhill, (2012) identified 7 strategies: experiment, survey, case study, action research, grounded theory, ethnography and archival research.

3.4.1 Experiment Strategy

Commonly used research in the sciences. This includes complex experiments and pseudo experiments, which involves many variables and elaborate structural equation models. Quasi-experiments use non-randomised design (Keppel, 2001). The aim is to establish causal links between variables and involves the definition of a theoretical hypothesis and the application of strict sampling procedure into enhance the validity of findings. Experiment is a feasible strategy in some contexts due to ethical reasons, or inability to get a representative sample.

3.4.2 Survey

Survey is another research strategy. It is commonly associated with quantitative research. Survey may be longitudinal or cross-sectional, using interviews or questionnaires for data collection. Data analysis involves the use of statistical methods to draw inferences. The aim is to generalize from sample to a population (Saunders *et al.* 2012). Commonly used in deductive research to identify relationships between variables. Draw back include poor responses to questions; poorly designed questionnaires and it can be time consuming.

3.4.3 Action Research

It is a research in action rather than a research about action (Saunders *et al.* 2012). Participants of interests are involved in the research in the form of a partnership between themselves and the researcher. It is characterized with an iterative process of diagnosis, planning taking actions, evaluation, and analyses. It is a collaborative research strategy involving stakeholders and the researcher working together in each stage.

3.4.4 Grounded Theory

Grounded theory is an inductive strategy and involves building theory from direct observations made within a specific context. Particularly useful in predicting behaviour and explaining behaviour. However, Grounded theory is time consuming, messy and requires the researcher to develop a tacit knowledge for data collected (Creswell and Poth 2017).

3.4.5 Ethnography

Ethnography is an inductive research approach which involves studying a group of entities or a phenomenon in their natural habitat or setting over a period. Methods often used include observation. Ethnography is context based, flexible and is time-consuming as objects of interests are observed in their natural environment (Creswell 2003). It can be time-consuming (Bryman 2012).

3.4.6 Case Study

Case study is a robust research strategy as the researcher explores in-depth an event or phenomena of interest. Data collection methods commonly used include a structured or semi-structured interview, focused groups and observation. Another research strategy is grounded theory, where the researcher builds and develop a theory from the view of participants involved in the study. Grounded theory involves multiple stages of data collection and refinement. Data are often compared with emerging categories and sampling of different groups to maximize similarities and difference of information (Creswell 2003). Archival Research is another type of research strategy.

Often it might be useful and beneficial to mix methods. Mixing methods offers a chance to increase the validity of research result. Campbell and Fiske were the first to mix qualitative and quantitative methods while studying psychological traits. Since then, researchers have adopted the practice of mixing method based on the grounds that methods have limitations and combining methods could result in a situation where the biases of one method cancels out the biases of another (Tashakkori and Teddlie 2003).

3.4.7 Research Strategy Selected

In order to address the research questions, a case study approach is adopted. Case study research is a qualitative approach in which the researcher explores *case* or *cases* which are bounded setting and context through a detailed collection of data over time (Yin 2011, Saunders *et al.* 2012). Creswell, (2013, p. 97) argue that a case study method “explores a real-life, contemporary bounded system (a case) or multiple bounded systems (cases) over time, through detailed, in-depth data collection involving multiple sources of information… and reports a case description and case themes” Guba and Lincoln (1994) supports the use of case studies in interpretivist research. (Guba and Lincoln (1994) argue that a case study approach identifies the voices of important stakeholders who have the power to shape or

influence the trajectory of organisations or communities or the affect the phenomena of interest the most.

The objective of a case study is to generate a multi-faceted understanding of a complex issue or phenomena in its real-life context. A case study can be confirmatory or illustrative. The former involves using the findings from the case or cases to confirm a theory while the latter is used to understand a phenomenon deeply. Though case study methodology is mostly associated with a qualitative approach (Bryman 2012), Yin (1994) argues that case studies can be used in all forms of social science research: exploratory, explanatory, descriptive, and quantitative.

Case studies are more suited for to what, how and why questions which allows the researcher to unearth or disentangle a complex set of factors and relationship within a single case or across a number of cases through an iterative with some sense of flexibility (Easton 2010, Yin 2018). Case study method allows a holistic description and it is flexible (Baškarada 2014). In fact, several critical realist researchers (Ackroyd and Fleetwood 2000, Mingers 2004a, 2004b, Easton 2010, Mason *et al.* 2013, Barrett *et al.* 2015) have highlighted the suitability of the case study approach to explore interaction of "structure, events, actions and context to identify explicate causal mechanisms" (Wynn and Williams 2012, p. 795). The authors further

However, a key constraint of a case study method is its low statistical representativeness. Also, generalizability is a problem in case study research, a problem Yin (2014) acknowledges. Case study method focuses on context and conditions that are specific to a study/research. This affects ability to reproduce similar results which does not augur well for reliability and credibility (Eisenhardt and Graebner 2007). Stake (2005) contends that new context be compared with old context while Eisenhardt (1989) argues for a multiple piece of evidence across multiple cases.

3.5 A Case- Study-Based Research Design

Research designs provide the plan and procedure for accomplishing the research objectives (Creswell and Creswell 2017). As already stated, this research is qualitative, exploratory, and case-based. A description of a case study research strategy is provided in the preceding section. Specifically, a two-stage design (Cooper *et al.* 2006) consisting of a literature review and an empirical components (semi-structured interviews) was employed. The former takes care of identifying research questions, while the latter involves establishing a qualitative

research protocol (interviews and analysing data) to address research questions (Pykäläinen *et al.* 2009, Huygh and De Haes 2018).

A review of the literature allowed the researcher to critique evidence and findings from existing studies, identify a gap and justify the need for further research. The result of this stage is the emergence of clearly defined questions.

The case study research design proposed by Yin (1994) was used to develop the qualitative research protocol. The research process follows a linear, but iterative steps and course of actions, involving –

1. Define Research Parameters
2. Fieldwork preparation
3. Data Collection
4. Analysis
5. Reporting

Figure 25: Case study process (Yin, 1994)

3.5.1 Define Research Parameters

3.5.1.1 Research Questions

The research questions are presented in chapters 1 and 2. The research questions were determined following the review of the literature and identifying a gap. The scope the research and objectives of the research are set in chapter one. The research aims to identified, which is to identify the conditions underlying the viability of PSS solution and to identify the complexity management strategies of PSS providers.

3.5.1.2 Theoretical Lens

The Viable System Model has been selected as theoretical lens (epistemological construct) for exploring complexity management strategies in PSS systems. The VSM is a well-formalized conceptual model developed by Beer (1979,1981,1985), and underlies the

conditions essential for the viability of systems. The Viable System Model provides the tools, concepts, principles, and structures for which to derive complexity management strategies. The VSM is based on cybernetics principles and able to recommend strategies for managing operational and managerial complexity (Jackson 2002).

In this research, the Viable System Model is not used as a functionalist instrument, the widely used mode and format of employing the VSM (Espejo and Harnden 1989b, Jackson 1992, Hutchinson and Warren 2002, Lowe *et al.* 2020), but in an interpretivist mode.

3.5.1.3 **The Unit of Analysis**

The unit of analysis is the value creating system, ***a PSS*** at a specific recursion level. The concept of a PSS in this research is not limited to a physical entity but includes a variety of elements ranging from humans, decisions, technology, support systems, hardware, software business organisations, and service activities. A value creating unit can be a department, an organisation, multiple organisations, or a network of organisations (Frow *et al.* 2014, Vargo *et al.* 2017). These systems are nested in a broader or larger system (higher recursive level). A value creating system can exist at different levels: dyadic (micro), meso and macro resulting in an ecosystem of actors integrating resources and co-creating value (Vargo and Akaka 2012, Matthies *et al.* 2016). The system boundary is assumed to incorporate all elements, which contributes to the achievement of value. Value in the context of complexity relates to the survivability and viability of the system.

3.5.1.4 **Establishing Research Quality Strategies/Protocol**

This includes ethical considerations to ensure safeguards were in place to protect the identity of participants – individuals and organisations. Names of participants have been anonymized to protect their identity. All specifications regarding the confidentiality of participants were adhered to. All participants were made aware of the purpose and scope of the research and its objectives. Furthermore, high ethical standards were adhered to while storing data collected. Data files were appropriately labelled and stored in the cloud with the researcher have the code for accessing the files.

In terms of validity, the essence of a qualitative exploratory study is the interpretation of events, meanings and actions and not to generalize findings (Creswell 2003b, Bryman & Bell 2015), Hence external validity is impossible. However, to ensure internal validity (Guba and Lincoln 1994), an appropriate research approach and design have been selected to address the

research questions. A qualitative exploratory case study design comprising an outlay of the sampling method used, description of data collection methods as well as the data analysis approach have been presented to ensure reproducibility.

3.5.2 Fieldwork preparation

This involves planning the fieldwork, which helps to limit operational confusion and establishes clarity about what to do and when to do it. Recognising the possibility of unforeseen circumstance and conditions, the need to build flexibility was essential. This stage include sampling, design of instrument and case study protocol.

3.5.2.1 Single Case Study versus Multiple Case Study Design

Creswell, (2007 citing Stakes, 1995) distinguished between three variations of case study research, based on intent: the single case study, where the researcher focuses on a single object of interest and selects a single case to illustrate or understand the issue; the multiple case study, where one issue is selected and multiple cases (from different sites or the same site) are selected to illustrate the issue; and lastly the intrinsic case study, where the focus is on the case itself.

It is important to highlight the differences between a single case study and a multiple case study. In a multiple case study, the researcher studies multiple cases to understand the differences and similarities between the case (Stake 1995). Multiple cases allow the researcher to analyse data across and within situations and scenarios (Yin 2018). As stated already in a previous section, multiple case studies can be used to illustrate or confirm by way of either auguring contrasting results for anticipated reasons or augur similar results in the studies (Chaiklin 1991, Yin 1996, 2009).

This is advantageous to the researcher as the clarity on whether findings are reliable or not can be sought (Eisenhardt 1991) and whether important influence from the contrasts and similarities can be brought to bear on the literature based on the findings. (Baxter *et al.* 2008) argue that the evidence created from multiple cases are considered strong and reliable than those of a single case study as multiple case studies create more convincing findings and theory as evidence is based and grounded on multiple empirical evidence. However, multiple case study has its limitations. It can be expensive and time consuming to implement (Baxter *et al.* 2008).

Some authors have argued in favour of single case studies. Siggelkow (2007), argues that a an empirically rich account of a phenomenon can be described by single case studies through the application of multiple qualitative and quantitative research. Dyer and Wilkins, (1991) claims single case studies produce extra and better theory. Furthermore, the issue of time is a drawback as multiple case study takes a lot more time than single case study. Yin, (2009, 2018) posits that if the object of interest is a single thing, then a single case study is appropriate and the best choice. The researcher can focus on the single case study to get a deeper understanding of the subject (Dyer & Wilkins, 1991). Levy (2008) claims single case studies can be valuable for testing theoretical proposition "provided that predictions are relatively precise and measurement error is low" (pp 12-13)

However, some authors claim the number of cases is irrelevant. Eisenhardt (1991), argues that the focus should be on how much new information or insight the case or cases bring rather than the number of cases. Dyer & Wilkins (1991) write that it is important that the researcher is able to describe the context and scenarios of the cases in a way that is understandable to the reader and produce a theory relevant to the context. It is not a guarantee that insight will be produced from either a single case study or multiple case studies as more of the quality of the case study strategy depends largely on the researcher.

In this research, the researcher is interested in the complexity inherent in the value-co-creation process and how this results in the emergence of outcomes and other system properties. Using a case study methodology, the researcher can study the concepts of complexity and emergence in the context and settings it occurs.

In this research, a multiple case study design is adopted. This is chosen to provide a broad and perspectives of complexity and emergence and the mechanism by which they occur or form in a PSS. A case study research aligns with the soft system methodology as the case study methodology is suited to exploring phenomena within their environment and context; that is, problems that have a definition of 'what' and 'how'. These settings and contexts may be messy, bounded, unbounded and unclear (Yin 1996, Wilson 2001). Furthermore, since this research is explorative, the adoption of a case study research allows the researcher to gain insight and document actual value-creation events, interactions and encounters and acquire a greater understanding of the nature and complexity of the phenomenon under study (Yin, 2003).

To generalize, representative cases are selected across the servitization spectrum (Stake 1995). These cases are selected carefully so that the design is replicated in each case (Yin

2011) and to get either similar results or contrasting results for expected and anticipatable reasons (Yin 2018).

3.5.2.2 **Selecting the Cases**

Central to a research design is the selection of cases. Adequate caution was displayed in the selection of cases based on specified characteristics. Stakes (1995) argues that the researcher must be able to identify some cases with boundaries.

Servitization is a budding concept, whose growth is facilitated by advances in technology and digitalization. Following the example of Rolls Royce's Power by the Hour (Smith 2013), the number of companies adopting a service-based offering has increased. However, the number of servitized firm are mostly limited to a limited number of large multinational firms like Xerox, MAN and Goodyear. However, the interest among small and medium size enterprises in adapting their offerings to offer services is growing (Kowalkowski *et al.* 2013). The limited number of firms providing servitized offerings influenced the choice of sampling method used for the selection of cases. Critical consideration was given to the choice of organisations to study to ensure that selected companies are spread across a range of industries. Th researcher ensured selected companies offered PSS offerings, regardless of the orientation or constellation type and the customers selected, were deemed to have purchased advanced services or services provided through a PSS. A check of website, archival record and documentary evidence were used to support the selection process.

3.5.2.3 **Sampling**

Sampling in case study research involves the strategies for selecting cases, the number of cases and the definition of the unit of analysis (Mills *et al.* 2012). There are differences in the sampling procedure for qualitative and quantitative research design. In quantitative research design, the overarching goal is to get a representative sample of a larger population so that generalization can be made. This informs the use of probability-oriented sampling techniques in quantitative research. (Saunders *et al.* 2012). There two sampling techniques, namely probability or representative sampling and non-probability and judgmental sampling.

In qualitative case study research like this, there is a less emphasis on getting a representative sample from a population; rather the focus is on how a handful of sample display or exhibits the phenomenon of interest (Bryman 2012). There are different types of non-probability

sampling techniques: quota sampling, commonly used for interview survey, purposive, snowball sampling, self-selection sampling and convenience sampling. The differences between these sampling techniques is shown below.

Table 5: A description of non-probability sampling techniques (Saunders et al. 2012)

Sample type	Likelihood of sample being representative	Types of research in which useful	Relative costs	Control over sample contents
Quota	Reasonable to high, although dependent on selection of quota variables	Where costs constrained or data needed very quickly so an alternative to probability sampling needed	Moderately high to reasonable	Relatively high
Purposive	Low, although dependent on researcher's choices:	Where working with very small samples	Reasonable	Reasonable
	extreme case	focus: unusual or special		
	heterogeneous	focus: key themes		
	homogeneous	focus: in-depth		
	critical case	focus: importance of case		
	typical case	focus: illustrative		
Snowball	Low, but cases will have characteristics desired	Where difficulties in identifying cases	Reasonable	Quite low
Self-selection	Low, but cases self-selected	Where exploratory research needed	Low	Low
Convenience	Very low	Where very little variation in population	Low	Low

3.5.2.4 **Choice of Sampling Technique**

Purposive sampling method is suggested for a case study research design (Yin 2018). Purposive sampling is a non-probability-based method of sampling that is based on judgement in the selection of cases (Saunders *et al.* 2012). It is commonly used when a small sample is required such as in case study design. It is characterized by a non-random selection of research participants based on how well participants meet the criteria/requirement or objectives of the study (Easterby-Smith *et al.* 2012).

Patton, (2002) identifies six variants of purposive sampling strategies:

- Extreme case or deviant sampling – here extreme and unusual cases are selected.

- Heterogenous or maximum variation sampling – this involves choosing cases as varied as possible using characteristics that have been defined prior to the start of the data collection.
- Critical case sampling – choose the critical cases.
- Typical case sampling – choose cases with typical, normal or average characteristics.
- Homogenous case sampling – focus on a subgroup with similar characteristics
- Snowball sampling – identify cases from sampling cases who of other groups.
- Disconfirming and confirming – cases are chosen based on their ability to confirm or disconfirm a theory.
- Others include stratified purposive sampling based on variations; opportunistic/emergent sampling that is based on opportunity or advantage of circumstances; lastly convenient purposive sampling based on the convenience of recruiting participants.

Patton (2002) grouped snowball sampling and convenience sampling as part of purposive sampling. The selection of any of these purposive sampling strategies is the ability to compare and contrast, to identify similarities and differences in the phenomenon of interest. Strategies like maximum variation sampling, extreme case sampling, intensity sampling, are used to identify differences and variation while strategies like homogeneous sampling, typical case sampling, criterion sampling, and snowball sampling are used to narrow the range of variation (Palinkas *et al.* 2015). However, there are issues raised about employing purposive sampling such as the willingness of participants (Bernard 2002), issues relating to validity, poor skills and a lack of knowledge in the recruitment of participants knowledgeable about the phenomenon of interest (Creswell 2007).

A heterogenous purposive sampling is appropriate for this research as there are not many firms offering advanced services. To capture a broad perspective of the complexity and emergence (Creswell 2007, Ortiz, DanielGreene 2007), three case firms in different industries, with different sizes and offering different offerings were selected. In all, there were three cases; two cases from the same firm operating in the printing industry, and one case each from other industries.

A heterogenous purposive sampling was supplemented by snowball sampling method. A snowball sampling method is a referral type of sampling, where the recommendation or referral of the first participant is used for the selection a second or more participants (Cooper *et al.* 2006, Maxwell 2014). Snowball sampling is appropriate in this research as a significant proportion of firm offering advanced services are large multinational companies and accessibility to these companies and staff that could provide the information required might

be limited. Besides, the researcher acknowledges the sensitivity of some of the issues considered in this research, which might discourage some firms from participating in the research or supplying the information required. Hence, the use of snowballing method is appropriate as participants who might not be willing to provide information would be willing to do following the recommendation of a service provider or a client.

3.5.2.5 **Reasons for Selecting the Cases**

The sample were selected using three criteria. First, the selected case firms are representatives of their industry in terms of their level of servitization, i.e., they are frontrunners in their market segments. Second, the case study firms offer different offerings, are of different sizes and are based in different industries.

For example, one of the case firm is based in the print and photocopier industry, which is famous as one of the forerunners of servitization and for its early adoption of advanced services (Visintin 2012, 2014, Baines and Lightfoot 2013). One of the large companies in the industry pioneered the implementation and development of service-based offerings like document management services, managed print solutions, and managed print services, by integrating hardware, software, system-integration, and development capabilities. Since several of these photocopier Original Equipment Manufacturers (OEM) offer their offerings through agents and vendors located around the UK, and organized as a network of partners, it provides a rich source of real-world network to study PSS complexity and emergence of complex behavior.

Furthermore, the adoption of services has also grown considerably in the Lighting industry, with the introduction of pay per lux, a form of advanced service in addition to the traditional maintenance services and warranty contracts (Ardolino *et al.* 2018, West, Gaiardelli, *et al.* 2018, West, Kujawski, *et al.* 2018). The financial services industry has also seen its fair share of shift to as-a service models, with the proliferation of independent ATM operators (Goedkoop *et al.* 1999, Ng and Maull 2009, Spohrer and Maglio 2010, Kleinaltenkamp *et al.* 2017)

However, it must be stated here that not all industries were represented. Accessibility issue was a major factor as the researcher could not get any participants from companies operating in that industry. Critical realism is focused on exposing the causal processes which produce events; therefore, the basis of case selection is not to generalize results across multiple contexts or confirm a theory. The focus is on conducting an intensive study that provides concrete explanatory details regarding an event (Sayer 2000, Bhaskar 2013)

3.5.3 Data Collection

Research methods can be qualitative, quantitative, or mixed methods. Mixed method involves the application of both qualitative and quantitative methods. Mixed methods are particularly useful in triangulation in an effort to reach a convergence of results or to validate a result (Creswell 2003). Mixed methods can also be used to achieve complementarity by employing the strength of each method to investigate different facets of a phenomenon in order to increase understanding of the phenomenon.

Data collection are the specific methods and techniques employed in the collection and analysis of data. Research methods can be categorised based on a continuum consisting of the degree and level of predetermined nature or the use of closed -ended or open-ended questioning. Data collection methods can be qualitative or quantitative. Qualitative data collection methods include interviews (which can be structured or unstructured), focused group, content collection and ethnography. Quantitative data collection methods include observation, interviews (close-ended), questionnaires and measurements (Bryman 2012).Yin (2009) identified six sources of evidence:

Table 6: Sources of evidence (Yin 2003)

Evidence	Merit	Weakness
Interviews (Can be structured or semi-structure.)	Insightful and focused.	-Questions can be poorly framed.
Focused group interview	Can be used to provide perceived causal inferences and explanation. Broad coverage of diverse opinions	-The presence of response bias can affect results -Poor response resulting in inaccuracies -Group think
Documentation	Broad coverage, saves time and money, contains written information that can be stored and retrieved easily.	Biased Low response rate Reporting bias
Physical artefact	Insight into cultural features	Selectivity and availability

Evidence	Merit	Weakness
Direct observation	Reality and contextual	Can be time consuming Access may be difficult Costly Presence may affect behavior
Participant observation	Provides insight into personal and interpersonal behavior	Subject to manipulation of events
Archival records	Precise. Both quantitative and qualitative	Accessibility, may be a problem

3.5.3.1 **Data Collection Techniques used in this research.**

In view of the objectives of this research, which includes gaining insight into mechanism by which PSS companies manage complexity, the purpose of the data collection process is designed to collect data which enable the researcher to:

- Identify VSM functions (five systems and six communication channels through the stories and meanings participants attribute to their interaction within the PSS.
- Identify variety operators (attenuators, amplifiers, and transducers) and mechanisms underlying complexity management and viability of a PSS.

Here the goal is to collect and obtain sufficient information about the structure, functions, and communication channels within the PSS as well as evidence relating to how complexity is managed. To achieve that, a combination of semi-structured interviews, a review of secondary data (websites, annual reports, company press releases, industry-based publications, and other publicly available documents).

The use of multiple sources of data have been advanced (Chaiklin 1991, Yin 2018) as a way of ensuring internal validity to the extent that the methods chosen is appropriate for answering the research questions (Guba and Lincoln 1994). Flick, (2014) contends that using multiple sources of data can be used for triangulation in case study research: to enhance credibility and enable different interpretations.

The data collection was carried out over a period of 3.5 years. A multimethod (not to be confused with mixed method) (Hesser-Biber and Leavy 2011) was utilized. These include:

1. Literature Review
2. Semi-structured Interviews – in the form of in-depth qualitative interviews with company staff and customer organisations
3. Follow-up interviews, comments, questionnaire
4. Publicly available documents and secondary data were analysed.

3.5.3.2 **Literature Review**

Initial data for this research was collected while reviewing the literature. The the purpose of the review of the literature was based on the grounds of

- Characterization of complexity - For example studies conducted by Zou *et al.* (2018) provided insights on the characteristics and features of complexity in Product services; Benedettini *et al.* (2015) and Valtakoski (2017) examined complexity and risk associated with a PSS.
- Identifying existing studies relating to complexity management in the context of product service systems -Visnjic *et al.* (2017), (Gebauer *et al.* (2017), Kohtamäki *et al.* (2020) and Davies *et al.* (2020) provide insight about a variety of capabilities required for a successful transition to service-based model.
- Studies relating to the theory and application of the Viable System Model in the context of complexity management (Beer 1981b, Schwaninger 2000, Espejo and Reyes 2011, Espejo 2015a)
- Studies relating to the specific use of the Viable System Model in the context of Product Service Systems, including (Batista *et al.* 2017) and (Ng and Briscoe 2012) who examined the development of co-capability in outcome-based contracts.

These studies provided a backdrop for the development of research questions and insight into the application of VSM in a variety of contexts and cases.

3.5.3.3 **Interviews**

According to Easterly-Smith, (2008), in-depth interviews provide an opportunity to uncover and probe deeply active and passive data, to open and unearth new clues and dimensions to the problem. The interviews were semi-structured to ensure that questions are well-tailored and directed to address the research questions on the one hand, while providing the room to stray when appropriate (Guba and Lincoln 1994, Bryman & Bell 2015).

The Design of Interview Protocol

The interview protocol consists of;

1. A checklist – this comprises notes, pens, video and audio recorder, phone, and watch.
2. The consent form, letter of invitation, participant briefing letter.
3. The interview guide- this consists of a semi-structured set of questions
4. Ending the interview

A major part of the interview protocol was the interview guide (Witzel and Reiter 2014). In the design of the interview guide, the interview questions were adapted from Burgess and Wake (2013) and Hildbr and Bodhanya (2015), and were tailored to identify the five functional systems, communication channels of the Viable System Model. Here the VSM served as a meta-language to guide the lines of questioning during the interview.

The core of the questions (a copy can be found in the appendices) covered -

a. Information and status of the stakeholders and their objectives.
b. The identify and purpose of the PSS
c. Levels of recursion.
d. The structure of the PSS system – the existence of the three main elements of the viable system model consisting of PSS operations, PSS management and the dynamic operation environment., whose balanced interaction is essential for organisational viability.
e. The communication between these three elements and the actions/mechanisms employed to balance variety between them
    i. The major issues they have confronted in the last period.
    ii. What are the complexity issues and how were they resolved?
    iii. How have they solved it? How are the systems configured to solve these problems?

iv. How is the overall system efficiency achieved?

Table 7: List of interviewees

Case 1	Particpant	Role	Total time	
	CompanyDoc	Main PS Provider	45mins	Method
	Partner1	managerial	30mins	in person
	Partner2	managerial	30mins	in person
	CustomerDoc1	managerial	45mins	in person
	Company Doc2	managerial	30min	Skype
	Sales	managerial	30mins	in person
	Sales -	ops	90mins	in person
	CompanyDoc	ops	30mins	in person
Case 2	LightComp	Operations	45mins	in person
	LightComp	Operations	45mins	in person
	LightComp	Managerial	30mins	Skype /email
	CustomerLight	Managerial - custome	60 mins	in person
	CustomerLight	operations - custome	60mins	in person
Case 3	CustomerATM	Operations	45min	in person
	CustomerATM	Operations	30mins	in person
	CustomerATM	Managerial	30mins	in person
	CustomerATM	Owner - customer	90mins	in person
	ATMComp	Managerial	30mins	in person
	ATMComp	Managerial	30mins	in person

Logistics of Interview

The semi-structured interview sessions involved a combination of formal and informal sessions. This provided the researcher with the opportunity to probe deeper, request for clarification when necessary (Hildbr and Bodhanya 2015) The focus was to get a rich volume of data. The formal sessions were mostly semi-structured interviews carried out face-to-face, via skype and on phone. These formal sessions were planned months ahead of the scheduled sessions to give the participants enough time to prepare and make room in their calendar. As it is typical with case study research, there were several cancellations and rescheduling. The questions were tailored to the designation, work function and responsibility of the participants. The interviews lasted at most one hour. Several of the interviews lasted 30mins. This was to ensure I was able to visit again to conducted some more interviews.

The identification of participants to be interviewed was based on having specific responsibility for the contracts or have experience with key parts of the PSS contract and operation (Settanni *et al.* 2017, Lowe *et al.* 2020).

Access to companies and customer companies were facilitated through snowballing. Due to the sensitivity of information, in some of the cases, the researcher sent the topics and part of the questions to participants prior to the interview. This was to give the participant a hint about the potential area questions would be asked. The researcher did inform participant to "pass" any question if they feel it was intrusive or required the disclosure of confidential information.

Besides face-to-face interviews, some interviews were conducted on Skype with further communication via emails and phone calls. These communication channels were used when face-to-face interview was not possible, or the participants asked for a phone interview or a Skype interview. In addition, these communication channels were also used for follow- up questions. These channels save a lot of time, provided more information the researcher would have missed and granted access to participants who were mindful of any distractions or interruption at their workplaces.

Each interview was conducted in the form of semi-structured mode. Interviews were recorded and stored and transcribed. Each interview spanned from 30-90mins

Taking a cue from studies carried out by Holt (2010), Jowett *et al* (2011), Pearce *et al* (2014) and (Hanna 2012), the use of internet technologies (such as Skype, Zoom and others), phone and email for conducting interview have grown due to the speed, flexibility, synchronous nature of real-time interaction as well as convenience. While these channels have their disadvantages such as the quality of answers/responses, the lack of contextual feel, the loss of visual and interpersonal aspects of interaction, the visual angle to web technologies have minimized some of these demerits (Holt 2010).

The Number of Data Collected

Yin (2018) explains that the general rule of thumb is more is better than less. This is to create confidence in the research findings. However, data collection can be limited by weather, budget, and time constraints. Yin (1994) recommended research participants can fall between 20-50 depending on the research question and the scope. Like already stated, the more participants are involved, the better the representation of perspectives in the research findings.

A total of 25 participants were interviewed – representing a spectrum of functional roles across five industries and sectors. Some of the participants were interviewed more than once to

clarify, expand, or elaborate on issues and claims that were made in a previous session. A total of about 70 hours were spent and across 15 interview sessions.

Obtaining data from a broad group of stakeholders involved in the delivery of the PSS provided insight on key issues relating to problems associated with communication channels between the three elements – operations, management, environment. Relations between these elements provided insight into the mechanism by which the system self-regulates itself against the backdrop of the dynamic environment it operates in.

The five functions, communication channels and the equilibria sites within the VSM provided a backdrop for the lines of questioning.

e. Recursion and Identify – The researchers asked questions relating to the basis on which the companies operate and organized – product lines, service lines, technology, markets (Espejo *et al.* 1999a) as well as what the system does.
f. Operations and implementation – questions were focused on the main operations of the system, what it does (a proxy for the identity of the PSS), the interaction between the operating units/functions (C3 channel). Importantly, in each case, the researcher asked questions about the challenges, fluctuations, dysfunctionalities, problems, hurdles, obstacles encumbering the achievement of objectives and most importantly, how these issues were resolved or would be resolved/addressed.
g. Management – the focus here was around the functions of coordination, and cohesion (S2 and S3). Participants were asked in each case how the operating functions were coordinated, how issues between the operating units were resolved, what mechanisms, instruments, apparatus, or operators were in use to address the issues (C5). In addition, the researcher was also interested in the mode, format, character, and processes underlying the control function and how cohesion, synergy, distribution of resources, accountability and unity of purpose were achieved. These lines of questioning provided insight into the channels – C1 and C2 used for resource allocation, accountability and communicate instruction between S1 and S3. Specific aspects of the system relating to leadership, trust, relationships and culture help to enrich the data collected.

   Investigating S4 involves asking about monitoring trends and strategy formulation. The researcher was interested in more in the processes and activities encapsulated within the intelligence gathering, strategy formulation and, adaptation. The systems 3-4-5 homeostat was explored as well. The

researcher investigated the process undertaken to integrated future strategies with existing practices and how conflicts and friction associated with these processes were addressed or resolved. Obtaining information about the influence of identity and purpose affect the overall system was also explored.

h. Environment – Questions relating to the nature of threats in the environment as well as the opportunities were explored. Participants in each case were asked how the environment is monitored (S4 and S1), customer touch points, scanning apparatus and instruments and addressing variety in the environment.

Attempts were made to avoid jargons and technical terms that could confuse participants. Questions were rephrased if participants indicated a lack of understanding. The use of questioning terms such as 'how', 'what' helped to elicit descriptive answers from participants, and allowed the researcher to gain a better understanding of the complexity management process.

3.5.3.4 **Follow Up Interviews**

Follow-up interviews were important as they provided an opportunity and means to clarify, extend understanding, and validate responses received during previous interview. These follow-up sessions assumed a variety of format – contact via email, phone calls, skype sessions and face-to-face contact and communication.

There were several occasions where the researcher had to conduct additional interviews including situations where words were used in a context that was different to its traditional use, some responses were not audible enough to be transcribed, and the need for more data to develop a broader picture of the mechanisms for managing complexity in each equilibria site.

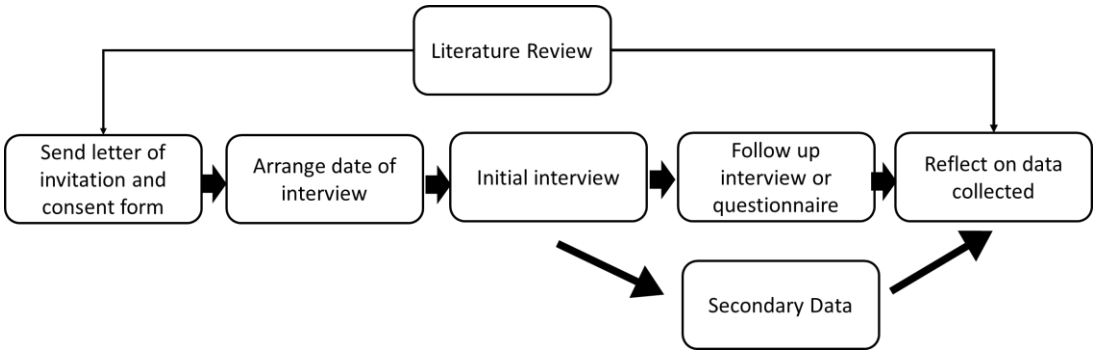
3.5.3.5 **Secondary Data**

The use of secondary data was useful in two aspects: in establishing a base around the current state of the literature/practices and in providing multiple data sources for triangulation. These sources of data were used to align publicly available information with claims made by participants/insights gained from the interviews as a way to corroborate evidence, provide

multiple lines of insights and expand the researcher's understanding of the research questions (Salkind 2012)

A lot of secondary data and publicly available data were collected and used to triangulate the findings in the interviews (Eisenhardt and Graebner 2007, Voss *et al.* 2015). Information from company website, industry manual, industrial workshops/seminars, print media, electronic media were employed to increase the validity of the findings.

Figure 26: Data Collection protocol



3.5.4 Analysis and Interpretation of Data

Qualitative modes of data analysis involve examining, comparing, and interpreting meaningful patterns or themes. How meaningful, a specific content of qualitative data is determined by the goals and objectives set for that research (Bryman 2012). According to Miles and Huberman (1994), qualitative data analysis deal with words and therefore are governed by a much fewer ground rules for drawing conclusions than in quantitative data analysis. There is no standardized procedure for analysing qualitative, however, some structured procedures can be found in the qualitative research methodology literature.

Saunders, Lewis and Thornhill (2012) grouped qualitative data analysis procedures into summarising meanings, categorization of meanings and structuring of meanings. The framework for qualitative data analysis proposed by Miles and Huberman (1994) to describe major phases of the data analysis is widely used in the social science and business management research. Miles and Huberman 1994 outlined four phases of data analysis, namely: Data reduction, a process involving the cleansing and organizing the data; data display, a well displayed image of the data to capture trends and relationships. The use of flow charts to visualize and highlight critical paths, decision points and relationships is a common practice. The third phase is conclusion and followed by verification. Conclusion involves extracting meanings from the data in view of the research questions at hand. Verification could mean revisiting the data multiple times to identify emergent conclusions and meanings.

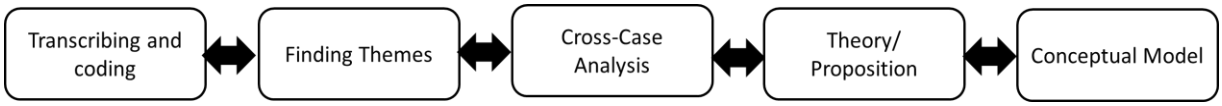
Yin (2003) presents three general analytic strategies for analysing case study data: relying on theoretical propositions, developing a case description, and thinking about rival explanation. The selection of any of the strategies largely depends on the research objectives. Yin (2003) contends that any of these strategies can be used to practice the five techniques for analysing case studies: pattern matching, explanation building, time series analysis, logic model and cross case synthesis. Yin takes a positivist approach to case study data analysis and assumes that the outlined analytic step would enable researchers to reach the objective truth. Hartley (2004) emphasizes that a valuable part of a case study analysis, which can enhance the validity of the research findings may involve checking the findings with the case study participants.

3.5.4.1 **Analysis Used in this Research.**

During this research, the collected data were analysed using qualitative thematic analysis by employing the VSM as a theoretical lens, with the goal of describing the complexity management strategies of companies offering PSS. An Inductive approach was adopted to identify specific complexity management approaches or strategies and the variety operates operating at each equilibrium site.

In this research, the analysis of the case study data was carried out in five stages. Each stage consists of a number of sub-steps.

Figure 27: Data Analysis protocol



3.5.4.2 Thematic Analysis

The goal of this research is to discover mechanisms and causes by which 'event' emerge, hence the choice of the critical realism paradigm. To answer the research questions, the researcher has chosen thematic analysis as the data analysis technique. Thematic analysis was conducted using a computer aided qualitative data analysis software (CAQDAS), precisely MAXQDA, a world leading software for qualitative analysis. Thematic analysis approach proposed by Marshall and Rossman, (1999) was adopted:

1 Preparing, Organizing and Exploring the data.

Preparing, organising, and exploring the data constitutes the first set of steps while analysing the collected data. The data collected were analysed as they were received, i.e. as soon as possible, to prevent the accumulation of a large volume of unorganized data. This step of the data analysis was broken down into smaller steps.

- ***Storage of the data and Labelling of folders and files –*** All data collected including audio-recorded interview files, interview notes, secondary data, emails were stored in a well-labelled folder titled 'PhD Data'. This main folder contained sub-folders for each case. Each case was labelled 'Case1', 'Case 2' and 'Case 3'. As more data were collected, they were uploaded to their respective folders. Within each Case folder, each data file was labelled appropriately for easy recognition of the content. For example, in the folder for Case 1, audio recorded interviews of business development manager from the parent company was labelled as 'CompanyDoc BusDevMgr' with 'CompanyDoc' representing the company's name and 'BusDev Mgr' representing the role: business development manager.

- ***Transcription:*** Due to the volume of the data collected, a combination of manual and automatic transcription was used to transcribe the data files. At the beginning of the data

collection process, transcription was done manually by the researcher using the transcription function on MAXQDA. However, as more data were collected, using manual transcription method consumed a lot of time, hence the use of automatic transcription for some parts of the data collected.

MAXQDA allows for the transcription of audio files in its Multimedia Browser. First, the audio file was imported into MAXQDA from the researcher's laptop and processed/transcribed as the audio is played on MAXQDA. The audio transcription on MAXQDA offers a play-forward and play-back buttons, which made it easier for the researcher to listen to the audio file several times and write down what was heard. It was time-staking, time-consuming and slow. Several hours a day were spent in transcribing each audio file depending on the length/duration of the interview. For the short interviews, less time was spent while for the large files, a considerable amount of time was consumed to transcribe the file.

Aa result of the time-consuming and slow pace of transcribing the data using a manual method, a transcription app, which offers automatic transcription using artificial intelligence algorithm was used to transcribe some of the larger audio file. Otter.ai, a transcription app offers both basic and premium plans in the form of monthly subscription. Although the use of the transcription app to transcribe some data saved a lot of time, the researcher had to carry out some post-transcription checks to ensure the audio files were transcribed correctly. This was done by listening to the audio file while reading the transcribed data. Some minor errors that were found were promptly corrected. The use of the app saved the research plenty of time. Following these checks, the text file in imported into MAXQDA.

Each question and answer were transcribed as separate paragraphs, with each paragraph either for the interviewer and interviewee, well-labelled with appropriate labels to distinguish between several people in the recording. The *interviewer* was labelled as "Me" to indicate that the speaker was the researcher. Participants were labelled differently with appropriate abbreviations such as "Mgr1', 'Mg2"; both used to indicate that the speakers were managers. The interviews were transcribed verbatim.

- ***Exploring the transcribed Data***

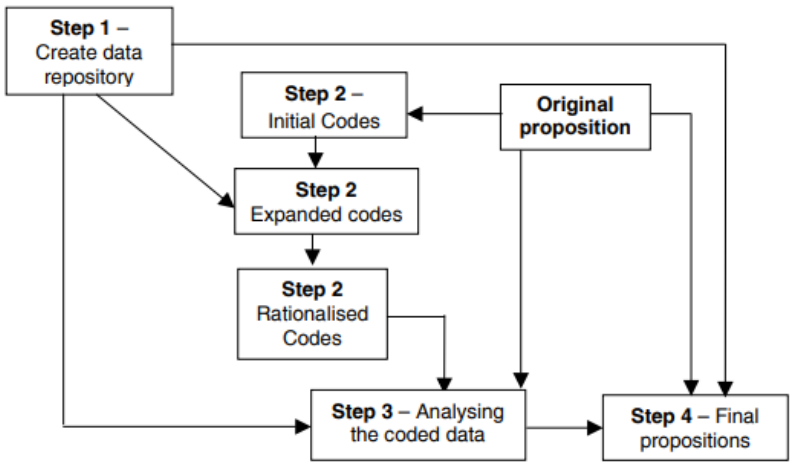
  The main activity in this step was to read the whole transcribed file for each participant in each case to identify if any trend exists. As the researcher read the transcribed data, special attention was paid to frequently used terms, conspicuous paragraphs, unique ideas for analysis, conspicuous features by highlighting them with colours, writing notes in memos and attaching them to specific paragraphs/texts. These memos helped the researcher to remember some salient comments made by the participants. At the end of

the exploring the data, a summary of the key points was developed for each data file. Some of these key points related to the 'operation', 'processes' or 'mechanisms' within specific function/system within the VSM.

2 Coding the data

The 'Codes and Coding' technique proposed by Miles and Huberman (1994) was adopted. The 'codes and coding' technique is selected because it facilitates the linking of data back to the research questions. The process involves creating codes first and then coding the data.

Figure 28: Coding procedure (Miles and Huberman 1994, Atkinson 2002).



- ***Generating Initial Codes***

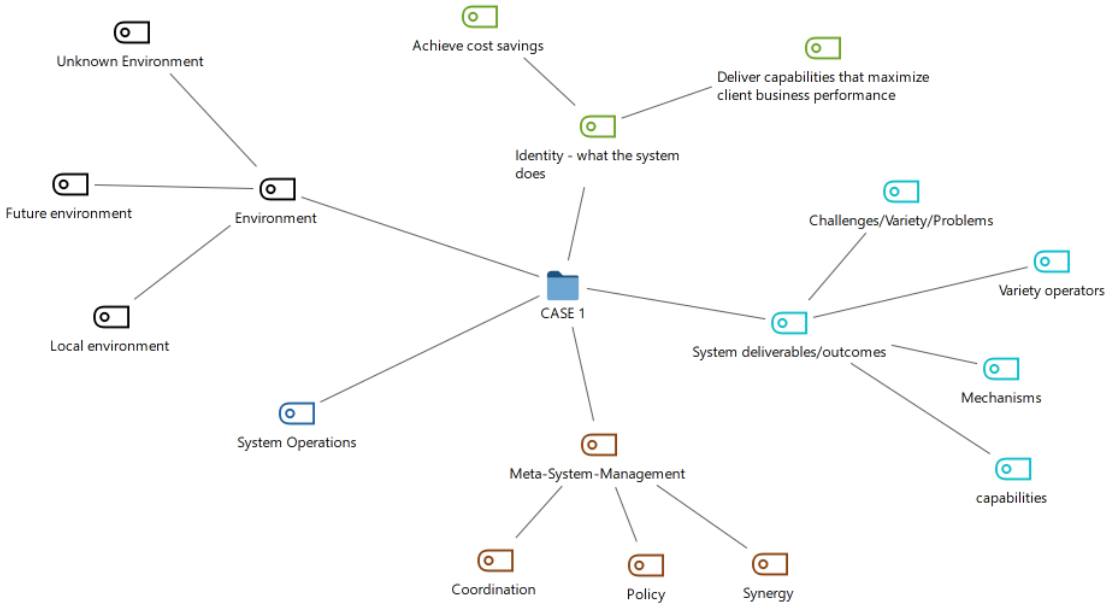
  The interview guide had provided a backdrop to the creation of the initial codes. The interview guide grouped questions based on the functions of the Viable System Model. The initial codes were further developed based on variety of questions in each function. For each VSM function, initial codes include.

  i. The Environment

ii. System Identity/Purpose and Objectives
iii. System operations
iv. Meta-system – Management
v. System Deliverables, challenges/problems and capabilities

To remember what each initial code mean, a description was provided in the form of memo notes on MAXQDA. MaxMaps were used to visualize the relationship between the initial codes. The MaxMap for Case 1 is show below.

Figure 29: Initial Codes



- ***Basic Coding (Expanded Coding)***

  Following the creation of the initial codes – (referred to as general codes by the researcher), the researcher proceeded to employ basic coding. In creating the initial codes, elements of the VSM served as a backdrop to guide the coding process (deductive). However, for basic coding, an inductive coding process was employed, which involves assigning pieces of data to the initial codes via the drag and drop on MAXQDA, extending and improving the initial codes.

In the transcribed data, statements/paragraphs with no relevance to the research objectives or research questions were not coded. However, memo notes were written to remind the researcher the reasons the paragraphs were not coded. These notes were used in the analysis later.

It was important to establish some rules for coding. This was to guide the basic coding process in terms of what was coded or not. The researcher established the following rules:

1. **Coherence** - To be coded, a sentence or a paragraph must be coherent. That is, it should express some idea relevant to the research question. This also applied to phrases, provided it is expressed some idea that is understandable and comprehensible.
2. **Verbs and adverbs** – verbs can be defined as 'doing or action words'. They express an action or being. Verbs were useful in the coding of specific activities performed by system function. For example, in Case 1, the presence of the words and phrases like "we provide", "we review and evaluate", "monitor", "provide training" and "finance" indicate the variety of activities and processes performed and carried out by the PSS operations (system 1). In addition, adverbs were also used as a base for coding as well. Adverbs modifies nouns, adjectives and provides insight about the degree of or intensity of action or being.
3. **The frequency of words or repeated comments –** Repeated comments are an indication of emphasis or represents an important feature of the system of interest. The frequency of words or comments were coded. A word cloud was generated for each case to identify the frequency of specific words and statements. For example, the "proliferation of Internet-of-Things enabled devices" and "advances in digital technologies" were frequently occurring terms and phrases in the interviews.

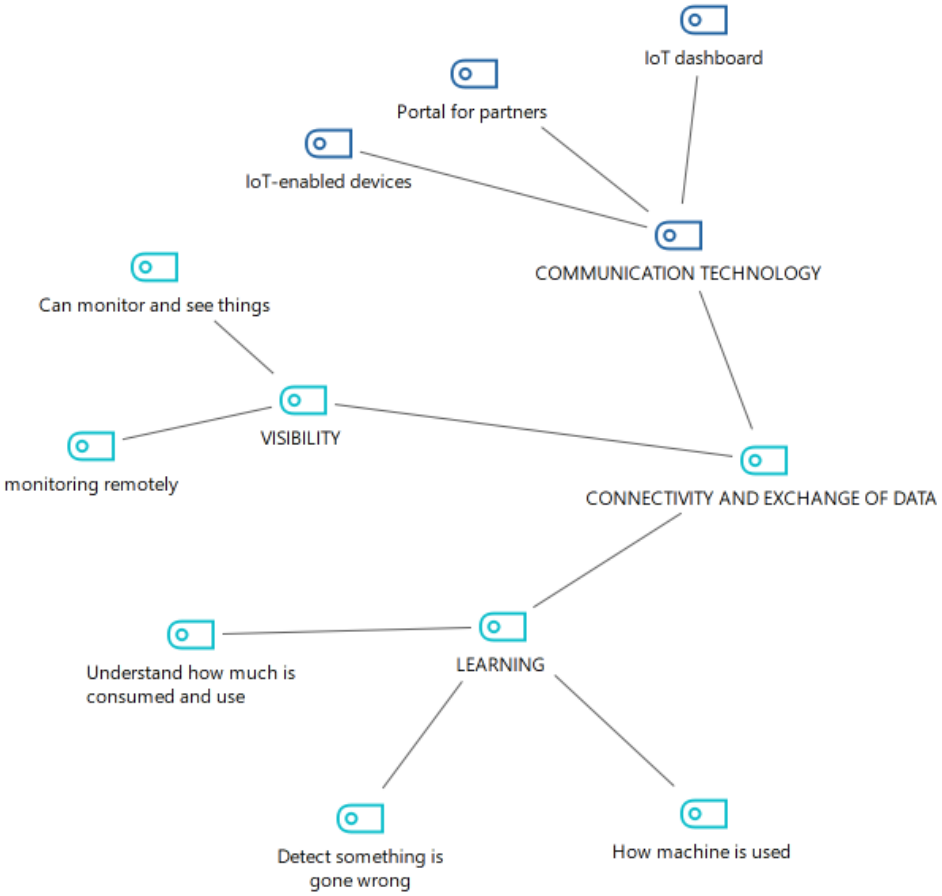
- ***From Codes to Categories and sub-categories – Rationalized codes, Recoding and Re-categorizing***

Here, the basic codes created were rationalized. This involved setting the order in which the basic codes were processed, merging codes into a larger one, establishing cause and effect relationships, collapsing repeated codes into one, re-arranging codes, grouping basic codes into sub-code groups and categories. The result is the emergence of new categories and sub-categories. Several categories emerged via the

process of consolidating the basic codes. There were reasons to create new categories and refine existing ones as the analysis evolved. Some of codes were facial codes, others were conceptual codes. The researcher was wary of the filters adopted in the coding of the interviews. Filters are like perspectives. They influence and affect our coding decisions. According to Merriam (1998) “our analysis and interpretation – our study’s findings – will reflect the constructs, concepts, language, models, and theories that structured the study in the first place” (p. 48).

For example, in Case 1, basic codes like ‘remote monitoring’, ‘can monitor and see things’ were consolidated into a sub-category called ***VISIBILITY,*** basic codes like ‘IoT Dashboard’, ‘IoT-enabled devices’, and ‘portal for partners’ were consolidated into a sub-category called ***COMMUNICATION TECHNOLOGY,*** other basic codes like ‘understand how much is consumed’, ‘detect something is gone wrong’ and ‘how machine is used’ were consolidated into a sub-category called ***LEARNING.***
The sub-categories visibility, communication technology and learning were consolidated into a single category called ***‘CONNECTIVITY AND EXCHANGE OF DATA’.***

Figure 30: Rationalized Codes



3 Analysis: After The Coding

The researcher employed a case-oriented post-coding analysis approach. A case-oriented post-coding analysis uses case as the basis of structuring the analysis of the basic codes generated in the previous section. The task here was to organise the codes and subcodes to answer the research questions. It involved capturing the essence of the codes and establishing their capacity in addressing the research questions. This process encapsulates the process of identifying patterns, meaning, essence in the codes and data– in a cyclical and iterative format.

- ***Frequency Of Codes***

  As part of the analysis of the codes, the number of times a code appears in the documents and interviews were noted. Frequency of codes indicated a point of

emphasis or a very important aspect of the participants' answer, activities, or system. The frequency of codes within a case help

For example, In case 1, 'knowledge' and 'support' alongside internet of things appears almost in every section of the interview and across multiple documents, indicating the place and role of technology as a variety operator in attenuating variety or amplifying the response capacity of the system of interest.

Figure 31: Word cloud for frequency of specific words in Case 1

- ***Duplicate Codes: Acknowledging the Context of Usage***

  The researcher observed there were codes appearing in multiple sections of the collated data. To ensure the context of each use is understood, the researcher had to read the paragraphs multiple times to gain insight into the context of the statements and to ensure the correct interpretation was presented. A summary was written to explain the context of use to help the researcher to remember.

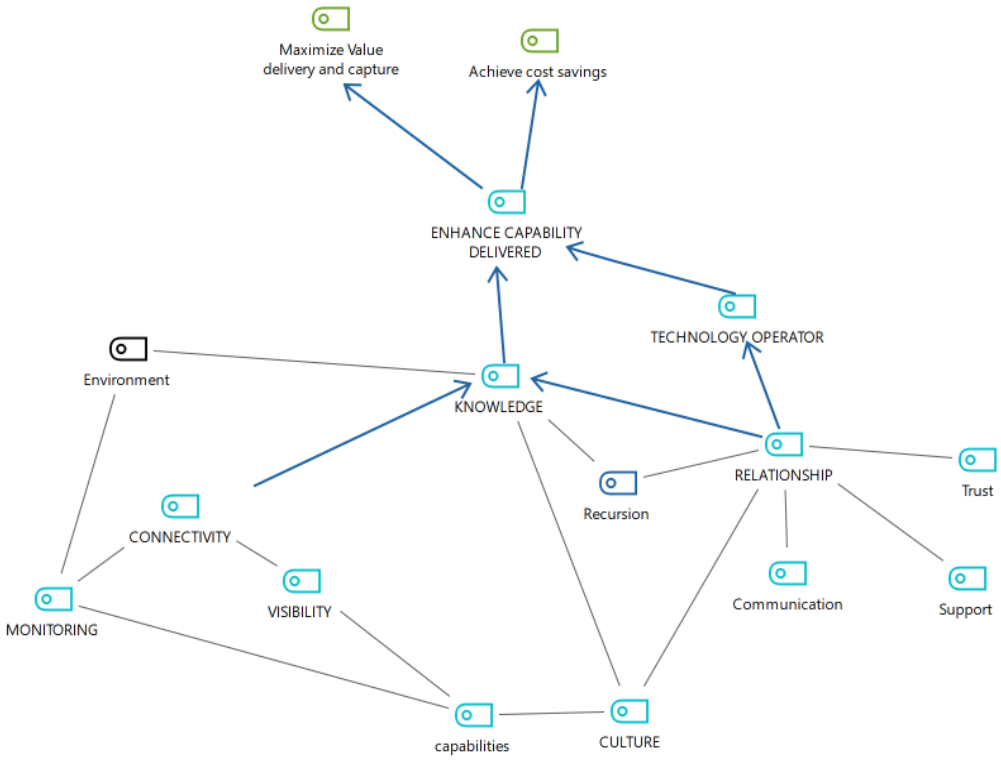
- ***Relationship between Codes***

  The task here was to compare statements within a case: for contrast and similarities; for trends and patterns. The aim was to identify uniformity and to grasp the 'whole story' or understand the holistic nature of complexity management in the cases. The use of MaxMap enabled the researcher to visualize relationships between codes.

These include the presence of cause-and-effect relationship, causative relationships, contrasting relationship, sequence relationships.

For example, in Case 1, certain capabilities of the company of interest were listed under sub-category called ‘Capabilities’. However, with further analysis , a relationship could be identified between capabilities and variety operators (operators used by system of interest to attenuate complexity or amplify their response capacity).

Figure 32: Relationship between codes in case 1



- ***Case Comparison: Structuring the analysis of the codes.***
  In this step, relationship (contrast and similarities) between the cases is investigated. Some of the questions outlined include do companies and PSS types use similar

complexity management strategies? What are the reasons for the differences between the cases?

A matrix was used to structure the analysis. Particular attention and focus were placed on the complexity management equilibrium sites identified in fig 11(section 2.5.5). A table is presented below, showing how texts, quotes and the respective codes were mapped to complexity management processes underlying the VSM. Some extracts for Case 1 are shown in the table.

Table 8: Matrix showing the structuring of contents following coding.

Cases	Recursive problem solving	Horizontal homeostasis	Vertical homeostasis Cohesion	Adaptation
Case 1	*"the company engages the services of partners around the world, who can help deliver our promise to customers" -RECURSION* *"You can always find an agent or partner closest to you" – GLOBAL presence*	*"... know what your business needs and we will help you to perform them, or we perform them for you effectively and efficiently. KNOWLEDGE &PERFORMANCE* *"We leverage our innovative technology to create intelligent system that increase efficiency and effectiveness in our clients' business" TECHNOLOGY OPERATOR EFFICIENCY, EFFECTIVENESS, BUSINESS PERFORMANCE*	*"We support partners in the path you choose" SUPPORT, DIRECTION* *"The official badge represents our brand and reputation.... It must be used according to the terms and conditions" GOVERNANCE, TERMS AND CONDITION*	*"... work with multiple partners across the manufacturing and service spectrum to innovate" MULTIPLE PARTNERS SPECTRUM OF COOPERATION* *"We are a technology business" IDENTITY*
Case 2	Text passages from participants • Structure • Process/mechanism (attenuate/amplify) • Transducer	Text passages from participants • Structure • Process/mechanism (attenuate/amplify) • Transducer	Text passages from participants • Structure • Process/mechanism (attenuate/amplify) • Transducer	Text passages from participants • Structure • Process/mechanism (attenuate/amplify) • Transducer
Case 3	Text passages from participants • Structure • Process/mechanism (attenuate/amplify) • Transducer	Text passages from participants • Structure • Process/mechanism (attenuate/amplify) • Transducer	Text passages from participants • Structure • Process/mechanism (attenuate/amplify) • Transducer	Text passages from participants • Structure • Process/mechanism (attenuate/amplify) • Transducer

Taking case-based matrix view of the analysis was useful as it allowed the researcher to take a holistic view of complexity management for each case, which later served as a basis for the case-oriented comparison.

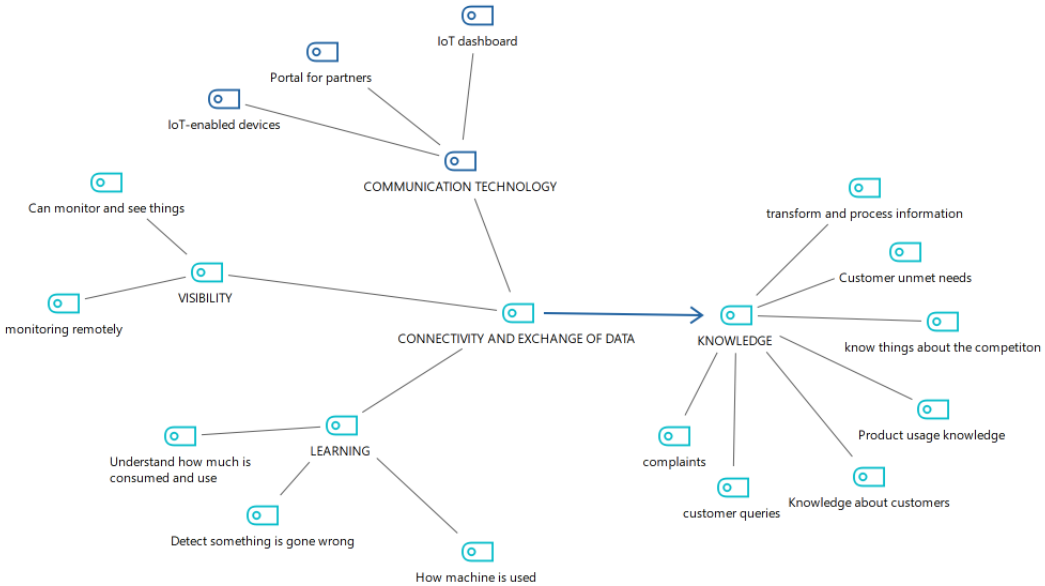
4 Moving from the Real to the Abstract - Developing Themes and Propositions

The researcher consolidated the codes into sub-categories and categories via the assessment of relationships between codes, analysis of contrasts, similarities and context between cases and within cases, the need to transcend and progress from data (real) toward "the thematic conceptual and theoretical" (Saldana 2009, p. 11). Morse and Richards (2002. p157) argue that "categorizing is how we get 'up' from the diversity of data to the shapes of the data, the sorts of things represented. Concepts are how we get up to more general, higher-level, and more abstract constructs".

In step 2, the basic codes generated were consolidated into categories and sub-categories (in fig). In this step of the analysis, the researcher attempts to progress from categories to specific themes/concepts and then to theory development (general propositions).

For example, in case 1, the analysis of the basic codes, categories and sub—categories resulted in the identification of a link between the categories '***Connectivity and Exchange of Data'*** and '***Knowledge'*** resulting in a new theme called ***Connectivity is designed to increase knowledge.*** This theme later served as the basis for the formulation of a theory/proposition about knowledge management as the basis of complexity management in a PSS system. A breakdown of the

Figure 33: From coding to themes/theory



Some of the codes and themes developed during the data analysis steps are presented in the table below:

Table 9: Coding Process for theme: Connectivity and Knowledge

Quotes	Initial Code	Basic codes	Rationalised codes	Themes
CustomerLight says: " *We care about the environment and sustainability. We like* ***the idea that we can regulate our energy consumption****. That explains the reason we decided to contract for the service. We searched around and we found that ….this is the best we can get".* *"The app is the best. We can control our light.. quickly and conveniently".*	Operations (System 1)	Need to see how the machine is used. ***Knowledge about consumption*** Control energy usage	Visibility And knowledge	Connectivity and Knowledge
Manager in LightComp says: *"Internet-of-things is the heart of what we do. It underpins our lines of smart products, services and solution.."* *"…delivers insights to the customer on energy consumption*	Operations (System 1)	IoT underpins lines of service./solution. ***Knowledge about consumption*** Delivers insight	Insight about consumption	
Manager in ATMComp says : *" The store owner or manager do not need to worry about anything. We will take care of it. The sensors are there to* ***capture data about performance*** *and how it is used. We*	Operations (System 1)	We take care of things.	Monitoring **Knowledge**	

can detect bad behaviour and …even fraud". *"We analyse every data … that way **we know** whether it profitable or not.*	Identity and Purpose	**Knowledge about performance** Analyse data		
Manager from ATMComp says *There is a sensor in the machine …**allows us to detect** when something is wrong….we can see it here. we do this everytime….monitor …the customer need not to worry as we take care of it.*	Operations (System 1)	Detect everything that is wrong. **Knowledge about what is wrong**		
Manager from CompanyDoc *"We leverage our innovative technology to create intelligent system that increases efficiency and effectiveness in our clients' business"*	Operations (System 1) Identify and Purpose.	Technology Knowledge that increases efficiency/effectiveness	Knowledge	Technology Knowledge enable effective and efficient in-service delivery
Partner1 says *"..access to a variety of mobile and cloud technologies which help to streamline customer processes"*	Operations (System 1) Identify and Purpose	Streamline customer processes.	Tech and Effectiveness	

Customer1 says *"…it is an office assistant kind of thing"* *"…saves us plenty of time and …in fact costs"*		Office assistant Money saving and time saving	Adding value to client business	
Manager from CompanyDoc *"… know what your business needs and we will help you to perform them, or we perform them for you effectively and efficiently"* *"another thing that has worked for us over the years is our customers is Trust. We have earned the trust of our customers…*	Operations (System 1) Identify and Purpose	Business needs Knowledge about clients business Trust from customers We earned the trust	Knowledge of customer business needs	knowledge of customers' business is key to delivering value to customers

…you asked how we earned the trust? Knowing the customer. Customers want to be understood…." *"they are not interested in people trying to upsell them or exploit them. When you earn the trust of customers, the sales flow..because they trust you to do the best for their business.."*		Trust from customers . Know customer's business Customers want to be understood. Customers wary of sales pitches or exploitation Sales and demand increase due to trust	Knowing your customer earn you trust	

Table 10: Coding Process for theme: extension of capabilities to other parts of customer's business

Quotes	Initial codes	Basic Codes	Rationalised codes	Themes
LightComp says. *" There are many things we can help businesses achieve. Not just light and smart cities. We have moved into areas that are interesting with IoT…..* *…we just need to convince customers about the potentials of these technologies".*	Operations (System 1)	More things they can do for clients. Areas with IoT Customers need to be convinced about potential	Let customer know we can do more with the tech we have	**Doing more for the customer's business** **Solutions enabled by Technology allow provider to extend capabilities to**

Manager from ATMComp says *" We can provide end-to-end solutions ranging from ATM to maintenance, depository services, self-checkout, to Point of Sales service….* *depending on what the retailer wants…our goal is to create value through a unified client experience …."*	Operations (System 1)	We can do all things only if you allow us End-to solutions Create value through unified customer experience	Create value through a variety of offerings	**other parts of the customer's operations and to increase value**
Manager in CompanyDoc says. *" our focus is …. is to exploit modern technologies like 3D-Printing, AI, …and machine learning and….Internet of things to drive growth..* *These days, we can build models that can help us to analyse and understand behaviour and make predictions…We want to help our clients to do what they do..even more effectively*	Operations (System 1)	We have enormous IT fire power to help our customer. Exploit Modern technologies Drive growth with tech	Modern techs allow us to do more	

Quotes	**Initial codes**	**Basic Codes**	**Rationalised codes**	**Themes (proposition)**
Sales staff from Partner1 *"We ensure that partners sell only what they want. That is,… we do not want our brand to be affected by poor customer service because one of our partners had no knowledge of the offerings"*		Freedom to sell whatever we want Avoid poor customer service and brand damage.	**Solving problems locally using knowledge**	**Autonomy, knowledge and flexibility to solve problems locally.**

		Poor knowledge could damage the brand.		
According to Partner1: ***"****A customer requested for ….capability that was not part of the contract…. Specifically, the customer requested for the capability to scan multiple copies of documents simultaneously. Since the hardware capability cannot deliver that outcome, the conventional response would have been to replace the machine with one that could deliver the requested capability. …This would seriously cause disruption for the customer-agent.* *However, due to a decentralized mode of problem-solving, we were able to develop an app which could deliver that capability…. The app was then shared with other partners in the network through the app studio.."*	Operations (system) 1 Operations (system 1) Management (System 3-cohesion)	Decentralized problem solving Ability to solve problem. Solve problem using app. Decentralized problem solving	Decentralized problem solving using tech	**Autonomy, knowledge and flexibility to solve problems**
Manager from CompanyDoc *" We give you almost everything you want – training, materials, information, ..so that you can be the best you can, …eh we also allow you to charge your prices so you not make a loss"*	Management (System 3-cohesion)	Empowered with resources. Supported with large number of resources. Opportunity and reward	Empowered with resources to solve problems.	

" we use tiered system..loaded with opportunities and ..we also reward performance"				
Manager at Partner1 says ***"**We are supported with a large number of resources – marketing, training, business development…even financing sometime…* *"in fact ..they empower you to succeed. You have the room to steer the direction of your business based on your capacity… it is very good"* *"They help with sales and marketing effort…"* *"the portal has stuff – logo, badge..these are reconfigurable and partners are allowed to use them …to advertise the partnership*	Management (System 3-cohesion) Operations	Supported with large number of resources. Marketing, training, and business development Empower to succeed.	Empowered with resources to succeed.	**Autonomy, knowledge and flexibility to solve problems**
	Management (System 3 - cohesion) Operations	Can steer the direction you like.	You are in control of your success.	
		Marketing, training, and business development Portal has stuff for use	Empowered with resources to succeed.	
Manager in LightComp *" We partner with companies around the world.. to help deliver our innovative products, service solutions …"*	Management (System 3 - cohesion)	Partner with companies Equip them with resources	Empowered with resources to succeed.	

" We equip you with the tools and resources you need to succeed and meet customers ' specific needs"		Equip them to succeed		
ATMComp manager *" We have well-trained field service technicians and agents. We support them with training and benefits ..* *"Importantly, we empower them to look out for preventative measures , raise issues and serve as an ambassador for us …"*	Management (System 3-cohesion) Operations	Well trained service technicians Support them with training. Empowered to succeed	Empowered with resources to succeed	**Autonomy, knowledge and flexibility to solve problems locally**

Table 11: Coding Process for theme: Recursion

Quotes	Initial Code	Basic codes	Rationalised codes	Themes
***Manager from CompanyDoc*.** *" We are almost everywhere; except we do not want to be there…(laughs). Since we operate through agents and partners, we can bring our services to our customers and prospective customers".*	Operations	Presence almost everywhere Operate through agents. Bring services to customers everywhere	**Ubiquitous**	**Recursion**
CustomerDoc says. *" you can literally find them everywhere. There is somebody somewhere selling their stuff"*	Operations	There is seller close to you	**Proximity**	
Manager in ATMComp says: *"What do you want… which type of business do you run? We can do a lot of things for the business. We provide solutions to large retailers, small shops, hospital, large complexes, government buildings.* *" There are dedicated teams for each type of business.."*	Operations	What type of business you have, we will serve you Solutions for all types of customers Dedicated team for each business	**Global spread** **Diversity of offering**	
Partner 1 says: *" Being a part of the partner's program offers a wide array of opportunities for my business. The portal is great for information. I communicate with other partners*	Operations	Being part of partner's program Communication on the portal	Communication up and down the chain	**Recursion**

and receive communication from several people up and down the chain..”		Communication from up and down the chain		

Table 12:Coding Process for theme: Customer Feedback and Knowledge

Quotes	Initial Code	Basic codes	Rationalised codes	Themes
From CompanyDoc Manager *“We aim to understand our customers better so we can meet their needs….Including the demand of their business*	Operations (System 1)	Understand customers’ needs	Understand customer through feedback	Customer feedbacks increase our knowledge and capacity to deliver value.
From CompanyDoc Manager *….want to understand them more… we welcome feedback ..”*	Operations (System 1)	Want to understand more		

"..there are legions of questions and answers in the online blog, portal and customer service and support forums" *…We have invested heavily in growing the knowledge base through the feedback, questions, queries and …even complaints we get"*	Operations (System 1)	Questions and answers in the customer service and support forums Grow knowledge base	Robust repository of customer feedback	Customer feedbacks increase our knowledge and capacity to deliver value
From Partner1 *"..[ ] feedback help us to know what we are doing right or doing wrong"* *"….feed that information into the system..to improve our services, products and..eh "*	Operations (System 1)	Feedback increases our knowledge. Feedback is entered into the system	Increase our knowledge through the feedback	
Manager from Partner1 *".there are thousands of questions and answers in the portal, which help us to resolve any issues that we face".* *..a call to support gets an issue resolved without delay"* *"…if there is a problem, it must have been solved somewhere.*	Operations (System 1)	Questions and answers help us to resolve issue. Quick answers from support		

		Availability and accessibility of answers		
Manager from Partner1 *"during assessment, we look out for what is stated and not stated. Many customers do not know what they want or what is the best option for their business"*	Operations (System 1)	During assessment look out for spoken and unspoken Are customers ignorant of their requirements	Identifying customer needs	Customer feedbacks increase our knowledge and capacity to deliver value

Table 13: Coding Process for theme: Collaboration for innovation

Quotes	Initial Code	Basic codes	Rationalised codes	Themes
CompanyDoc Manager says: *"We have this fantastic platform and digital architecture …where partners and independent developers can create super-apps… No they may not be our employees. Some partners with app development capabilities can do that.* *"the partner can choose to sell it in the App store..well call it studio… we check that it is not a malware* *"there are plenty of tools …on the platform and it integrates well with third-party tools.."*	Mata-System Adaptation Environment Mata-System Adaptation	good platform where everyone can create something. Agents as innovators Can sell app created. Platform integrates with third app.	**Platform integrates new capabilities.** **Interoperability**	**Collaboration for innovation**

"We partner with developers, programmers…These are third party agents" *" visit our website. There are several programs for agents of all types"* *"we want to add more services, functionality to our devices and platforms..hence we make it compactable for third parties to collaborate"*	Environment	Different programs for different type of collaborators New services from compactable platforms	**Working with others to invent new things**	**Collaboration for innovation**
Partner1 says: *Partners with app development capabilities can create applications to support their clients. …they may choose to use it locally or share with others via the app store."* *..CompanyDoc gets a cut…"*	Mata-System Adaptation Environment	Create app yourself or do it with others		
CompanyDoc Manager said*:* *We are continuously 'searching for' feedback from our global partners through a series of channels - advisory councils, partner meetings and partner surveys. …….latest developments in the environment including latest technology, prospective customer needs,… is fed into the system"* *Information about what customers are prioritizing, the changing way form of work -mobile printing, cloud storage and printing, remote printing, and scanning, paperless workflows, digitalization, data recovery, security, format document"*	Mata-System Adaptation Environment Operations	Search for feedback from global partners Feedback from channels Recent technology Technology fed into the system. collect information from everyone down the chain	**Information down the channels driving innovation**	

ATMComp manager says *"the world of payment has gone digital. We do payment, POS, Self-checkout, Self service booth… We have partnered with FinTech company to integrate new knowledge and capabilities to deliver new solutions*	Mata-System Adaptation Environment	Changing world of payment Partner with fintech company Integrate new knowledge	**Exploit new opportunities via collaboration with other companies**	

3.6 The Credibility of Research Findings

A very essential part of a research design is the issue of credibility of findings. Credibility of research findings address the question: do these findings and conclusions stand up to scrutiny? Paying a close attention to two areas of the research design: reliability and validity is a way to reduce and possibly avoid the possibility of getting the answer wrong (Saunders *et al.* 2012).

Yazan (2015) admits that a researcher's philosophical viewpoint and worldview influences hugely the notions of validity and reliability in research inquiry. Qualitative research authors like Merriam (Merriam 2009) and Stake (Stake 1995), who take a constructivist viewpoint argue that reliability and validity is not possible. However, both authors point to the need for triangulation: data source triangulation, methodological triangulation , investigator triangulation and theory triangulation (Stake 1995) and (Merriam 2001) outlined various strategies to enhance internal and external validity and reliability to build safeguards against self-delusion into the process of data analysis.

- Internal validity: This includes, long-term observation, triangulation, disclosure of researcher bias, member check and peer examination.
- External validity: use of thick description, typicality or modal categories, and multi-site designs.
- Reliability: explanation of investigator's position with regards to the study, triangulation, and use of an audit trail.

Yin (2003), who takes a positivist viewpoint, outline the importance of construct validity, internal validity, and external validity as well as reliability as being essential to judging the quality of a research. According to (Yin, 2003), to ensure internal validity, the use of established analytic techniques such as pattern matching is important; to ensure construct validity, triangulation of multiple sources of evidence, chains of evidence, and member checking can be used; and to ensure external validity, analytic generalization can be used. A check on the case study protocols can be used to check for the reliability of the procedures and findings.

Although Patton (2002) and Yin (2003) use the term "reliability" and "Validity", Guba and Lincoln, (1994) argue that the criteria for qualitative research should be Dependability/Consistency, Neutrality/Confirmability and applicability/transferability. The authors emphasize that dependability can be used in place of reliability. Since this is qualitative research, the quality criteria selected is adopted from (Guba and Lincoln 1994)

3.6.1 Credibility

This is concerned with the trustworthiness of the research and how believable it is. It relates to how conclusions are arrived at based on participant's original data (Korstjens and Moser 2018).

- Prolong engagement – In addition to the interviews, there were multiple back and forth communication between the researcher and the interviewee, either to clarify or buttress points that have been made previously during the interview. The use of emails (Burns 2010, Pearce *et al.* 2014) provided an opportunity to the researcher to ask follow-up questions. Answers provided via emails were elaborate and complementary to the insights gained during the interview. The researcher studied these information sources to grasp a large picture of the processes underlying the provision of service.
- Triangulation – Methodological triangulation was used to collect data from multiple sources – interviews, emails, websites, industry newsletter. Systems dynamics diagrams were checked by attendees at the 2018 Winters Simulation Conference.
- Conformity – The viable system model was developed based on quotes. Extended observations were not possible.
- Member check – Some of the completed VSM models were sent to the main participants in the cases 1-3 for feedback and to provide an opportunity to correct any misinterpretation. The member check was backed a questionnaire.

3.6.2 Transferability

This is concerned with the aspect of applicability. Here, the focus is on the research process and the selection of participants, which are both essential for a reader to draw conclusions. Adequate care has been taken to provide a clear description of the cases, their content, specific scenarios, broader influences, settings, main interviewees, and interview questions. In building the VSM, additional information transcending those that are associated with the main organisation were provided in order to provide context and a bigger picture.

Further, the approach and strategy applied in this research has been described and justification for their selection explained. Like in most qualitative research, generalization and transfer of findings do not apply. Each case company is different, and each PSS customized to the requirements of a specific customer (Settanni *et al.* 2017, Korstjens and Moser 2018)

3.6.3 Confirmability and Dependability

Confirmability assesses the extent to which the conclusions are the most reasonable ones confirmed from the data (Miles and Huberman 1994). This connotes consistency in design standard (Guba and Lincoln 1994). On the other hand, dependability means the interpretations need to be grounded in data and not on one's subjective preferences or viewpoints.

In terms of confirmability, the VSM model sent to the main interviewees to ensure that their interpretation matches the content of the VSM. The VSM and systems dynamics model is rooted in the information provided by the participants and from other available sources of information .

For dependability, all the interviews record, transcripts and coding are available. To avoid observer error and bias. The thematic analysis was conducted by a second researcher who used the same codes on MAXQDA and arrive at the same conclusion. This exercise was also useful in enhancing the reliability of my data analysis and findings.

Furthermore, data collected are available for testing and re-use. The methodology used in this research is stated explicitly and is well-documented. Multiple cases were used and triangulated to identify similarities as well as dissimilarities between industry. Multiple sources of data were used: both from primary and secondary sources, the latter serving as a validation process for the primary data. The primary data include the direct quotes of participants, which reinforces the links between the data and the findings (Saunders *et al.* 2012).

3.7 Chapter Summary

In this chapter, the research methodology has been outlined and presented. The selected philosophical paradigm and research design/strategy are interpretivism and explanatory-qualitative case study, respectively. The summary of the key choices is shown in the table below:

Table 14: Summary of key choices

Paradigm	Interpretivist
Ontology	Subjectivism
Epistemology	Interpretivist
Research Strategy	Case study
Data Collection	Semi-structured interviews, secondary data
Data Analysis	Thematic Analysis
Quality of Data	Credibility, dependability, transferability, confirmability

4 Results and Findings

In this chapter, the results and findings of the research is presented. First, the results and findings for each case is presented. The findings are presented in two folds for each case: the identification of the five functional systems and communication channels encapsulated within the Viable System Model and second, the presentation of the complexity management mechanisms across the equilibria sites in a VSM.

In chapter 2, four main equilibria sites were presented.

- Equilibria between Recursion Levels – this is underpinned by the principle of the recursive structure of a viable organisation (Beer 1979)
- Equilibria between the operational units and its local environment – This is called Horizontal homeostasis (Ashby 1961). Horizontal Homeostasis is enhanced via the principle of autonomy.
- Equilibria between Management system and operational units – this involves balancing horizontal variety with vertical eigen-variety. This is known as the vertical homeostasis (Lassl 2019a) The mechanism is underpinned by the principle of control/cohesion.
- Equilibria between the future environment and the organisation – This is the heterotactic function. This is underpinned by the concept of adaptation.

VSM as a system of dynamic equilibria allows for the exploration of structure, processes, mechanisms by which variety is processed to achieve homeostasis (the balance of variety between a system and its environment).

The results for Case 1 is presented in section 4.1, Case 2 in section 4.2 and Case 3 in section 4.3.

Figure 34: Sequence of sections in this chapter

4.1 CASE 1: Managed Print Services

Partner1

Partner1 is a privately-owned firm based in the United Kingdom. It provides a variety of printing products, services, and solutions. It is a highly rated channel partner of *CompanyDoc* Partner1 offers managed print services, hardware sales, warranty, and maintenance contracts/services. They are equipped to meet the needs of their customers.

Partner1 have their in-house field service operations team saddled with the responsibility of carrying out repairs and maintenance of hardware. Customer accounts are managed by account officers. Participants interviewed are stated in the table above.

CompanyDoc

CompanyDoc is a multinational enterprise with a presence in many countries. It is the global leader in terms of market share and in revenue in the global print industry. It is also the number provider of copiers and print services in the world. *CompanyDoc* sells, leases and rent printing machines/copiers to her clients. It has evolved its business to become an innovative solution provider that delivers value throughout the life of the relationship. *CompanyDoc* sells hardware such as photocopier, laser and inkjet printers, multi-function devices and scanners. It also provides spares to partner sellers and independent sellers. One of its service offerings is the managed print services, an integrated product service solution.

CompanyDoc runs multiple partner programs comprising a large number of partners resulting in a network of interconnected actors collaborating to create value. Partner1, Partner2, Partner3, Partner4, Partner5 are all partners of *CompanyDoc.* These are independent sellers, agents, developers. They constitute the network of partners through which products, service and solutions are delivered to customers/end users. They are at the frontline engaging with customers, particularly small and medium enterprises. They are supported by *CompanyDoc* with training, provision of hardware and software as well as innovative technology and access to its platform.

The case in focus is the Managed Print Solution provided by Partner1 to CustomerDoc1. However, the other partners were interviewed to a get a broad picture of the influence the wider network exerts on the solution/service delivered to the end-user.

Managed Print Solutions: PSS Contracted to Deliver Cost Savings and Boost Productivity

A Print Managed Services contract is an outcome-based contract whose content include asset availability, repair, and maintenance to optimization of the whole IT configuration of the client's business operation. Offering is tailored to client business requirements and needs. The client uses the outcomes derived from using the solutions offered to achieve its own goals (cost savings and reduction in print cost). Often the client's digital footprint and coverage is reviewed prior to the deployment a customized and tailored PSS solution (with clear details of components and services). Service coverage often cover the client's entire ecosystem associated with output devices.

A typical Managed Print Services contract is executed through a system consisting of a tangible product (device) and spares with a range of intangible services that include device monitoring, maintenance, equipment replacement, supplies, helpdesk support, device network, configuration of print environment and network, the supply of cartridge, ink and toner as well as remote monitoring to track device usage. Payment is based on print volume (i.e., cost per copy). All at a fixed fee. That way, clients have a stable and predictable operating (OPEX) with zero capital expenditure (CAPEX).

MPS promises cost savings of about 30% of customer's current printing costs. The procurement of managed print services involves a paradigm shift from the traditional commoditized approach to print, scan and copy asset and function acquisition and procurement.

CustomerDoc1

This is a business organisation that has engaged the services of Partner1 to supply managed print service solutions. Prior to engaging the services of a Partner1, printing cost contributed significantly to stationary overhead, resulting in *Customer1* to spend above budget annually. *Customer1* wanted to "tame" print cost as it was "eating deeply" into the annual budget. For *Customer1*, printing, scanning, and copying were used in the day-to-day running of the business. The value proposition offered by Partner1 was the promise to reduce print cost by 30%.

4.1.1 Identifying the Purpose of the System

According to Beer, the purpose of a system is what it does. In this case, the definition of the purpose of the system depends on the context and specific role/designation of the participant (provider, technology company, customer, parent company). Speaking to multiple actors within the PSS, the purpose of the PSS can be described as

"A collaboration between Partner1 (a Gold Partner of CompanyDoc, a technology company known globally for its innovative products) and Customer1, relating to the provision of managed print solutions through the integration of print devices, software, consumables and services, to achieve a coordinated documents processing resulting in cost savings and boost productivity.

4.1.2 Unfolding Complexity and Recursion: System of Focus

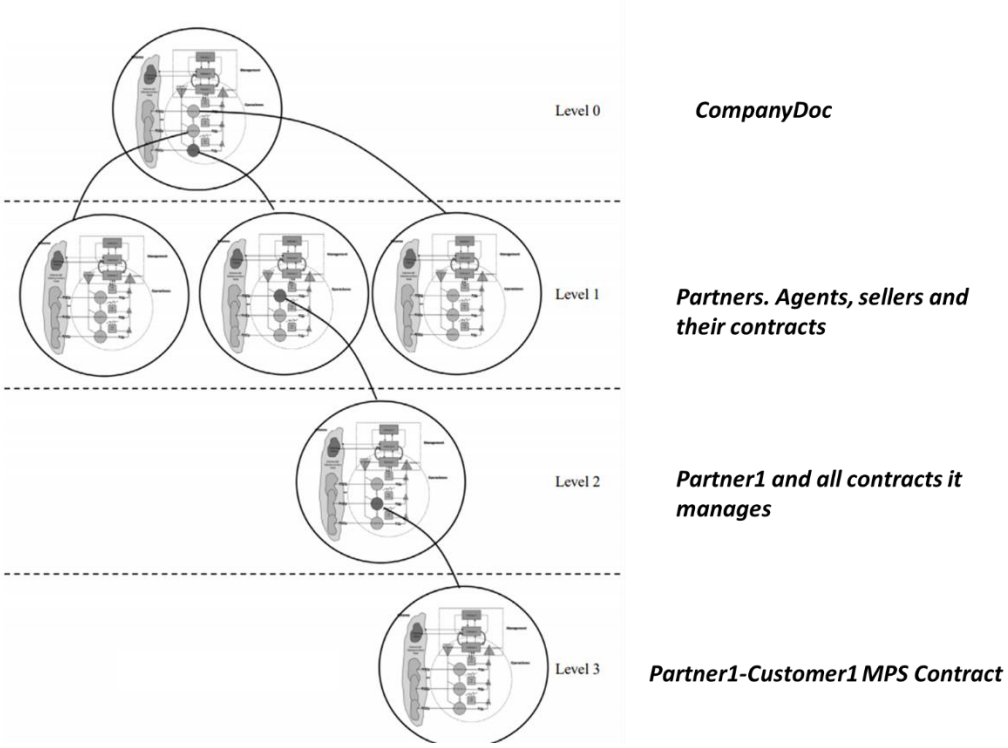
This is concerned with identifying the recursive and autonomous levels of the PSS system. Managed Print Service involves a collaboration between *Provider1 and Customer1* at a dyadic level. In fact, it is a partnership rather than a transactional provider-customer relationship. The customer is endogenous to this relationship. CompanyDoc is a global company with presence in all 7 continents. Its recursion is based on customer markets segmented along geographical dimensions (Hoverstadt and Bowling 2005, Hoverstadt 2010, Ríos 2010). It acknowledges that different customers want different things – product, service and solutions

The following recursion levels were identified for the PSS. The PSS encompasses all activities and organisations involved in the service delivery process – whether directly or indirectly, remotely, or closely.

Recursion level 0: *CompanyDoc* at the global level

- Recursion Level 1: **–** This consist of all partners, agents, and sellers contracts.
- Recursion level 2: One partner and all contracts it manages.
- Recursion level 3: *Partner1-Customer1* MPS contract

Figure 35: Recursion levels



Two recursive levels were examined in this case. For recursive level 3, the system of focus is the *Partner1-Customer1* MPS Contract. For recursive level 0, CompanyDoc was evaluated. The next step is to outline the five systems of the Viable Systems Model.

4.1.3 Primary Activities (SYSTEM 1)

The primary activities make up the Operations of a viable system. These activities are important and fundamental to the purpose of the PSS. At the recursion zero level, the main activities include:

- ✓ Production of products – production of monochrome and colour system for a variety of customers environment – enterprise printing, transaction printing and production publishing
- ✓ Sales of office devices – the sale of printing, scanning and copying devices and systems to national, regional and small and medium commercial customers

- ✓ Services and Solutions – these are a variety of services and solutions delivered in the form of contracts.

The Managed Print Service Solution falls within the service and solution business segment of CompanyDoc. A traditional MPS contract is characterized by three operational activities.

- ✓ Assessment – This includes a thorough analysis of the customer print requirements.
- ✓ Installation of devices and systems – this involves the identification of most efficient mix of hardware and software for the customer organization.
- ✓ Management and Support – These include maintenance of devices, repair and replacement of parts, the supply of consumables, updating software and the monitoring of devices.
- ✓ Optimization – This is a review function focused on recommending essential improvement for productivity, cost savings and efficiency.

A manager in Partner1 says:

> "*We assess the needs and requirements of prospective customers. Our sales team arranges a meeting ….sometimes there may be more than one meeting. The aim is to understand the business of the customer".*

> *"Understanding our customer is very important. We must get it right; else our reputation suffers down the road…. When we understand what a client needs then we identify the mix of devices and applications that can be tailored to meet the needs of the client"*

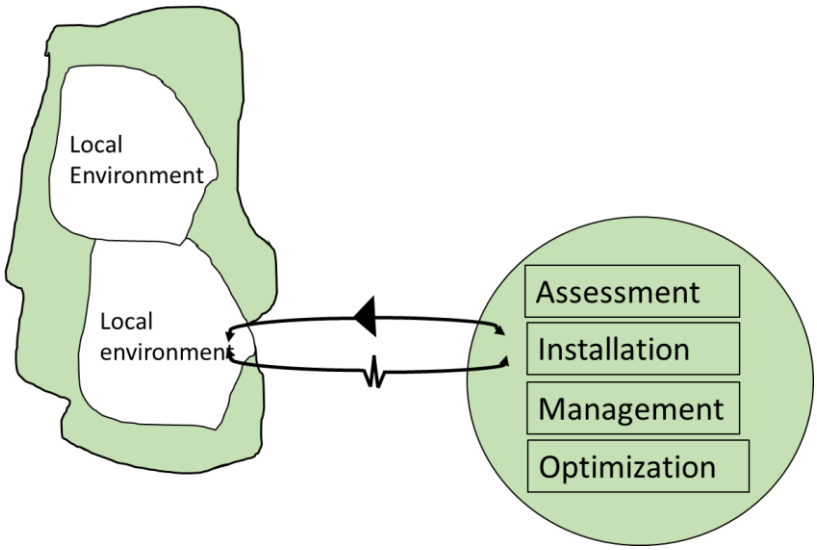
> *" No. it is not a static process. We also manage the repairs and maintenance as well as the supply of ink. ….update software and install new programs"*

At the local level (recursion level 4), the management of this operational units include the project manager/account manager, who plans, controls and monitor the delivery of MPS provision and manages the supply of hardware and software. The project manager manages a whole variety of other functions such as driving sales, involved in the budgeting process, invoicing and billing, asset management and collections. The project manager works with

other individuals within the team – field service representatives, account officers, sales team members.

In a managed print service scenario, operations transcend activities at the provider-customer interface. There a legion of indirect activities taking place within the wider network of actors comprising partners, agents, maintainers organisations, apps and software developers, business development organisation, who work behind the scenes and far away from the local provider-customer space.

Figure 36: Operational units (Managed Print Service)



Variety in the environment include product obsolescence, prices of parts, changing needs of customers, customer affordability issues, competition.

Customer1 says.

> "*Price is a real concern. We want to reduce our cost. We are always looking at different suppliers for better value".*

Manager in Partner1 says

> *" Our goal is to help customer achieve cost savings".*

"we take over the burden of managing their printing and business processes and make it very efficient…. The goal is to demonstrate to our clients the value we deliver….although some clients highlight about prices and affordability.

4.1.4 System 2 – Coordination

The account manager coordinates the activities of the operational units, issues directives and schedules activities of the operational units. The project manager works with the operations managers or procurements teams in customer or client organisation. Sometimes, an account officer is assigned to manage client account depending on the size.

The Ops Manager in *Customer1* deals directly with the Account Manager in *Product1.* The Ops Manager in *Customer1* ensures that consumables and print papers are available at each print station to avoid conflict over resources. The Ops Manager also ensure invoices are raised by the Account and Finance unit, organizes training where necessary.

At the *Partner1* end, the Account Manager for the PSS contract, coordinates the management of operations and optimization procedures. This is carried in liaison with other teams within *Partner1* (Technician, Sales, Procurement, Accounting and Finance). Account Manager ensures consumables are dispatched accordingly and schedule for the maintenance of devices are created and followed.

The Account Manager at Partner1 says:

"*I have overall responsibility for the delivery of unrivalled service to our clients. I work with a bunch of very hardworking staff, who are dedicated to the ethos and values of the company".*

"I schedule appointments for our field service agents depending on the signals we get from the field".

"The remote monitoring app helps us to understand how the machine is used and to schedule inspection, update, upgrade and repairs".

4.1.5 System 3. Control

The control function was managed by both the Account Manager in *Partner1* and Operations Manager in *Customer1.* The governance of service delivery and provision were embedded within an operational manual and presented in contractual documents. This document provided a clear outlay of the targets, deliverables, expectations, and responsibilities. The control function was more of a collaborative effort between CompanyDoc/Partner1 and her clients/Customer1/Customer2.

First, CompanyDoc/Partner1 ensured the activities or processes of each of the operational units (service provision) are carried out seamlessly. This involves accessing to the device for repairs and inspection when required, managing the supplies of consumables, managing monthly invoicing and billing, managing the budget associated with service provision, providing training to Customer1 if necessary. The account managers managing MPS contracts in CompanyDoc/Partner1 maintained a record of each contract, the deliverables and resource consumption of each contract. Accounts Managers/Project Managers work closely with other IT partners (particularly when providing services to clients in distant locations) and operations manager at Customer1 and other clients to achieve contractual outcomes.

The Operations Manager in Customer1 monitored print usage according to each unit/department's needs/requirements and amend print volumes as the need arises. The Ops manager worked with other unit heads to ensure the document workflow between departments operates seamlessly without hitches. The Ops Manager managed authentication issues, issues privileges and access, creates usage accounts on devices, relocate print stations where necessary and print volumes and cost according to department/unit usage levels. The ops manager also set up rules relating to the use of the machine However, the Ops Manager did not have enough 'powers' to dictate or control the print requirements or processes of operational units (that is, other departments within *Customer1*). Monthly print volume is allocated to each business unit and if there is need for more, it is negotiated between the Ops manager and Unit head.

The Operations Manager at *Customer1 and* Account Manager in *Partner1* were in constant communication to explore how both operational units (production and consumption units) can be optimized to deliver more value. Integration of existing IT infrastructure and print technology was an area of concern both parties worked on. *Customer1* ensured that *Partner1* was paid according to the terms and conditions of the contract. In return, it monitors the level of service performance by *Partner1.*

CompanyDoc allows its partners and agents the freedom to manage their businesses and set their prices. It provides partners with training, marketing, financing, and support to manage their business. In return, CompanyDoc provides a variety of reward programs like sales rebate, market development and investment, depending on the performance of each partner.

4.1.6 System 3*: Audit

The monitoring app provided visibility to all parties on print volumes, print level, device usage, nature of usage. There were instances where a direct intervention by the Ops Manager was necessary to stem the use of the device for personal printing or to curb waste. As the volume of business changed, there was the need to review the set of deliverables assigned to each aspect of the contract.

The IoT-enabled Dashboard provided greater visibility to all business processes. It placed Clients/Customer1 in charge of its consumption, management of its spending and the monitoring of its costs.

4.1.7 System 4 and 5 – Intelligence and Policy

The policy making decision role is shared by the CEO, Ops Manager, and other Units heads in *CompanyDoc*. CompanyDoc considers itself as a technology company and values the feedback it receives across the whole company and online channels.

The focus of System 4 is not to scan the operational environment but the future environment at the strategic level.

For *Customer1,* a change in demand for its own service could impart future profitability and affordability of managed print service. When the demand for the services of *Customer1* slows or increases, it affects the operations of *Customer1* either positively or negatively. *Customer1* reviews its business requirements and makes forecast based on available information. Some of the markets that *Customer1* serve is unpredictable, hence it is sometimes difficult to plan ahead.

For *Partner1,* issues in the future environment take the form of a new technology, and changes in the future requirements of its customers, which could impact the affordability of the PSS. *Partner1* receives a huge amount of support from CompanyDoc. In terms of policy , what gives

the PSS its identity is what has been agreed in the contract. The outline of responsibilities, terms and conditions, requirements, and penalties, without which there is no PSS.

Figure 37: Schematic diagram of the relationship between elements of the managed print service PSS

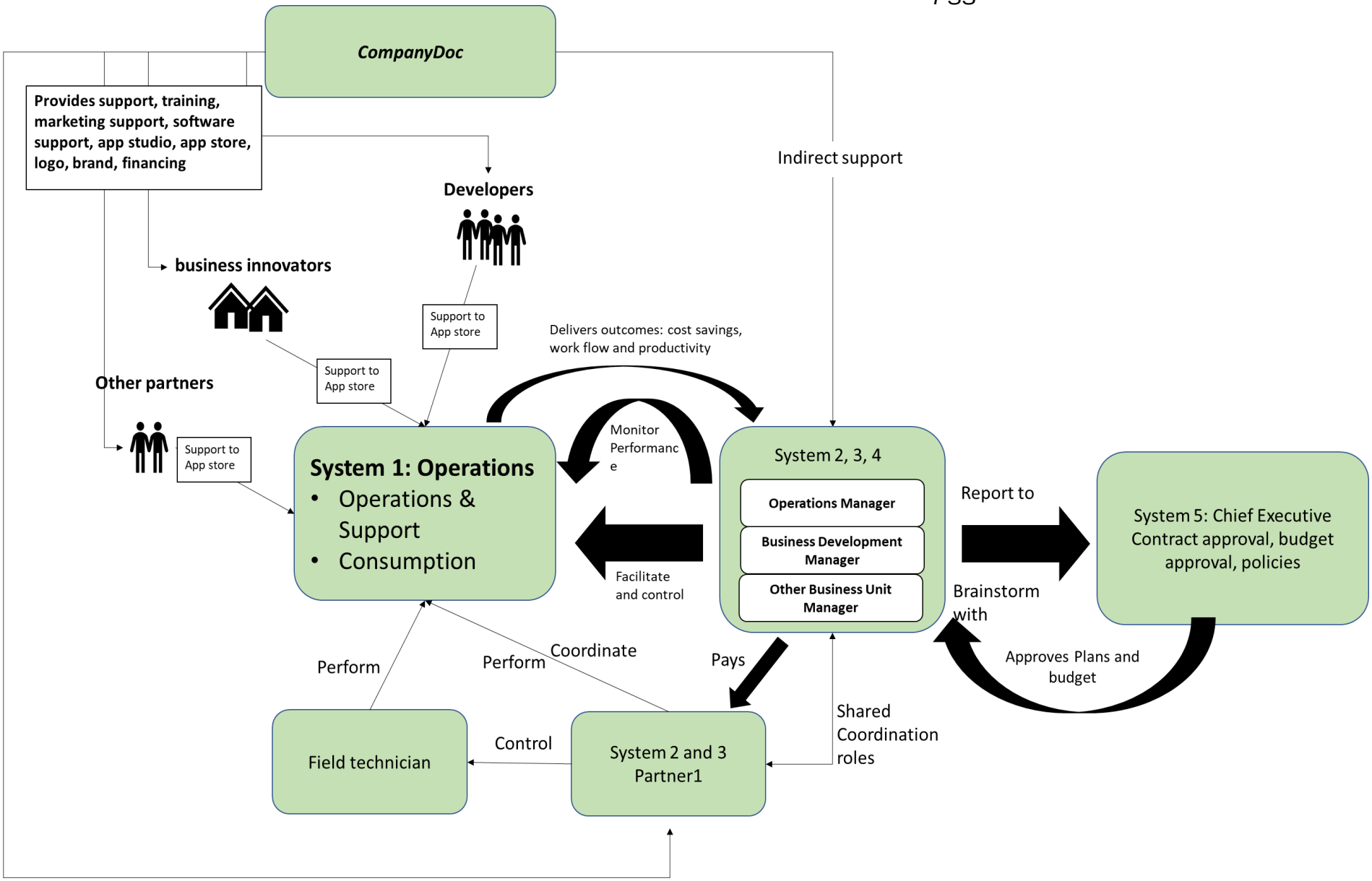
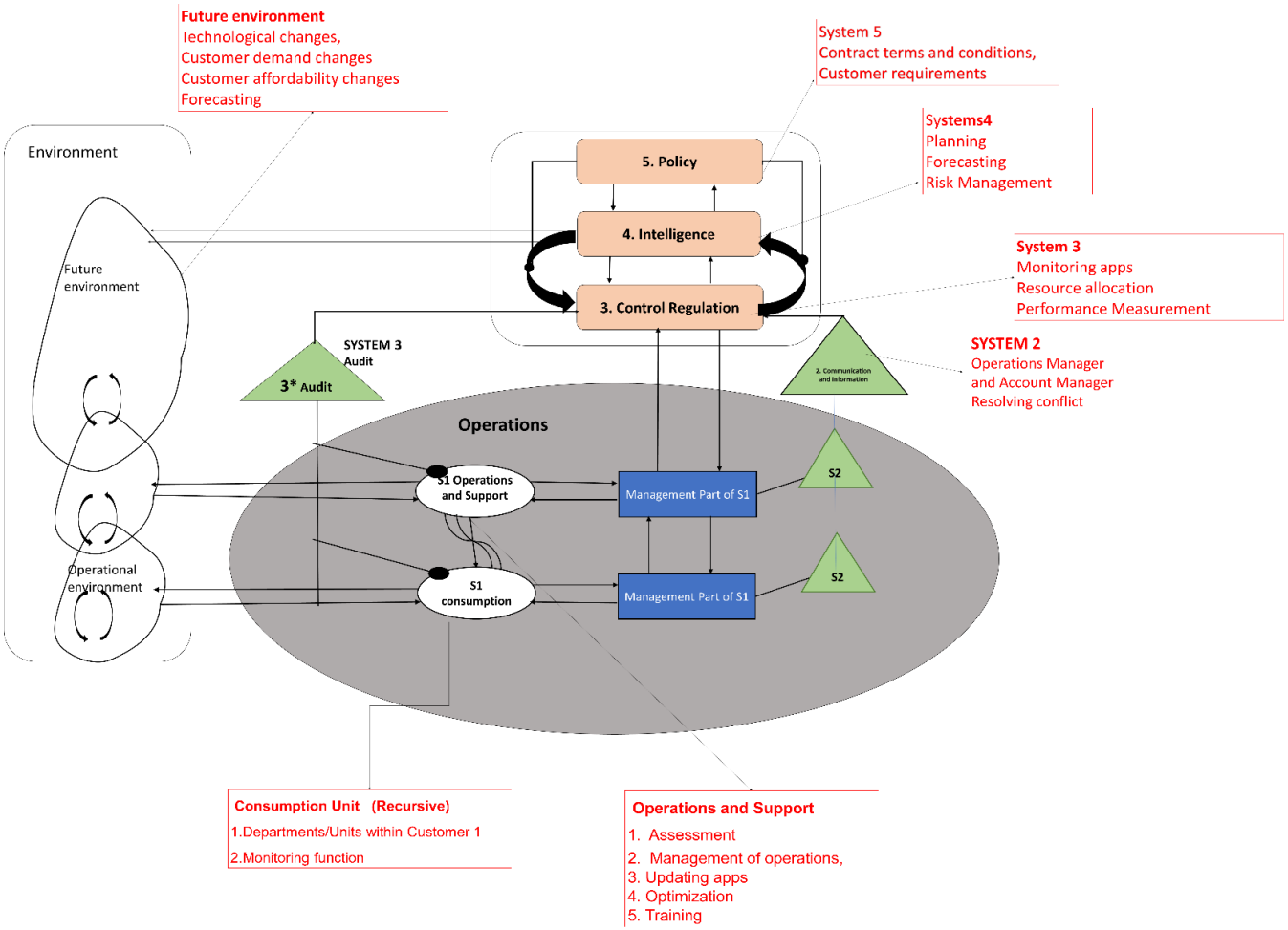


Figure 38: The VSM of ManagedPrint Service PSS at a recursive level



Complexity Factors

- Device failure
- Customer unable to define requirements.
- Context of use -minor
- Overpricing
- Competition

Variety Operators

- IoT Dash boards for monitoring
- Connected device for control.
- Analytics
- DIY resolution
- Extending solutions to other areas of the business (workflow)
- Ecosystems

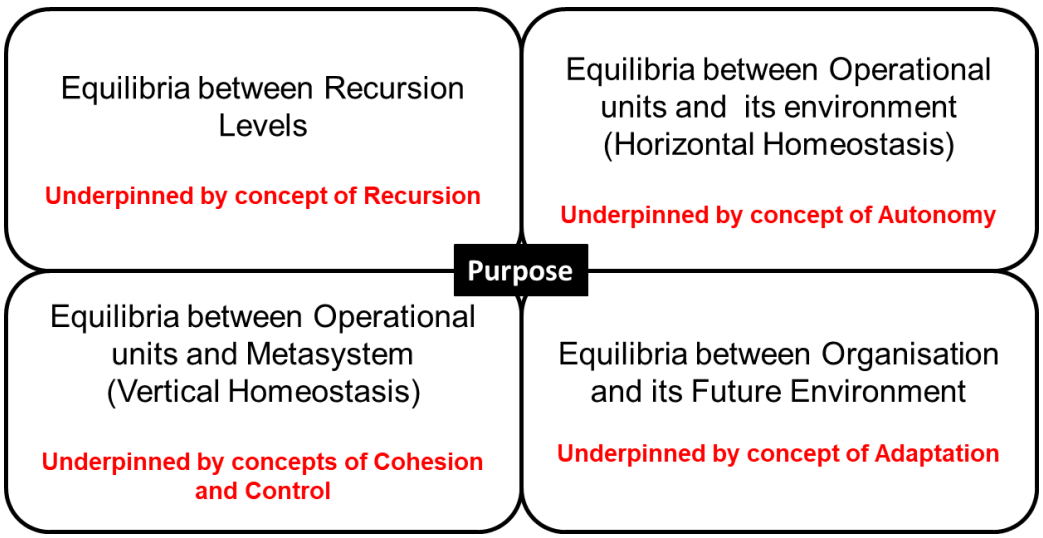
4.1.8 Applying Variety Engineering to the Case 1

In the literature, it was pointed out that the VSM manages complexity using Ashby's Law of Requisite Variety (Ashby 1956) , which states that variety is absorbed by variety . The Law of requisite variety provides a foundation for the design of complexity management strategies and attenuators and amplifiers to manage variety.

Four equilibrium sites were identified in the VSM.

- Equilibria between Recursion Levels – this is underpinned by the principle of the recursive structure of a viable organisation (Beer 1979)
- Equilibria between the operational units and its local environment – This is called Horizontal homeostasis (Ashby 1961). Horizontal Homeostasis is enhanced via the principle of autonomy.
- Equilibria between Management system and operational units – this involves balancing horizontal variety with vertical eigen-variety. This is known as the vertical homeostasis (Lassl 2019a) The mechanism is underpinned by the principle of control/cohesion.
- Equilibria between the future environment and the organisation – This is the heterotactic function. This is underpinned by the concept of adaptation.

Figure 39: The four Variety Engineering processes of the VSM



4.1.8.1 Equilibria between Recursion Levels – this is underpinned by the principle of the recursive structure of a viable organisation (Beer 1979).

The PSS provider is a multi-national corporation and is well diversified. It maintains a robust layers of business offices around the world. For each continent, there are multiple regional offices covering a specific region within the continent. Furthermore, each country is headed by a country-coordinator.

A Global Network of Independent Agents and Partners

The provider uses a large network of agents, which it calls partners. These partners are classified into tier-system depending on the nature of business, type of industry, volume of sales, size of business, and capabilities of the partner. With a large network of partners, customers can locate the service of the provider not far away. This is from one of the manager*s of CompanyDoc*.

> *" We are almost everywhere; except we do not want to be there…(laughs). Since we operate through agents and partners, we can bring our services to our customers and prospective customers".*

A strategy used by the PSS provider is to engage independent retailers as partners. This means, the partner is not employed by the PSS provider; however, the PSS provider provides a large spectrum of support in the form of marketing, training, financing, branding and market research. Another sales and account officer *from Partner1* says:

> *"We ensure that partners sell only what they want. That is, we do not want our brand to be affected by poor customer service because one of our partners had no knowledge of the offerings".*

Another senior manager from CompanyDoc said about autonomy.

> *" We give you almost everything you want – training, materials, information, ..so that you can be the best you can, …eh we also allow you to charge your prices so you not make a loss"*

Using a large network of partners allows the PSS to target specific markets with its unique set of solutions. Partners are only trained in the offerings they provide. That means partners are specialist and expert in what they provide – whether product, service, or solutions. The PSS provider maintains a large database that is accessible to members of the public. Prospective

customers can find information specific to their requirements - what a partner offers and the location of the partner.

CustomerDoc says.

> *" you can literally find them everywhere…..There is somebody somewhere selling their stuff" ..*

Sharing of Resources Between and Across Recursive Levels

Through the sharing of resources and the support offered to partners, variety is transferred and processed at the partner interface while management handle residual variety. Only a little amount of variety gets to management since most have been dealt with already at the partner level.

The sharing of resources is particularly helpful to the way CompanyDoc does business. There are robust channels of communication between the various levels of recursion. As a technology firm, information flow is organized systematically to drive the sharing of knowledge. At the partner level, the partner portal provides a medium for communications from every level of management and from other partners/agents. Examples include the release of new products, the roll out of new services, information relating to how to address specific problems, ideas on winning new businesses.

Partner 1 says:

> *" Being a part of the partner's program offers a wide array of opportunities for my business. The portal is great for information. I communicate with other partners and receive communication from several people up and down the chain.."*

Viable Businesses within a Viable Corporation

The recursive nature of the PSS provider enables it to serve its local, national and international markets, customers, and clients effectively and efficiently. Serving its local, national, and international markets operate along the lines of geography and product/service basis. A geographical recursive structure allows CompanyDoc to offer solutions/offerings tailored to specific geographical markets. Within geographical markets, CompanyDoc serve the specific requirements for a large spectrum of customers. CompanyDoc is composed of product and

service businesses, which are themselves consist of product and service business. These businesses are viable systems in themselves as they have the five functions of the Viable System Model. Recently, CompanyDoc have spined off some of its service and integrated solution business into separate businesses, with the aim of conferring greater flexibility in responding to the demands of its markets, growing the business, and increasing profitability.

The intersection between the geographical and product/service recursive levels provides CompanyDoc with the capability to leverage the knowledge of its local market to enhance its product and service offerings, which is then deployed to local, national and international markets in a cycle of observe, learn, create, deploy.

Table 15: Variety operators and attenuation and amplification

Variety Operators	**Variety Engineering**
1. Multiple partners around the globe	Amplifies the response capacity of the PSS, by increasing its presence around the globe. Organising the business into regions and recursive units provides a mechanism to attenuate the variety and diversity of its market size and customer requirements. On the other hand , it allows the provide to deal with residual variety while amplifying its response through the partners. Increased flexibility
2. Directory	Allows companyDoc to specify the range of solutions/products and services it offers – attenuating the variety associated with customer requirement.
3. Each partner offers a specific range of offering – whether product, service, or solutions	Attenuates the variety arising from the diversity of customer requirements so that customers understand the range of offering available. It also attenuates the probability that customers might be confused by the multiplicity and diversity of its product range.

4. Maintaining a database of partners	Amplifies the reach of the PSS provider and attenuates the difficulty of serving each customer. Customer can get the information that they want through the database.
5. Recursion – Product and services basis Geographical basis	It attenuates the variety associated with the heterogeneity of customer needs and requirements and amplifies the capability of CompanyDoc to meet these needs. This enables problems to be solved locally using a combination of local and product/service knowledge.

4.1.8.2 **Equilibria between the operational units and its local environment**

The main equilibrium of system 1 is the one between the operating units of the PSS and its environment. In the traditional Viable System Model, the customer is exogenous to the operations of the system in focus. However, for a result-oriented PSS, the customer is endogenous to the operations of the PSS. Since operations encapsulate the purpose of the PSS, it is valid to consider any barriers to achieving the purpose of the system as a variety purpose of the PSS.

Purpose of the PSS

Beer defined a purpose of a PSS as what it does. In Case 1, the purpose of the PSS is to reduce cost, achieve business efficiency and effectiveness. This purpose is implemented through the activities of its operational units (system1).

Variety

The following complexity operators were found in the data collected:

- ✓ Variety associated with reliability and availability of devices.
- ✓ Variety associated with the inability of customers to customers not.
- ✓ Variety associated with multiple and varying customers' requirements.

- ✓ Variety associated with competitor's prices.
- ✓ Variety associated with obsolescence.
- ✓ Variety associated with customer affordability.
- ✓ Variety associated with customer complaints and queries.
- ✓ Variety associated with customer passive requirements.
- ✓ Variety associated with fluctuating business cycles.
- ✓ Variety associated with range of purchasing and service options.

There is a robust ecosystem of firms drawn from upstream and downstream collaborating to design new devices, update and improve existing solution, share knowledge and to design new applications. The main PSS provider operates a digital platform which serves as the space for collaboration, resource sharing and integrating a diverse number of capabilities.

Requisite Variety, Transducers and Variety Engineering

The core of *CompanyDoc* complexity management capacity is *capacity* uses a variety of variety operators as it interacts with its clients, prospective customers, suppliers, and competitors.

1. Knowledge Management – There is a robust system for processing information and knowledge. This includes the use of forums, blogs, customer support, IoT portal and dashboard, which collects information, stores and re-use them for training for partners and agents across the company.
2. The IoT-enabled dashboard – Here customers can monitor the usage and performance of its device as well their consumptions. This way, customers become value co-creators as they are empowered to control their own consumption and cost. They can set the amount of they want to the solution they want to consume. This attenuates the high variety of manually monitoring consumption. On the flip side, providers can monitor usage of their devices and performance (attenuation) with the aim of understanding the issues like failure rate, intensity of usage, then learn to develop and improve the device (amplify).
3. Platform and App building capability - These are the collaborative service architecture, which brings people together to collaborate, share resources and integrate resources and capabilities to create solutions. The PSS provider provide the tools, while customers and developers can integrate their own tool to create solutions. A platform orchestrates the coming together of resources, which would be difficult for the PSS to

achieve without the platform (attenuate). As independent users collaborate, novel solutions emerge (amplification). The standards and rules attenuate user behaviour and amplify appropriate behaviour.

4. App gallery - This collection of easily downloadable apps is a gateway to expanding and customizing the capabilities of devices by integrating capabilities and knowledge from CompanyDoc. The App Gallery has built-in licensing flexibility, allowing customers to add, drop or switch out apps from your custom collection of workplace apps whenever their business needs change.

5. The Autonomy of Partners and Agents - Partners are trained, provided with marketing resources, product and service information, business development opportunities. Partners determine their own prices. They have access to a legion of support resources including badges, logos, new technologies.

Manager from CompanyDoc

> *" We give you almost everything you want – training, materials, information, ..so that you can be the best you can, …eh we also allow you to charge your prices so you not make a loss"*

> *" we use tiered system..loaded with opportunities and ..we also reward performance*

These platforms are powerful transducers for attenuation and amplification processes. They allow the PSS provider to engage with customers and non-customers, solve problems (since many questions have been answered already), to understand what customers needs and develop appropriate offerings.

The launch of new innovative products keeps customers and partners on their contracts. *Company Doc* reveals new set of products that enhances the performance and productivity of customers business. These stream of new provide enable customers and partners to achieve cost savings and efficiency; a situation that prevents them from going to the competitor.

Partner1 Says

> *" We received significant amount of support from ….. through the innovative product and services, they seem to develop…our customers tell us that they have saved on ink, paper, printing and most importantly time"*

Table 16: Variety operators and attenuation and amplification

Variety operator	**Variety Engineering**
ICT technologies such as website, forum, accounts (Transducers)	Enhances the capabilities of the PSS provider – it amplifies its reach and relationship with clients and customers. It helps the PSS to manage the variety of customers' requirements since customers can get the information they need from the website and forums. Engaging with customers through these forums allow customers, prospective customers, non-customers to engage with the design process. This attenuates the requirements of customers and amplifies the response of the supplier.
IoT Dashboard	Attenuates performance and use variables. Helps providers to translate and interpret user information (attenuators)
Platform The App store	Leverage diversity of collaboration, resources, and capabilities of multiple users (attenuation) to create novel solutions that are accessible via the app store (amplification). The App store creates represents central marketplace for users to sell apps that can be integrated in the devices of the PSS provider (amplification) and

	attenuates the requirements of customers since the PSS specifies the range of solutions on the app store.
Division of offerings into Product, Service and Solutions	By specifying classes of its offerings, it attenuates the diversity (high variety of customer requirements). Customer are guided by the specification of information about the company's offerings . These helps customer to choose the specific solutions they want (attenuation)
Innovation days, innovation shows	The PSS provider showcase the latest technology, receives feedback, and incorporate those in its design. It amplifies its offerings, capabilities, and solution
Analytics	Allows provider to attenuate performance issues and variables without undertaking rigorous search
Modularity and serviceability	Allow for the ease of replacing faulty component – This attenuates the variety matching components to products.

4.1.8.3 **Equilibria between Management system and Operational units – this involves balancing horizontal variety with vertical eigen-variety.**

At the provider-customer level of the PSS, the integration and cohesion of the operational units is delivered through formal governance mechanism. Formal governance mechanism assumes the form of contract where roles and responsibilities are specified. One of the managers claims that.

> "*All specifications can be found in the contract, including what we promised to do as well as the responsibility of the customer regarding payment, changes to the contract and affordability…..IF a customer uses the machine or device or is careless and a fraud passes, then we haves stated explicitly in the contract what would happens"*

The coordination of maintenance occurs through an automated process. The IoT dashboard notifies the service provider about a potential breakdown. Sometimes, there is a delay in getting a machine or a system service restored, but this is quickly resolved.

Besides the rule-based variety operator, the PSS provider tries to communicate more with the customer often, to understand what the customers' requirements are and explore ways by which the provider could offer more solutions.

Trust is important.

***CustomerDoc* says**

> " *there was a time we could not pay the bill on time due to some problem, the provider was gracious, ….and they granted us some additional days to sort our issues." …We were more than impressed and we remember that action to today".*

At the higher recursive level, there is a balance of decentralization and centralization to maintain cohesion and brand quality. A centralized knowledge management system was developed to log problems that service partners and staff were facing in the field. Everyone could see how a problem has been logged without been resolved. When a solution is proffered for a problem, it remains on the portal and partner can access that solution when a similar problem is encountered.

This shared problem-solving approach created a spirit of "we are all in this together". It enhanced communication, collaboration and shared-risk taking.

Partner1 says…

> *"We have this shared problem approach…… it is like you have a problem and everyone comes at you with a solution and ways to help and before you know it is solved. … I just love that there is somewhere I can go to find help with things and …I can get help".*

Another variety operator is the rules associated with the contracts that partners sign. Partners are required to only offer offerings they have been signed to. Partners can progress from level to level but must satisfy the requirements. However, within a level, a partner is free to decide the price to charge, the combinations to offer and to target a specific target market.

The balance of decentralization and centralization ensures that every partner is free to decide how to run a business locally while complying to the rules of game decided centrally. This serves as an attenuator of bad behaviour and amplifier of expectations, and positive behaviour, which drives good performance,

4.1.8.4 **Equilibria between the future environment and the organisation –.**

The digital platform plays a very important role here. The PSS provider see itself as a technology provider, and therefore leverages advances in technology to drive adaptation.

A manager in ***CompanyDoc*** says:

> *"We are a technology company and not a print solution company…… Though we offer print solutions, we leverage technology to solve your print and workflow problems.*

The platform architecture allows independent partners and developers to combine tools and digital product/service modules create new solutions. Innovation occurs via a grassroot approach, where random users, unknown to each other integrate capabilities to drive innovation and novel solutions. The PSS provider leverage the ecosystem of creators on the platform to expand the spectrum of solutions that enhance the performance of its offerings.

Secondly, the PSS provider collaborates with outside firms and companies to develop new streams of that ensure customers and partners save money. Innovation tends to implicitly lock customers and partners in.

4.2 CASE Two: Light as a Service

4.2.1 Context

LightComp

This is a multinational company. It is a global brand in electronic devices, appliances, and lighting. *LightComp* has shifted into providing service and solutions as opposed to just products. It has adopted a customer-centric approach to providing solutions that meet the needs of customers in lighting. *LightComp* provides light-as-a service and other innovative lighting fixtures. Most of the solutions provided to organizations by *LightComp* is bespoke. Light-as-a-service is a type of performance-based contract that is contracted based on energy consumption, sustainability, and cost savings as outcomes.

PSS Solution Contracted to Deliver Lower Energy Consumption

The contract investigated was between the *LightComp* and *CustomerLight, a charity* based in London. The outcome for the contract was the achievement of a certain level of energy usage at the head office of the organization in order or achieve its sustainability goals. *LightComp*

was responsible for the provision of low energy-consuming electrical bulbs and fittings for a period of 10 years. The bulbs, fittings and intelligent control systems remain the properties of *Light Comp*. Energy consumption must not exceed specifically stated threshold, else, the customer is compensated by *LightComp* in the form of a discount to the charge paid quarterly by *CompanyLight* in following payment period.
LightComp works with a range of other companies to develop innovative lighting systems that are energy efficient, less costly and protect the environment. These include universities, developers, system integrators, manufacturers, retailers, customers, *LightComp* takes care of design, installation, maintenance, and decommissioning. *LightComp* sells its product and services through retailers as well as directly to businesses (B2B).

CustomerLight

This is a charity based in London. They have contracted the services of *LightComp* for the supply of lighting. *CustomerLight* wants to decrease its energy consumption in line with their sustainability goals and ethos. Further reason was to cut energy costs. The contract pays for itself via the energy savings *CustomerLight* gets.

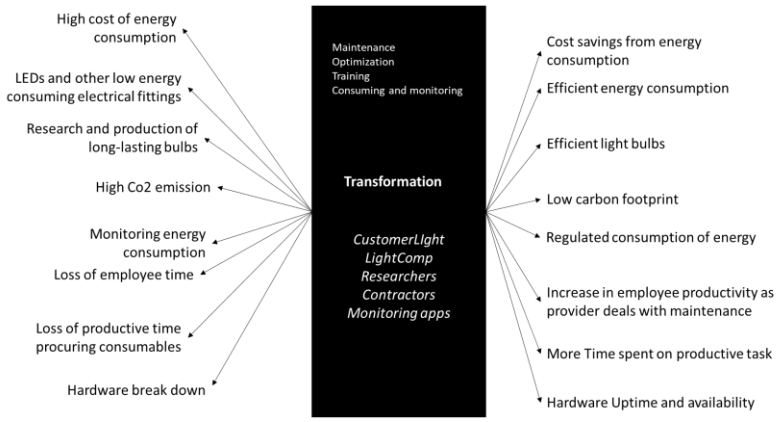
4.2.2 Identity Statement

Based on the responses from stakeholders, the identity statement is presented below:

"LightComp is a global brand in lighting and has partnered with CustomerLight to deliver pay-per-lux-service, which delivers significant cost savings and reduces carbon emissions".

The Purpose of the system is what it does. For the PSS contract, the purpose was to reduce energy consumption and costs.

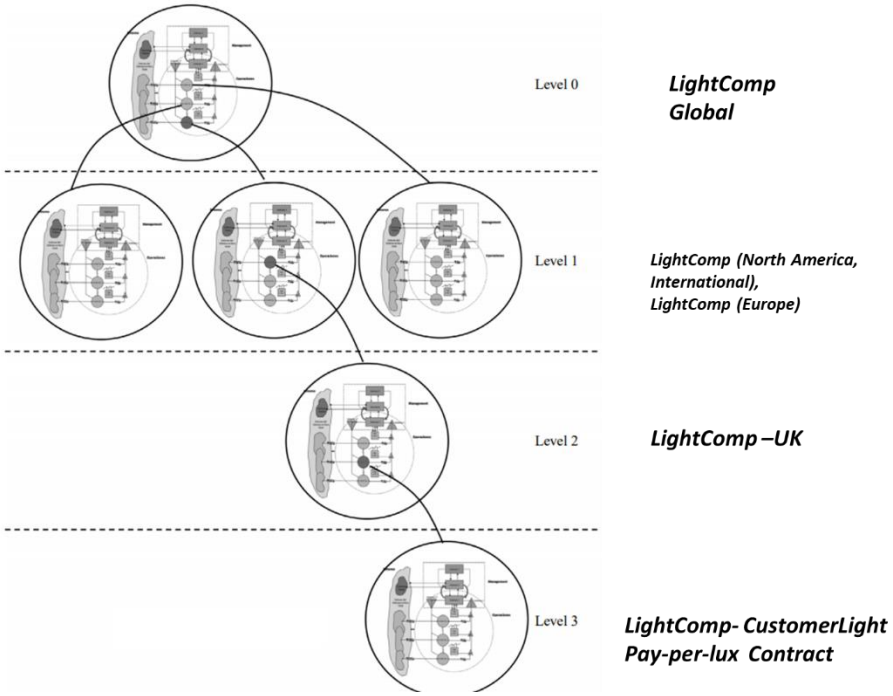
Figure 40: Input-Output Transformation for Pay per Lux



4.2.3 Recursion

Recursion levels were based on geography.

Figure 41: Various Recursive level



4.2.4 Primary Activities (SYSTEM 1)

The primary activities in this PSS include:

- **Consumption Unit**
  Capturing Energy Consumption **-** This includes the use of energy by *CustomerLight* and the simultaneous capture of energy usage, thus giving *CustomerLight* visibility of their energy consumption.

- **Operation and Support**
  Maintenance **-** This involves carrying out repairs, maintenance work, replacement of fittings and light bulbs. LED lights are easy to maintain, last longer and saves money. *LightComp* takes care of repairs and replacement tasks in short order. They carry out annual health check.

  Optimization **-**This includes identifying where more savings can be achieved. Upgrading the system with new technologies. These upgrades comply with facility maintenance legislations.

  Training and the Provision of Manuals **-** *LightComp* provides training to clients as well as documentation manuals.

4.2.5 System 2 AND 3 – Coordination, Control, Audit

Overall, it is a shared responsibility between the provider and the customer sides, with each taking responsibility for specific segments of the coordination and control function.

Coordination was carried out by the facility operations manager alongside the sustainability officer, who performed System 2, 3 functions: monitoring energy levels, regulating energy consumed, updating and promoting sustainable best practices. The facilities operations manager ensured maintenance visits by technicians (from maintenance contractor) were recorded and supervised while they (technicians) carried our replacement and repairs. The sustainability officer monitored the lighting level, computed the energy consumed within a period, agreed with the facility operation manager to keep energy use to a minimum in response to motion detected or day light. The accounting and finance team processed the quarterly payment to *LightComp* based on the energy consumed for the period.

Since the contract runs on a KPI model, the monthly savings are captured by the sustainability officer, who shares this with other members of staff in *CustomerLight.* Both *CustomerLight* and *LightComp* collaborate to make the arrangement work, as each party understands its responsibility towards the success of the contract.

Regulation was local and the sustainability officer and facility operation manager had the discretion to make decisions when appropriate particularly as it relates to energy consumption. The app was used to monitor energy consumption and the performance is sent to Light*Comp.*

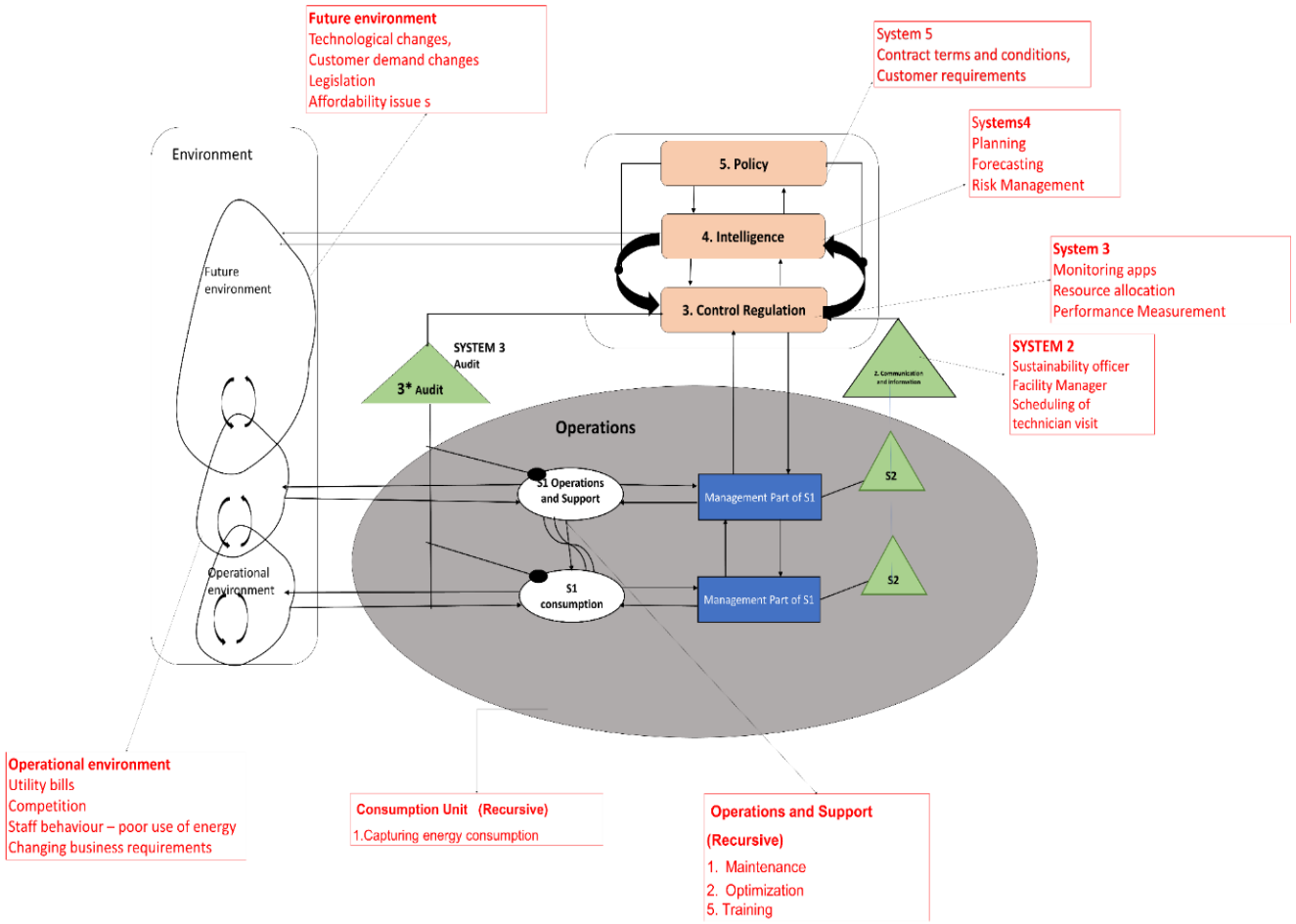
Importantly, decisions relating to the manufacture and supply of long-lasting electrical fittings were made by *LightComp. LightComp* were responsible for monitoring the maintenance processes and to assess whether it met agreed standards. *CustomerLight* had not input in the maintenance and optimizing processes except to grant LightComp access to the property. Complexity associated with the quality of work carried by the contractors is a real source of concern. *LightComp* makes sure there is a robust mechanism in place to monitor the activities of contractors. However, the relationship is not autocratic. The contractors are not outsiders, they are joint parties and they are bound by the shared collective meanings of the group.

Since the operational processes interact with the external environment, adequate steps are taken to minimize the effect of perturbation. Perturbations affect both the operations and consumption end of System 1. These perturbations include fluctuating energy bills from energy suppliers, fluctuation in the prices of electrical fittings, competition from other Light-as-a- service provider, mal-functioning monitoring device. Faulty fittings and light. Poor behavior from staff of *LightComp*.

4.2.6 System 4 and 5: Intelligence and Policy

Information gathering and forecasting is carried out by the sustainability officer, who run campaigns and look out for sustainable best practices. He holds regular meetings with the team from *CompLight* to discuss how further improvement could be made to achieve cost savings and lower energy consumption. The sustainability officer makes forecast about energy consumption and discuss this with the management team and sustainability committee (SYSTEM 5) at *CustomerLight*. Sustainability committee (System 5) make recommendation to management team (system 5), which they either approve or decline. Sustainability officer, sustainability committee and management team share the overlapping functions of system 4 and 5.

Figure 42: The Viable System Model for Case 2



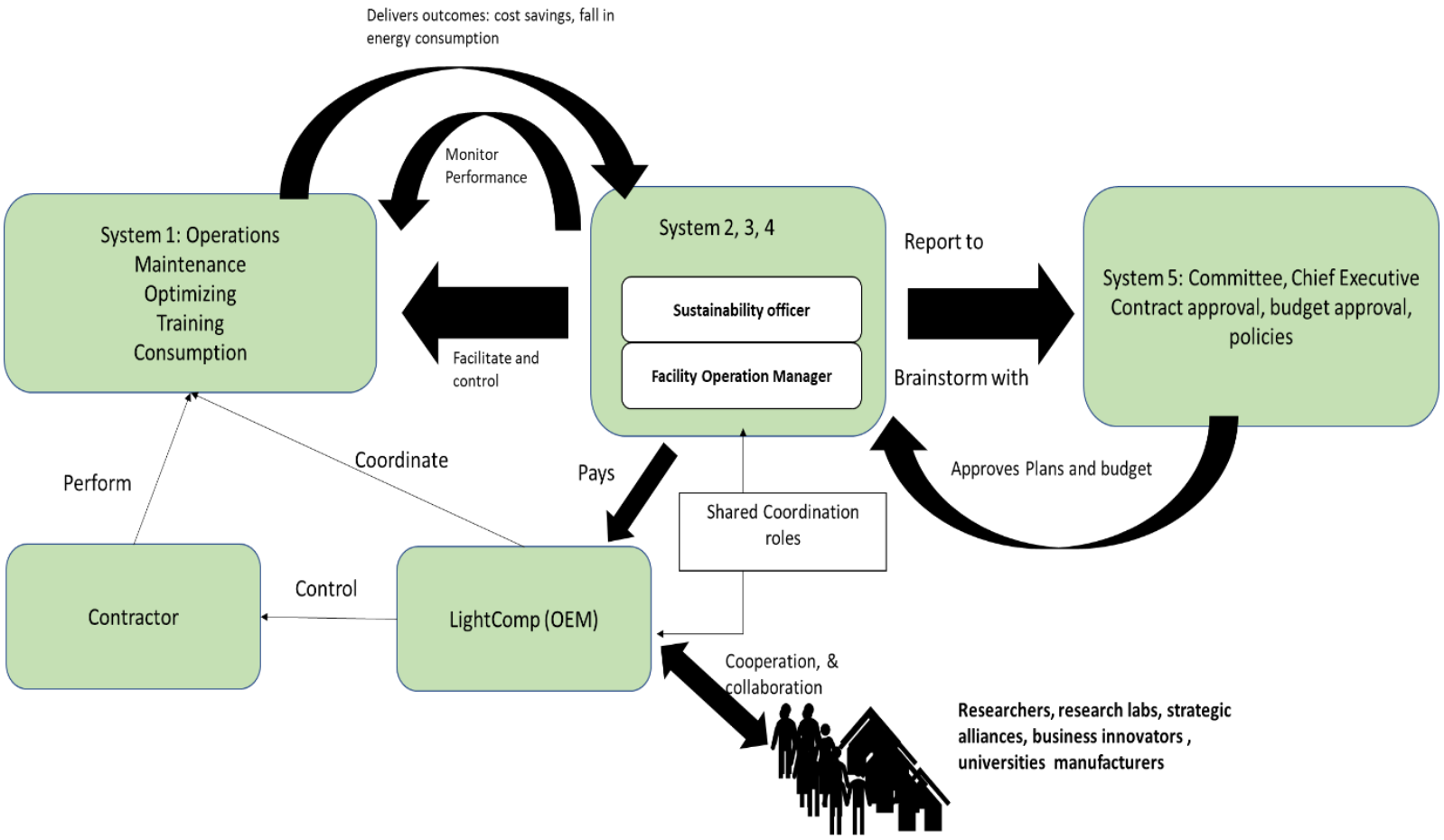
Complexity Factors

- Device failure
- Customer unable to define requirements.
- Context of use -major
- Competition pricing due to a lack of differentiation
- Performing below sustainability targets
- Poor uptake of service/solutions
- Financial loss due to heavy investment
- Falling Demand

Variety Operators

- IoT Dash boards for monitoring
- Connected device for control.
- Analytics
- DIY resolution
- Extending solutions to other areas of the business (workflow)
- Ecosystems
- Serviceability
- Modularity

Figure 43: VSM of Pay per Lux



4.2.7 Applying Variety Engineering to the Case 2

4.2.7.1 Equilibria between Recursion Levels.

LightComp changed the name of its service business to separate it from its product business. The company chose to change its name because it wanted to differentiate its service business from its product business. It indicated that the strategic move to change its name was intended to avoid confusing customers about what it stands for and does: its identity. With the new identity, *LightComp* can advance its strategic objectives of targeting specific markets interested in sustainability including energy consumption and carbon emissions. Changing its name is a variety attenuation move that attenuates the variety associated with creating confusion about its strategic intent. To remain with its product business would make it difficult for customer to understand that is it a service and solution business and not a product firm.

Besides, by changing its name, *LightComp* amplifies its identity to the whole world, that they are a service and a solution business. The renaming has allowed the company to focus on its core mission of promoting what it does.

LightComp is just part of a group of companies with different but adjacent capabilities. While these companies have their markets and product and service lines, they collaborate by integrating with resources and resources to develop complete solutions.

LightComp have partners particularly system integrators, who meet specific requirements.

4.2.7.2 Equilibria between the Operational Units and its Local Environment

The exploitation of customer tribes – the growing interest in sustainable development and energy consumption enables the PSS provider to tap into markets to drive growth. *LightComp* promotes two deliverables in its message – reduction in energy consumption and cost savings. Hence, it engages with the market segments that want to reduce their energy consumption. It also promotes its ability to help clients achieve cost savings.

LightComp leverages the use of internet of things (IoT) to drive energy savings. Customers are impressed with their ability ***to regulate*** **their energy consumption.** This provides a way to co-create value with the customer.

LightComp also offers financing to help customers acquire its offerings. In essence, *LightComp* offers end-to-end offering to customer. Customers are incentivized to demand for its offering when they know they do not have to make any investment.

A representative fro*m CustomerLight says*.

> " ***We care about the environment and sustainability. We like the idea that we can regulate our energy consumption. That explains the reason we decided to contract for the service. We searched around and we found that ….this is the best we can get".***
>
> ***"they are trying to sell other solutions to us but we are not sure we need them"***

However*, LightComp* is struggling with higher costs. As a proposed solution, it has tried to expand its offering into other areas by leveraging on internet-controlled data collection system, a kind of capability that businesses could use. By expanding into areas such as security, atmosphere management, health, and safety*, LightComp* attenuate the variety of falling demand and disinterested customers and amplifying the spectrum of the capabilities it delivers to customers and businesses.

By expanding its affordance of its offerings, *LightComp* is targeting multiple markets. And morphing into a different competitive space where competition is rife. **Integration theme**

A manager from ***LightComp says.***

> ***" There are many things we can help business achieve. Not just light and smart cities. We have moved into areas that are interesting ….. we just need to convince customers about the potentials of these technologies".***

Besides attempting to convince users about the affordance of its products, it also attempts to deal with some of issues mitigating against the demand for its offering***: standardization, interoperability, and security of*** connected devices.

Above all, the theme is CONNECTIVITY. *LightComp sell connectivity.* Another theme is expanding its products to other areas of the clients business.

Table 17: Variety operators and attenuation and amplification

Variety operator	**Variety engineering**
IoT-enabled connection	For monitoring and control – attenuates variety associated with usage and performance.

	For control – integrates the customer into the value creation process- Attenuates variability associated with information asymmetry between customer and provider
Cyber-physical systems	Decision-making algorithms. Takes actions based on signals and stimuli received.
Offer financing to customers	Customers are incentivized to contract for the supply of solution. It is a way to attenuate variability in customer demand
Modularity	Provide the ease and flexibility of repair and replacement of parts. Attenuates variety underlying mismatch in product components
Interoperability	Enable the provider to expand the range of service and solutions. Amplify its capabilities – solve more problems for the customer.
Expanding in other areas	To attenuate variability in demand for its core offering and amplify its capabilities to deliver solution in other areas via the expansion into new market.

4.2.7.3 **Equilibria between Management system and operational units**

When *LightComp* changed itself name to differentiate itself from her parent company, there was the concern that it might take a while for the employees to adapt to the new culture. One of the participants admitted that the parent company had provided all forms of support in the forms of tools and processes, how what was important was the mindset and culture of the workers in the organisation.

From a manager in LightComp:

> *"Changing our name means we are ready to show our client what we are about……. Having the right tools is good…. Optimizing our operations is great. We created new processes. However,….having the right culture and mindset is what drives the success and progress made so far in new business. ,… This is important for everyone … else we will be stuck with the old way.*

4.2.7.4 **Equilibria between the future environment and the organisation**

LightComp operates an ecosystem approach to adaptation, which is built **on collaboration**. It has invested heavily in digital technologies by collaborating with companies in adjacent industries to expand the affordance of their offering.

The transformation to a new identity has not gone smoothly as expected but it is attempting to establish its footprints in the lighting space. It has been able to shed the legacy of its old name.

A Manager from LightComp;

> *"We are a world-leader in this area….people know us… we want to change how people use light. …we want to collaborate with everyone everywhere to create new things - that will change how people live".*

4.3 CASE 3: Automated Teller Machine as a Service

4.3.1 Context

ATMComp

This is one of the largest ATM Independent Deployers in the United Kingdom. They provide a variety ATM and cash-machine-deployment services to retailers, forecourts, hotels, and Gyms. These services are tailored to their requirements and aimed at boosting business performance. The case of interest is an on-going contract for the supply and maintenance of ATM on premises in *CustomerATM* retail shops. The PSS is called 'solution' by *ATMComp* and it consist of ATM installation on premises, Account managers are assigned to manage independent retailer accounts. ATM on premises have been found to increase revenue through surcharge charged on transactions. It is also found to increase on-premises spending and reduce processing charges by keeping cost down for retailers with ATMs on premises.

CustomerATM

This is an independent proprietor of a number of shops around the West Midlands. These shops have been installed with cash machines (ATM), which are owned and maintained by *ATMComp.*

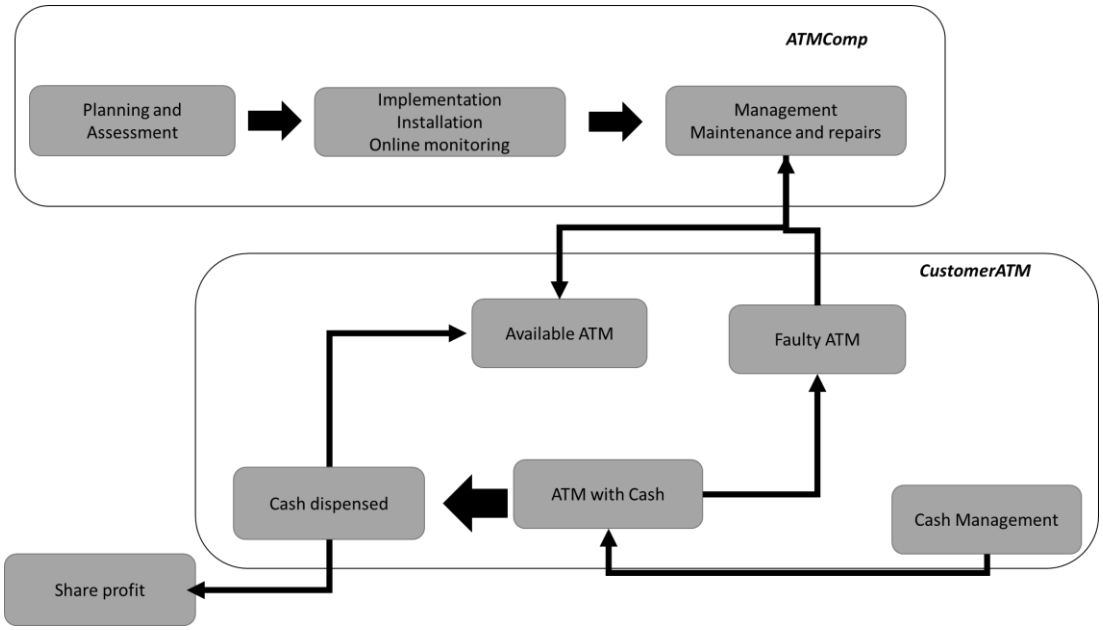
4.3.2 Identity Statement

"ATMComp, one of the largest ATM operators in the UK, is contracted with CustomerATM for the supply and maintenance of cash machines, to facilitate transactions and the easy access to cash by customers of CustomerATM"

4.3.3 Purpose of a system is what it does.

The transformation process of a cash dispensary as a service starts with ***ATMComp*** searching for the right location to place a cash machine. CustomerATM has four shops in the West Midlands area, with each having an ATM. The structure of the flow of activities is shown in the diagram below.

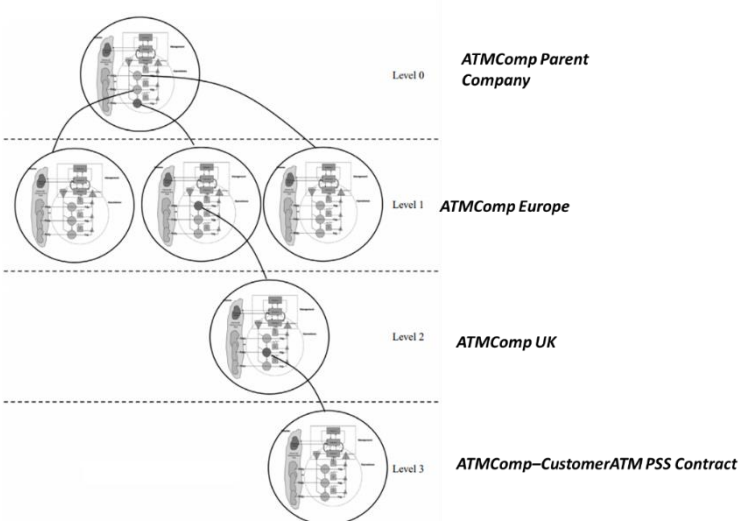
Figure 44: Structural model of ATM as a service



4.3.4 Recursion Level

Recursion level was based on geography. Recursion Level 3 is selected

Figure 45: Recursion level



4.3.5 Primary Activities

The primary activities fundamental to the function of the PSS include.

- Maintenance services – this involves routine preventative maintenance designed to reduce downtime, failure, card errors, and network problems.
- Cash Management – This is aimed at keeping the cash machine afloat with cash and to prevent cash-out.
- Repairs – This relates to a repair of the machine or a complete replacement when the machine fails.
- Processing of transactions with banks – This is handled by *ATMComp* who facilitates the routing of transactions between ATMs and banks through the ATM controller network.
- Security – CCTV on site and on ATM to monitor nefarious activates and prevent hacking.
- Software Update of ATM – to prevent hacking and ensure security of cash.
- Facilitate cash withdrawal - Customer usage.

The local environment is littered with customer complaints, poor network connection, faulty ATMs, unresolved customer issues, delay in resolving customer queries. The lack of

autonomy at operational level undermined the ability of CustomerATM to respond to variety in the local operational environment.

4.3.6 System 2: Coordination

The coordination function is carried out jointly by *ATMComp* and *CustomerATM,* however *ATM*Comp coordinates a large proportion of the coordination role. *CustomerATM*, mostly makes sure there is cash in the ATM

Monitoring Systems - There is a live monitoring system set up to monitor ATM usage, detect fault, raise tickets, and alert the technical teams. A customer support team from *ATMComp* is always available to attend to reported fault that may not be reported by the monitoring system. Contractors handle repairs and maintenance.

Sources of Conflicts- Conflict resolution and stability are the objectives of System 2. Issues that have generated conflict include customer's card trapped in the ATM, network issues, customer bank accounts debited without the dispense of cash.

Resolving Conflict: LINK Network Set the Rules- Issues were resolved at the card issuers level. If there was a dispute over dispensed cash, the card issuers would raise a dispute with the Independent ATM owner (*ATMComp*).

Fraud reporting and Investigation- Issues relating to fraudulent activities were investigated by the fraud investigation unit. Store owners like *Customer ATM* are encouraged to report and escalate suspected criminal activities around the ATM.

4.3.7 Systems 3: Control

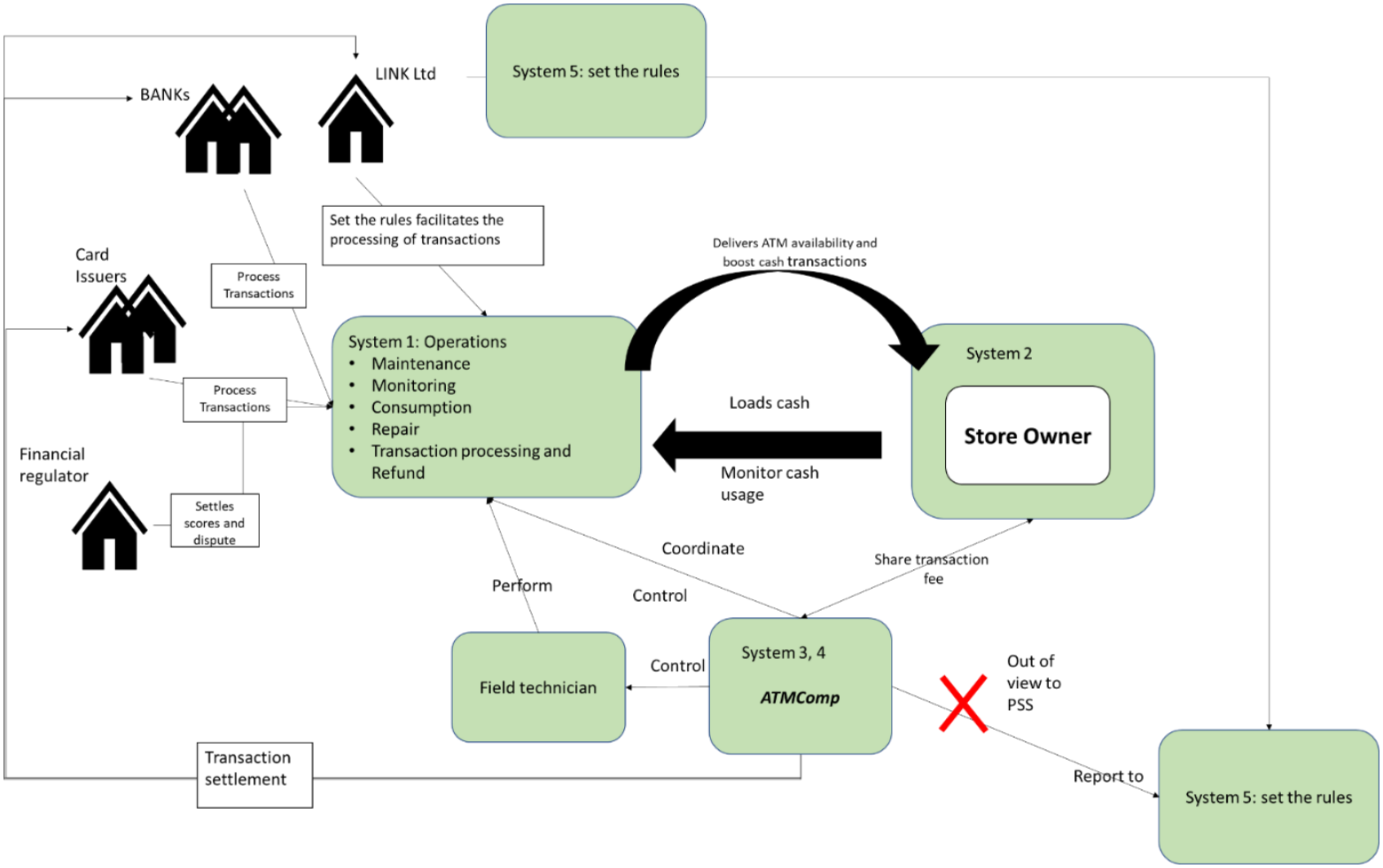
At higher level of recursion, it was organised. *ATMCom*p has well-structured chains of command that control and coordinate the activities of field service agents.

4.3.8 Systems 4: Intelligence and Policy

The variety in the future environment were rules set by LINK Ltd, increase in business rates and the low level of cash usage by customers. Extra cost of *ATM Comp* is passed to customers.

However. ATMComp is committed to adapting to its changing environment by partnering with companies to develop new products and service offerings.

Figure 46: Key relationships



4.3.9 Applying Variety Engineering to the Case 3

In the literature, it was pointed out that the VSM manages complexity using Ashby's Law of Requisite Variety (Ashby 1956) , which states that variety is absorbed by variety . The Law of requisite variety provides a foundation for the design of complexity management strategies and attenuators and amplifiers to manage variety.

Four equilibrium sites were identified in the VSM.

- Equilibria between Recursion Levels – this is underpinned by the principle of the recursive structure of a viable organisation (Beer 1979)
- Equilibria between the operational units and its local environment – This is called Horizontal homeostasis (Ashby 1961). Horizontal Homeostasis is enhanced via the principle of autonomy.
- Equilibria between Management system and operational units – this involves balancing horizontal variety with vertical eigen-variety. This is known as the vertical homeostasis (Lassl 2019a) The mechanism is underpinned by the principle of control/cohesion.
- Equilibria between the future environment and the organisation – This is the heterotactic function. This is underpinned by the concept of adaptation.

Figure 47: The four Variety Engineering processes of the VSM

4.3.9.1 Equilibria between Recursion Levels

ATMComp has a presence everywhere in the UK and they are focused on a spectrum of organisations ranging from retailers, petrol shops and supermarket. They tailor their offering to the specific requirements of the business. There are units saddled with responsibility for each type of retailer or shop.

Manager in ATMComp says:

> *"What do you want… which type of business do you run? We can do a lot of things for the business. We provide solutions to large retailers, small shops, hospital, large complexes, government buildings.*
>
> *" There are dedicated teams for each type of business.."*

4.3.9.2 Equilibria between the operational units and its local environment

ATMComp offers end-to-end services from cash replenishment to full maintenance, part supply, depository collection and security and cash management. Hence, the strategy here is to **lock-in** the customer, considers the services offered as being complimentary. It also offers customers the option to select and pick specific services. They take off the weight and burden of managing cash management and payment off the retailer or customer.

The Internet of Things (IoT) provides the enabling driver and technology for the end-to-end delivery of services.

Manager in ATMComp says :

> *" The store owner or manager do not need to worry about anything. We will take care of it. The sensors are there to capture data about performance and how it is used. We can detect bad behaviour and …even fraud".*

> *"We analyse every data … that way we know whether it profitable or not.*

ATMComp leverages **relationship management** as a variety operator to understand the customer's needs/requirements.

A manager from ATMComp claims:

> " *often customers whether they are shop owners or retailers, may not know what they want. ..they may find it difficult to tell you. We try to go close to them and listen… by listening we can tell what they need".*

> *"we ask them about their business needs and what go….goals they want to achieve…….they want to paint a picture of where they want to be like in ….6months -12 months….* ***"***

From payments to business processes. There are signs tha*t ATMComp* is exploring with integrating payment systems services with business processes. **Integration theme**

Table 18: Variety operators and attenuation and amplification

Variety Operator	Variety Engineering
End-to-end services	Amplifies its capabilities, lock-in the customer to attenuate variety in customer's requirements
Tight relationship	Understanding what customers want – helps to attenuate variety of customers need to specific problem space
Risk bearer	Attenuate the probability of risk behaviour. And amplifies the capability and capacity to manage risk better than the customer.
Connectivity, Data processing and analytics	Attenuates failure rate and abuse of match, amplifies response capacity – business opportunity

4.3.9.3 **Equilibria between Management system and operational units – this involves balancing horizontal variety with vertical eigen-variety.**

ATMComp supports its agents in the field through RFID power-ed field service machines. Everyday, field service agents are logged for service across specific areas they cover. Those that load the ATM machines with cash or transfer cash across stations, banks and sites have the proper documentation and security gears for such work. Field services agents are requested to allow enough time for parts to be delivered before setting out for the day's task. Health, safety, and security are important feature of the tasks, hence, management at ***ATMComp*** ensure that every field staff signs the health and safety pack.

Manager ATMComp says*:*

> *" We take health and safety as well as security issue seriously. We try to support out field service people ….. that they have the right tools and gears to work"*

> *"We do ask them to sign the health and safety regulations form … so they understand what is required for the job"*

4.3.9.4 **Equilibria between the future environment and the organisation**

As the technology advances, *ATMComp* recognizes that online fraud and hacking of facilities is a threat. The company launched several products in the last years through collaboration with other firms in the finance industry for example Fintech firms.

ATMComp recognises that the way people shop is changing, hence, it has chosen to leverage collaboration with industry partners to create new solutions that protect payment processes, cash depository and cashless transactions.

4.4 Cross Case Analysis

The cases are compared based on the variety engineering requirement in each equilibria site. The table below shows that although these firms operate in different industries, they develop requisite variety across the equilibrium sites.

Figure 48: Cross Case Analysis Table

Cases	Recursive problem solving	Horizontal homeostasis	Vertical homeostasis Cohesion	Adaptation
Case 1	*"the company engages partners around the world, who can help deliver our promise to customers" –RECURSION* *"You can always find an agent or partner closest to you" –*	*"... know what your business needs and we will help you to perform them, or we perform them for you effectively and efficiently. KNOWLEDGE &PERFORMANCE* *"We leverage our innovative technology to create intelligent system that increase efficiency and effectiveness in our clients' business" TECHNOLOGY OPERATOR EFFICIENCY, EFFECTIVENESS, BUSINESS PERFORMANCE*	*"We support partners in the path you choose" SUPPORT, DIRECTION* *"The official badge represents our brand and reputation....* *It must be used according to the terms and conditions" GOVERNANCE, TERMS AND CONDITION*	*"... work with multiple partners across the manufacturing and service spectrum to innovate" MULTIPLE PARTNERS* *SPECTRUM OF COOPERATION* *"We are a technology business" IDENTITY*
Case 2	*" We partner with companies around the world.. to help deliver our innovative products, service solutions ..."* *RECURSION*	*" The store owner or manager do not need to worry about anything. We will take care of it. The sensors are there to **capture data about performance** and how it is used. We can detect bad behaviour and ...even fraud". TECHNOLOGY OPERATOR* *KNOWLEDGE &PERFORMANCE* *" There are many things we can help businesses achieve. Not just light and smart cities. We have moved into areas that are interesting with IoT..... EXTEND CAPABILITIES /KNOWLEDGE* *...we just need to convince customers about the potentials of these technologies". EXTEND CAPABILITIES /KNOWLEDGE*	*" We equip you with the tools and resources you need to succeed and meet customers ' specific needs" AUTONOMY/KNOWLEDGE*	*"We are committed to innovation... going ahead of the curve to develop new products and solutions ...as well as ..as experiences for our clients regardless of their industry" INNOVATION/ADAPTATION* *"We are a world-leader in this area....people know us... we want to change how people use light. ...we want to collaborate with everyone everywhere to create new things - that will change how people live" INNOVATION/ADAPTATION*
Case 3	*" We have well-trained field service technicians and agents. We support them with training and benefits . RECURSION*	*" We can provide end-to-end solutions ranging from ATM to maintenance, depository services, self-checkout, to Point of Sales service.... EXTEND CAPABILITIES /KNOWLEDGE* *depending on what the retailer wants...our goal is to create value through a unified client experience ...." EXTEND CAPABILITIES /KNOWLEDGE*	*Importantly, we empower them to look out for preventative measures , raise issues and serve as an ambassador for us ..." AUTONOMY/KNOWLEDGE*	*We prefer to use what we have to get to where we want to be... I mean we have a core technology which we use on ATM and like POS... and self checkout. INNOVATION/ADAPTATION*

4.4.1 Complexity Management approach

One area where CompanyDoc has an advantage is it has a digital platform, utilizes IoT platform and maintains a very broad breath of collaborations, which allows it to innovate and create new solutions. Due to its size and experience, it operates a grass-root approach to complexity management. A grassroot approach is a bottom-up approach, which integrates employees, suppliers, independent vendors, customers into the complexity management process. Using its digital platform, it facilitates the integration of resources, capabilities and competencies, functions, and tools to co-create value. In fact, these values are created without the direct orchestration of the *CompanyDoc .* This makes the company agile and versatile. Since it operates a grassroot approach, innovation, synergy and cohesion emerge without being induced. This gives it strength in managing complexity.

For Case 2 firm, it operates a strategic complexity management approach, that is top-down. It maintains an alliance of relationships outside the firm via its hubs and labs . It creates new products and service offerings, some of which may not be pervasive . Hence, it faces the high variety of poor demand . It has a large gamut of innovative product in the pipeline which the market is yet to appreciate. It has decided to shift the focus on its technology to other industry by collaborating with adjacent industries. Manging complexity would rest on how well it manages the falling demand.

While cases use a grassroot approach and case2 firm uses a strategic approach, case 3 uses a “smash and grab” approach. ATMComp has positioned itself to deal with complexity by engaging with local companies within a specific market. It recognises that market needs are different; therefore, it develops solutions that are tailored to the needs of the specific market.

However, regardless of each of the case company’s specific approach, the goal is to extend the breath of service/solution to a large proportion of the customer’s business.

4.5 Summary

The results and analysis of the cases have been presented. The VSM has been used an epistemological lens to identify complexity management strategies in PSS. A VSM model was created for each case as week as the mechanism across the four equilibria sites of the VSM.

5 Discussion

5.1 Introduction

This chapter discusses the findings in the light of existing literature. Three cases have been examined using concepts related to the viable system model, variety engineering and Law of Requisite to explore complexity management and viability in providers of product-service systems.

In section, 5.2 examines complexity through the lens of cybernetics In section 5.3, customers endogeneity in PSS operations is discussed. Section 5.3 presents the role of digital technology as a powerful variety operator. In section 5.4, the transition from physical asset to knowledge asset is discussed. The place of cognition and institutionalism are presented on section 5.6 and 5.7 respectively. Summary follows in section 5.8.

5.2 Seeing Complexity Management through the Lens of Communication and Control

The findings show control and communication mechanisms in PSS systems. However, communication is used in the context of coordinated actions rather than just the transfer of information (Espejo and Reyes 2011, Espejo 2015b). Used the VSM as a heuristics tool, underpinned by the Law of Requisite Variety and the epistemology of the second order cybernetics, the VSM provided deep insight into coordinated actions within the PSS system aimed at self-regulating and self-organising itself against perturbations arising from its objective of realizing its purpose. The following are observations from the analysis of data.

5.2.1 Information Flow as Coordinated Actions

The VSM emphasizes the importance of the information channels in driving the viability of organisations. Information and communication channels have improved as a result of advances in technology, and they play a prominent role in connecting devices, people and driving collaborations. Findings shows that communication channels at like channels of coordinated actions rather than just channels of information transfer/flow.

Partner1 says:

> *" The whole portal thing makes it easy to follow what is happening… when new machines are delivered. … new apps are developed…..resolve issues of supplies…also complaints. We can see when they are resolved.*

"The notification system is very good"

CustomerDoc says:

"We can easily reach the provider to request for something … directly from the machine. It is so impressive that you can contact them from the machine .. the whole thing is integrated…."

Partner2 says:

" The portal contains a lot of things…a lot of information can.. find on the dashboard. I can see who is doing what …in fact, we can regulate our consumption…

The essence of this finding is that the collation of information through devices enabled by technologies like IoT is not a passive activity. Information flows are coordinated actions aimed at knowing and learning, both of which affect the perceptions of individuals within the PSS and the actions they take. Previous studies have focused on the object (the data) and the device or technology (IoT), However, this research shows that the collation of data or information represents coordinated actions designed to achieve a specific aim(s). This is consistent with findings in the servitization literature (Hagmark and Virtanen 2007, Greenough and Grubic 2011, Boucher *et al.* 2015, Grubic and Jennions 2018, Zheng *et al.* 2020)

5.2.2 The Cohesion function as a form of coordinated actions rather than a one-way flow of information.

A finding from the data analysis However, another noticeable point identified from the case studies is nature of the cohesion function. According to the Viable System Model, the cohesion mechanism is necessary to control the operational units while preserving the unity of the whole the organisation. Control in the context of the VSM is not in the traditional terms of using bureaucratic force but driving behaviour through resource allocation, accountability and loose monitoring (Harnden 1989, Espejo *et al.* 1999b).

The purpose of control is to derive synergy among the operational units; it is to support the implementation of the purpose of the organisation. This happens via coordination, supporting, debating, communicating, and integrating. The purpose of synergy is to ensure that everyone in the organisation is focused on the collective purpose, imbibes the culture and values of the organisation, and represents the identity of the organisation (Lassl 2019b). This was

demonstrated through the sequence of specific actions the primary units were required for adhere to.

From Partner1*:*

> *The support we get from Company Doc is 'wow'.. Customers get the best solutions because we are empowered with software, marketing tools, business development tools, advisory tools, products and newest technologies so we can forge our own path….[..]… CompanyDoc knows that those of us at the bottom of the ladder..know the market very well and we can cover the turf when given the right tools*

ATMComp manager

> *" We have well-trained field service technicians and agents. We support them with training and benefits ..*
>
> *"Importantly, we empower them to look out for preventative measures , raise issues and serve as an ambassador for us …"*

Manager from CompanyDoc

> *" We give you almost everything you want – training, materials, information, ..so that you can be the best you can, …eh we also allow you to charge your prices so you not make a loss"*
>
> *" we use tiered system..loaded with opportunities and ..we also reward performance"*

Instability arises when operational units have disparate objectives that conflicts with the collective objective and purpose of the whole organisation. It leads to wastage of resources, in-fighting, opposition to change and undermine the productivity of employees. This inhibits the ability of the organisation to process variety either between itself and the environment and within itself (Lassl 2019a).

Manager from CompanyDoc says

> *"We assess every potential partner whatever category they are before we admit them to the team. We provide plenty of support just ..so they can serve your customers…*

using our badges is something we do not take lightly…..expect partners to abide by the terms and conditions.

Cohesion and synergy are achieved through effective deployment of relational assets (Dyer and Singh 1998, Kleinaltenkamp *et al.* 2012, Xie *et al.* 2016). Whether it relates to customers or suppliers or integrators in the co-creation of value, governance mechanisms which promotes trust and cooperation are the most effective (Kreye 2017b).

5.3 Customers and suppliers are endogenous to the service delivery process and hence, the complexity management process.

A prominent finding from the cases indicates the prominence of the customers and suppliers in the realization of the purpose of the PSS. According to Beer (1981), the purpose of a system is what a system does. Customers and suppliers affect the ability of PSS providers to realise the purpose of the PSS; they influence the variety in system 1. This finding is consistent with the finding in the literature. However, competitors and government regulations are exogenous to the PSS. Although, they also affect how the PSS deliver solutions and outcomes, they are not located within system 1 (primary activities).

Batista *et al.* (2017) argue that within a PSS operation, the customer is not outside system 1 as it is described by the Viable System Model, but within system 1 and co-creating value with the provider and other actors. The authors argue that since the customer becomes a part of the service delivery system, relational operators which fosters partnerships and harmony between actors can dampen variety. Green *et al.* (2017), (Ng *et al.* 2013), and (Kreye 2017b) point to relational assets, alignment between customer and provider and partnerships are operator to manage system complexity within PSS operations.

Finding from this research reveals an ecosystem-type scenario, where a wide variety of actors – customers, developers, integrators, third party businesses and companies, independent agents, work together to deliver solutions through a set of coordinated actions. Whether it is in the developing of apps, streamlining operations, carrying out repairs, integrating products and services, these agents work together to facilitate the delivery of outcomes. Variety generated from changing and evolving business landscape is quickly processed leaving residual variety for management. This is consistent with the emerging literature on value co-creation in triads and networks. Recent published works include (Wieland *et al.* 2012, Barile *et al.* 2016, Korkeamäki and Kohtamäki 2019, Sklyar *et al.* 2019, Meierhofer, West, Rapaccini, *et al.* 2020)

5.4 Digital technology is the heart of Complexity Management.

A common denominator across the three cases examined is the potency of technology as a variety operator. Advances in digital and communication technology has resulted in the proliferation of tangible and intangible operators which facilitates and enables the regulation of systemic activities according to specific objectives. Importantly, technology

The capabilities provided by digital technologies has been researched extensively in the PSS literature (Gremyr *et al.* 2010, Baines *et al.* 2014, Ardolino *et al.* 2016, 2017, Martín-Peña *et al.* 2019, Gebauer, Paiola, *et al.* 2020, Uçar *et al.* 2020, Ranta *et al.* 2021). Across the functions and systems of the viable system model, the impact of technology is visible and apparent.

5.4.1 Complexity Management enabled through Connectivity: Digital Technologies drive the Emergence of new service offerings and Business Penetration.

In operations (system 1), a function which implements the purpose of the PSS, digital technologies serve as an enabler for the adoption of new business offerings. In the case studies, companies leverage existing technologies or integrated with other technologies to expand the range of their offerings. These digital technologies include cyber-physical systems (Ivanov *et al.* 2019), internet of things (IoT)- enabled services (West, Gaiardelli, and Rapaccini 2018, Schroeder *et al.* 2019, Wellsandt *et al.* 2019), smart services, and digital platforms (Hung *et al.* 2014, Thomas *et al.* 2014, Eloranta and Turunen 2016, Ardolino *et al.* 2020). PSS providers can leverage the interoperability of existing digital technologies to allow combination with third party technologies and capabilities either via a digital platform or through some other means (Hajimohammadi *et al.* 2017, Xu *et al.* 2018).

Manager from ATMComp says

> *" We can provide end-to-end solutions ranging from ATM to maintenance, depository services, self-checkout, to Point of Sales service….depending on what the retailer wants…our goal is to create value through a unified client experience …."*

> *There is a sensor in the machine …allows us to detect when something is wrong….we can see it here.. we do this everytime….monitor ..analyse …the customer need not to worry as we take care of it.*

LightComp says.

> *" There are many things we can help businesses achieve. Not just light and smart cities We have moved into areas that are interesting ….. we just need to convince customers about the potentials of these technologies".*

Manager in CompanyDoc says.

> *" our focus is …. is to exploit modern technologies like 3D-Printing, AI, …and machine learning and….Internet of things to drive growth.. These days, we can build models that can help us to analyse and understand behaviour and make predictions…We want to help our clients to do what they do..even more effectively*

The emergence of new service offerings allows PSS providers to deepen their penetration in the clients business by extending services and solutions beyond originally contracted aspects of the customers operations (Gebauer, Fleisch, *et al.* 2020). The implication of this is the service provider is able to lock in the customer and extract value from the contract in the long-term (Visnjic *et al.* 2017). Customer-lock in is a **potent variety operator**, which attenuates variability in customer contextual use and the risk of customer loss to competition (Sjödin *et al.* 2019). Sjödin *et al.* (2019) argues that customer lock-in provides a relational governance mechanism, which drives superior financial performance.

Customer lock-in allows the PSS provide to get closer to the customer's business to gain understanding and knowledge (Aarikka-Stenroos and Jaakkola 2012, West, Gaiardelli, Resta, *et al.* 2018), hence, **attenuating** variability associated with customers' demands and requirements and presenting an opportunity for the provider to amplify solutions which delivers capabilities to the customer's business.

Table 19: Connectivity and Integration Mechanism and variety operators

Device	Mechanisms	Result	Variety Operator	Outcome
Digital technologies	Connectivity Interoperability Monitoring Analytics Prediction	Expand services	Lock-in customer Learn and increase knowledge	Attenuates variability associated with customer demands Provider can amplify solutions that enhance capability of customer

5.4.2 Complexity Management Enabled through Collaboration: Digital Technologies Drives the Emergence of Service Ecosystems

Secondly, digital technologies enable the development of a service ecosystem (Eloranta and Turunen 2016, Cenamor *et al.* 2017, Zou *et al.* 2018, Martín-Peña *et al.* 2019). The operation (System 1) of a PSS interacts with a wide range of events/actors internal or external to it. Since the customer and provider are involved in the development of co-capabilities and the co-creation of value, stimuli or variety generated in course of interaction from the customer are considered as internal variety (Batista *et al.* 2017). Furthermore, in the process of value creation or value delivery, the PSS might need to co-opt and integrate the resources or capabilities of actors external to the firm to co-create value. This creates a multi-actor and multi-firm project and relationship, where actors and firms exchange and integrate resources and capabilities to create value or achieve mutually beneficial outcomes.

The concept of an ecosystem is defined in the service literature as "relatively self-contained self-adjusting systems of resource-integrating actors connected by shared institutional logics and mutual value creation through service exchange" (Vargo and Lusch 2018, p. 723). Digital technologies like digital platform provides a base and space for the emergence of an ecosystem of actors integrating resources, capabilities and competences within and outside the firm boundaries (Eloranta and Turunen 2016, Xie *et al.* 2016, Kohtamäki, Parida, *et al.* 2019)

CompanyDoc Manager says:

> *"We have this fantastic platform and digital architecture …where partners and independent developers can create super-apps… No they may not be our employees. Some partners with app development capabilities can do that.*

"the partner can choose to sell it in the App store..well we call it studio… we check that it is not a malware

"there are plenty of tools …on the platform and it integrates well with third-party tools."

The collaboration of capabilities and resources via a platform permits the sharing of resources, facilitates relationships and the integration of new capabilities outside the PSS boundaries. The implication of this is a platform ***attenuates variety*** from source, that it absorbs the variety associated with diversity and multiplicity of skills and capabilities within and outside the firm, aggregate them and ***amplifies*** the ability and capacity of the firm to create solutions (Ardolino *et al.* 2018).

Integration of capabilities via a platform can facilitate the emergence of novel solutions, which increases the overall customer experiences (Hagiu 2009). Creating unique customer experience is a powerful variety operator, innovation via digital platform collaboration provides an efficient path for the development of new application that improves the overall experience of the end user. It is efficient because building and developing optimal content comes at a cost. Platform reduces the cost of creating new applications by driving the efficient use of resources (Eloranta and Turunen 2016, Cenamor *et al.* 2017).

Digital platform provides an efficient way for a PSS to capture value by driving the sale of application created on the platform. Collaborating with third party developers and integrators, platform orchestrators provide a channel to increase revenues.

Partner1 says:

Partners with app development capabilities can create applications to support their clients. …they may choose to use it locally or share with others via the app store.." ..Company Doc gets a cut…"

Table 20: Collaboration Mechanism and variety operators

Device	Mechanisms	Result	Variety Operator	Outcome
Digital Platform	Collaboration Sharing Integrating resources and capabilities	Leverage resources/capabilities within and outside the firm to create value	Facilitates Innovation Learn and increase knowledge Saves costs	Attenuates the diversity of skills within and outside the firm Amplify solutions creating capability of the PSS provider and capacity to earn revenue

5.4.3 Complexity Management Enabled through Flexibility: Digital Technologies Drives Flexibility and Optimization

Besides connectivity and collaboration mechanisms, digital technologies also drive flexibility mechanism. Digital technologies include the digital twins, simulation, platform, and 3-D printing. The core of these technologies includes modularity and modelling. They provide managers with the capability to select, test and modify objects. These attributes fall under the principle of "control". They allow PSS managers to CONTROL products, processes, systems in any way they choose in order to meet set objectives.

Manager in ATMComp says :

> *" The store owner or manager do not need to worry about anything. We will take care of it. The sensors are there to capture data about performance and how it is used. We can detect bad behaviour and …even fraud".*

> *"We analyse every data … that way we know whether it profitable or not.*

Table 21: Flexibility Mechanism and variety operators

Device	Mechanisms	Result	Variety Operator	Outcome
Digital technologies	Flexibility Modularity Modelling and analytics	Proact Prevent Modify Optimize	Prevent Insight Learn and increase knowledge Management	Attenuates variability associated with performance and use Provider can amplify solutions that optimizes the capability delivered to the customer.

5.4.4 The Three Legs of a Tripod Stand

Three mechanisms enabled by digital technologies have been presented. Each of the mechanisms can be viewed as coordinated actions aimed at realizing specific objectives relating to complexity management in PSS systems.

- ***Connectivity as variety operator***

  This is aimed at ***knowing and learning***. The object of learning could be previous historical performance and usage or customer requirements/situations or future requirements. At the intelligence and strategy level (System 4), the objects include technological changes and changes in government regulations/policies.

  Evidence in the servitization literature identify connectivity as a risk modulator: these includes remote monitoring (Wennerholm 2012, Grubic 2014, 2018, Alabdulkarim *et al.* 2015, Wrasse *et al.* 2015, Grubic and Peppard 2016, Gebauer *et al.* 2017, Grubic and Jennions 2018), prognostics (Jazouli and Sandborn 2010, Teixeira *et al.* 2012, Grubic 2014, Zaki and Neely 2014, Sandborn *et al.* 2017, Tahan *et al.* 2017, Antikainen *et al.* 2018, Erguido *et al.* 2019, Meierhofer, West, Rapaccini, *et al.* 2020), diagnostics (Jonsson *et al.* 2008, Brax and Jonsson 2009, Rymaszewska *et al.* 2017), behavioural analytics (Pogrebna 2015), knowledge base (Bolton *et al.* 2018, West, Gaiardelli, Resta, *et al.* 2018)(Meierhofer, West, Stoll, *et al.* 2020).

  Connectivity as a variety operator does not only relate to processing variety at system 1 (operations), but it is also useful in the scanning of the environment for emerging trends and changing customer usage requirements (System 4). The use of customer support portals, support blog and forum where multiple actors connect using their shared requirements and shared knowledge enable PSS providers to identify emerging trend in terms of issues raised by customers and the type and nature of

solutions discussed in the forum. Remote monitoring specifically contributes to providing insight into how customers use equipment, devices, and machines. Changing usage pattern can indicate a changing business landscape or requirements.

- ***Collaboration as a variety operator***

  This is integrating ***knowledge*** from multiple actors to ***produce or create.*** This is essentially important in system 1. The concept of collaboration enabled by the proliferation of platforms and other digital technologies is well covered in the servitization literature (Eloranta and Turunen 2015, 2016, Ardolino *et al.* 2018, Gebauer, Fleisch, *et al.* 2020). These technologies present a platform for knowledge sharing, integration of capabilities, efficient use of resources and act as a catalyst and gateway for innovation (Hagiu 2009, Gebauer, Fleisch, *et al.* 2020). They provide a means to develop both customized and standardized offerings (Gawer and Cusumano 2014)

  Standardization of practices and protocols are influenced by the degree in which actors are willing to collaborate to minimize or eliminate disparate rules and ambiguity in processes, products, technical standards (Hein *et al.* 2019). Standardization can emerge de facto (spontaneously) or deliberate. Standardization can be considered as coordinated actions aimed at promoting collaboration, integration of technologies and interoperability. Interoperability has been identified as complex management operator in the servitization literature (Durugbo 2011, Hajimohammadi *et al.* 2017, Xu *et al.* 2018). A lack of standardization increases variety across collaborating vendors and undermines interoperability. Standardization in addictive manufacturing (Ng *et al.* 2009, Windahl and Lakemond 2010, Kowalkowski *et al.* 2015, Hein *et al.* 2019, Moroni *et al.* 2020, Vendra *et al.* 2020) provides a means to attenuate variety and amplify the creation of innovate solutions.

  Collaborative governance mechanism has been identified as an alternative to the governance mechanism proposed by the Transaction Cost Theory (Williamson 2007). Relational governance is founded on open communication, trust and cooperation between parties and actors. In the servitization literature, studies have identified the role of collaborative governance mechanism particularly in result-oriented PSS types (Windahl and Lakemond 2010, Kreye 2017b, 2017a, Sjödin *et al.* 2019, Kamalaldin *et al.* 2020). Findings from the case studies show a mix of governance mechanisms from control to coordination to collaborative governance. However, it was found that trust

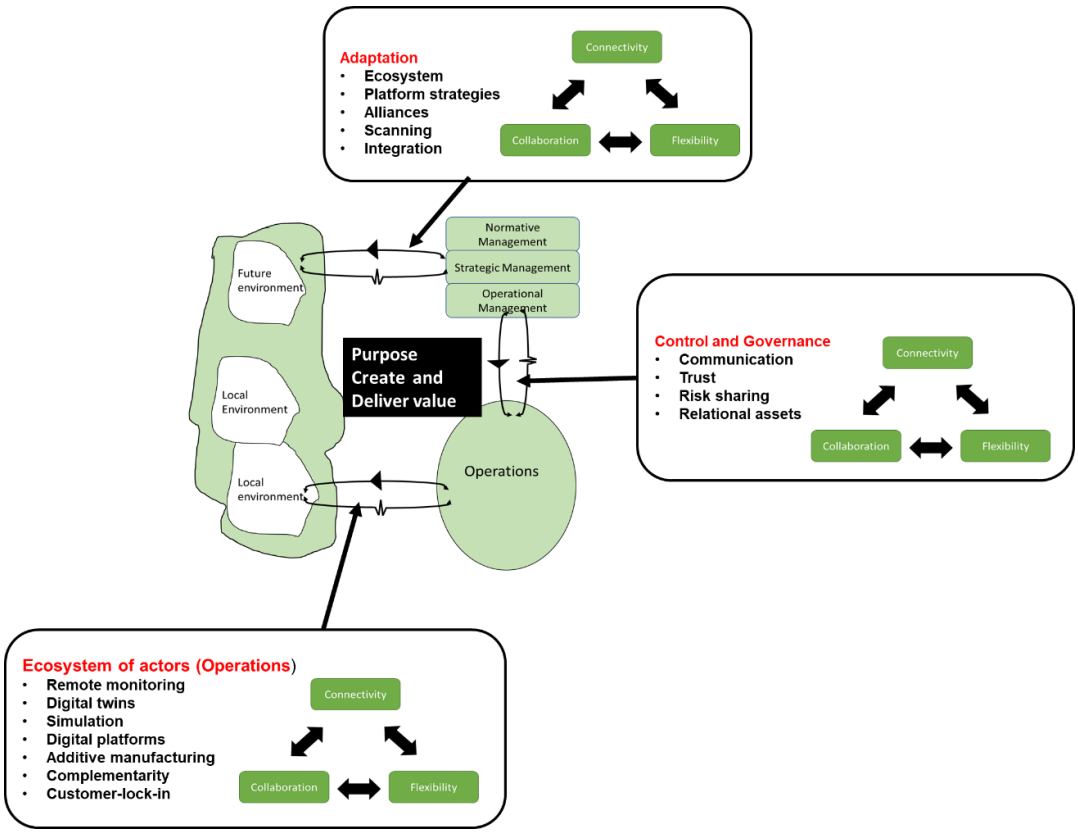
emerged in the contract with collaborative governance. Collaborative governance fosters and facilitates knowledge sharing, shared understanding, alignment of expectations, communication focused on building consensus as opposed to emphasizing on differences (Paulin and Ferguson 2010, Martins *et al.* 2020). Coordination and Collaborative governance mechanisms are particularly useful when the level of risk is high in PSS contracts (Kreye *et al.* 2015, Bastl *et al.* 2019).

- ***Flexibility as a variety operator***

  Technologies like digital twin, simulation, 3-D printing and modularity represent or produce knowledge bundles that increases the flexibility of PSS providers. Flexibility is designed to increase the capacity to respond, address and alter. For example, a digital platform provides the means to customised solutions using a variety of modular products or components. In addition, additive manufacturing leverage knowledge relating to modularity to create standardized and customized product designs that saves time and cost for the PSS provider. For example, Ivanov *et al.* (2019), Sala *et al.* (2017) and Davies *et al.* (2020) can be used to absorb variety arising from changing customer requirements, contextual variety of use scenarios and structural inflexibility (Green *et al.* 2017), increase flexibility to PSS providers and minimize losses arising from product obsolescence.

  According to the findings in this research, not only in Operations (system 1) is flexibility necessary, but it is also necessary in the cohesion and adaptation functions (System 3 and System 4). In the cohesion, flexibility is demonstrated in how much regulatory capacity was assigned to the operating units and the degree of centralization. Both issues affect the autonomy of the operating units and how quickly they could process variety against the backdrop of their changing environment. Rather than employing bureaucratic control, standardization of the rules, providing a framework and supporting through the use of objectives was found to generate more cooperative behaviour. In the adaptation function, adaptation followed the deployment of existing capabilities in adjacent markets. In some cases, new capabilities acquired through merger or acquisition and then integrated flexibly with existing capabilities. New capabilities were designed to add value to existing offering.

Figure 49: Connectivity, Collaboration and Flexibility across the equilibria sites



5.5 From Physical Assets to Knowledge Asset – Organisational Learning and Knowledge Management

A very important feature of the case studies is the emergence of knowledge asset as variety management operator/instruments. The emergence of digital technology underpins the growth of knowledge assets. The likes of software, applications, digital technologies, cloud technology, 3-D printing, Additive manufacturing, Digital twin provide large repository of knowledge to collect, manage, integrate, and create – attenuate variety and amplify responses. Repository of knowledge express themselves in the form of competence, capability, and technologies.

Although evidence from the case studies acknowledge the place of digital technology as an enabler, a prominent feature of the cases is the role of organisational learning and knowledge management in complexity management. Digital technologies like IoT and digital twins present the opportunity to collate, share data, analyse data (if embedded with analytics capabilities), but more importantly, it presents a platform for learning and to apply knowledge in choosing appropriate response to attenuate complexity or amplify response capacity. Even with the right technology, it is observed that unprocessed variety remains, which could lead to instability of the PSS. Therefore, the acquisition of digital technology is not enough. Complexity management must be built on the capacity to learn and apply knowledge enabled by technology appropriately.

The importance of organisational learning (Senge 2006) and knowledge management in driving adaptation in viable systems has been examined in the literature. Yolles (2000) argues that viable organisations seek for new ways to survive in complex situations by leveraging opportunities for learning, creating new opportunities, and managing knowledge. When complex systems are stretched by the forces in their environment, the assume a position between chaos and order, where they adopt new form via creativity and innovation. Articles by Mark McElroy (McElroy 1999, 2000) has sought to integrate complexity theory, Organizational Learning and Knowledge Management.

5.5.1 Complexity Management as a Knowledge Management Process encapsulating Organizational Learning.

Drawing from second generation knowledge management (McElroy 2002), a PSS is conceptualised as a system where competences are continuously created, developed, shaped and maintained and protected; a cycle that is underpinned by organisational learning and knowledge management (Amin and Cohendet 2000). Here, knowledge management is defined as the creation, storage, flow, transfer, and release of organisational knowledge . In this definition, knowledge management encompasses data and information management. Information management which involves information created and codified in information system.

Knowledge Management entail ***coordinated actions***. It involves the systematic coordination of processes, activities, tasks, technology, and structure to a enhance value through the creation, sharing and maintenance of knowledge. Knowledge managements are presented as life cycle models. Knowledge assets include knowledge repositories, relationships,

information, technologies, communication, skills know-how, responsiveness, organisational intelligence declarative knowledge (Bukowitz and Williams 1999)

There are multiple knowledge lifecycle models (KMC) including the Wiig KMC (Wiig 1994), Bukowitz and Willaims KMC (Bukowitz and Williams 1999), Nonaka and Takeuchi Model, (Nonaka and Takeuchi 1995) McElroy KMC (McElroy 1999, 2000). Each model outlines the steps and phases encapsulating the creation, storage, maintenance, transfer, and integration of knowledge. However, knowledge management cycle phases can be categorised into:

1. The production of knowledge, which increases an organisation's rate of learning, encompassing procedural and declarative knowledge. During this stage, groups and individuals interact to share, and exchange information: they form communities of knowledge.

2. Knowledge validation - Here, the new knowledge is validated through formalized processes within the system (enterprise, organisation) .

3. Knowledge integration – This involves the integration of the knowledge within the system – codified into business processes, organized/or expressed in the form of rule sets and are expressed in organisational practices, used, shared, transferred, stored, retired.

Amin and Cohendet (2000) argue that these ***organizational practices*** stress how well the firm knows how to do certain things – which they label "competencies": coherent sets of capabilities (operational and strategic), which the increases the competitive advantage of the PSS provider (Teece *et al.* 1997, Teece 2018).

Drawing on phases of the knowledge management cycle, the researcher explains how PSS providers manage complexity to achieve viability. In each of the equilibria site,

5.5.1.1 Variety Engineering, Complexity Management and Knowledge Management

According to the Viable System Model, achieving viability involves the five functions and six communication channels operating properly to drive self-organisation and self-regulation of the whole system. Whether it relates to the horizontal homeostat, vertical homeostat, or systems 3-4 homeostat, organisational processes are social processes where relationships between social actors result in the co-production of value. Since complexity arises from the

ability of individual actor to make distinctions, which is a function of cognitive ability, it is natural to find complexity (variety) asymmetry between actors. These actors could involve providers versus customers, between operational employees and management, between senior management and strategic management.

The challenge is managing the variety imbalances to achieve viable performance. Requisite variety is a construct to assess this performance. According to the Law of Requisite Variety (Ashby, 1964), only variety can absorb variety, which means the variety of the regulator must be as large as that of the regulated to achieve desired performance. This is where knowledge management comes to the fore.

5.5.1.2 **PSS Operations (horizontal homeostasis)**

First, Information systems such as portals, databases, customer service forum provide an essential storage of ***codified*** knowledge such as customer data, customer location, repository of agents and business processes and procedures for carrying out a tasks and activities. This repository of data, information and knowledge allow PSS operators to carry out processes which deliver value to customers. In the context of variety engineering, codified knowledge absorbs the variety generated by the problem its addresses. However, codified knowledge is not enough to achieve desirable performance.

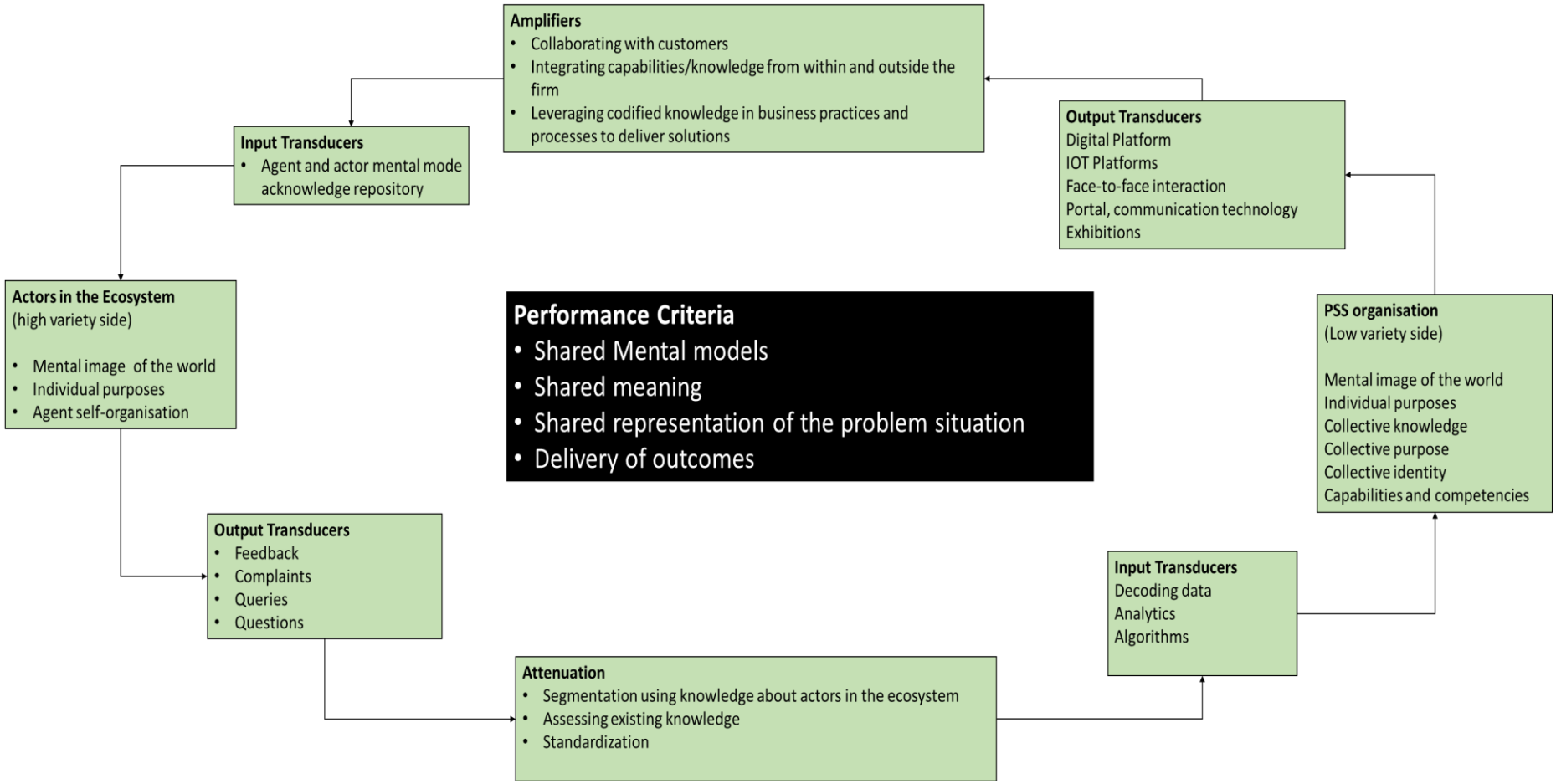
As indicated already, in result-oriented PSS, the customer and suppliers across the supply chain are endogenous to the service delivery system. As these actors interact, individual knowledge is expressed and transferred to the group through socialization processes (Nonaka and Takeuchi 1995). Passive and hidden customers' needs, and requirements are unpacked and understood, non-performing knowledge is identified or modified and shaped. The new knowledge created is codified into the system repositories through routines and rule sets, policy manuals and recommended for addressing frequently occurring situations. The interaction between actors provides a platform to learn, share existing knowledge. By codifying the knowledge, it can be transferred across the network or enterprise.

The creation, dissemination and use of knowledge in a PSS dependent on the conversion of tacit to explicit knowledge. Nonaka and Takuechi (1995) propose a four-way model of knowledge transfer including: Socialisation, (which is tacit-to-tacit knowledge), Externalization (tacit to explicit knowledge), Internalization (explicit to tacit) and Combination (explicit to explicit). Although, digital technologies play a role in the conversion of knowledge across PSS operations, the conversion is essentially human-based.

Through a process of observe, assess, actions and implement (OADI), actors within PSS operations produce a pattern of ***'shared meaning' and 'shared mental models'*** (Espejo 2007), a feature that reflect the cognitive capacity of the network (Espejo 2015a).

To leverage the creation of knowledge from the collaboration of actors, the use of digital platforms, facilitate and fosters the emergence of ***virtual*** communities of knowledge, where actors integrate resources, share information, test existing knowledge, create new knowledge. Digital platforms permit access to rich knowledge base outside the boundaries of the PSS, which increases the value and quality of the knowledge created as more actors interact and integrate their capabilities. Digital platform act as robust infrastructure of learning and knowledge creation. Here, actors' actions are affected by the actions of other participating actors and their own actions resulting in a reflexive learning process.

Figure 50: Variety engineering across PSS operations



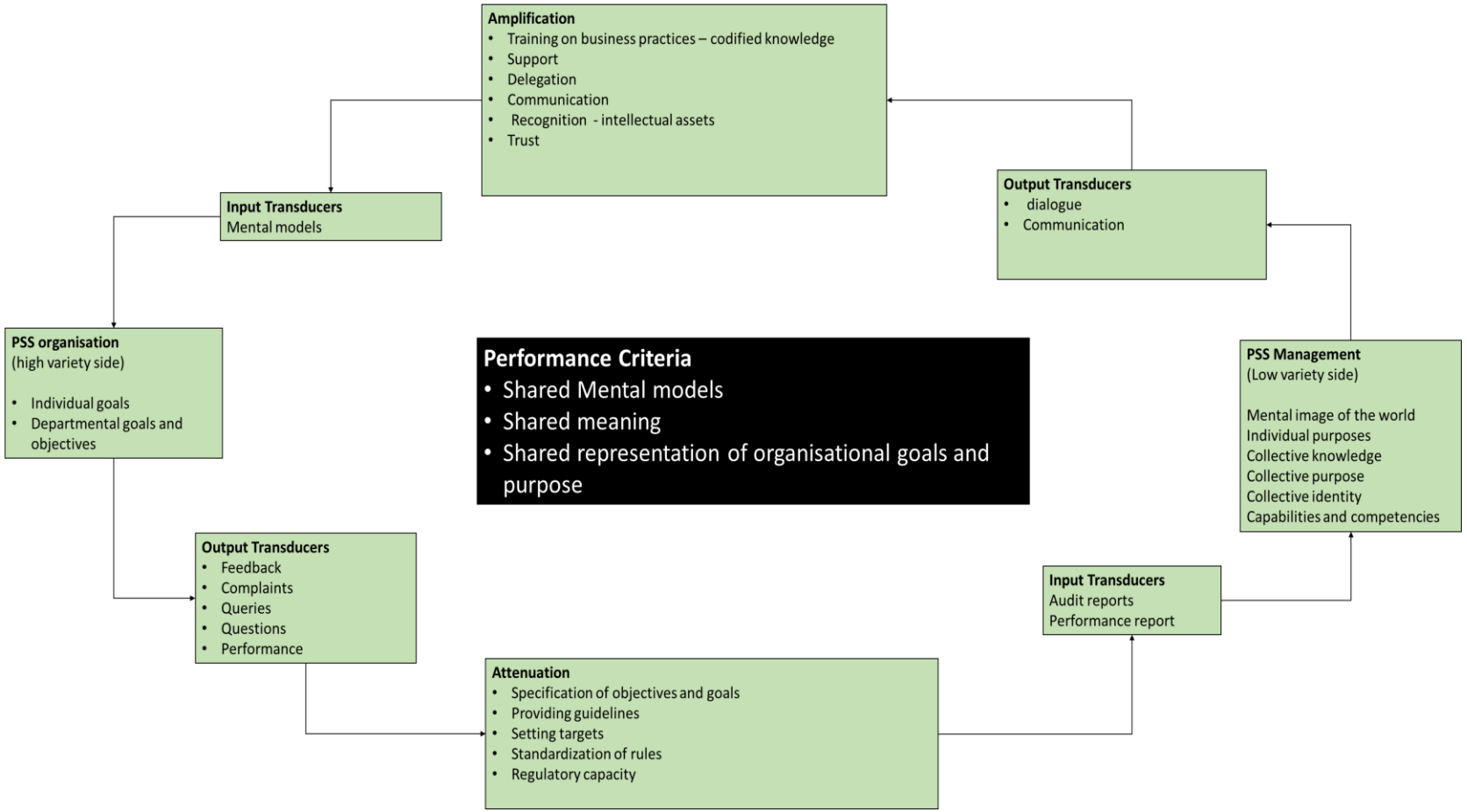
5.5.1.3 **Coordination and Cohesion (Management system 2-3)**

In enterprises, knowledge would be held across three domains: knowledge held by individuals, groups, and the organisation (McElroy 2000). There may be disparity between these levels triggering conflict and friction such procedural knowledge (know-how knowledge codified into business practices and operational processes) versus declarative knowledge (know-what knowledge relating to organizational purpose, identity etc). Managing this tension becomes a test of the cohesion and adaptative potential of the PSS. This is akin to the tension that builds up between system 3 and system 1 of the viable system model.

Variety imbalance within a PSS network results in internal complexity issues. Espejo and Reyes (2011) stress the importance of choosing appropriate levels of decentralization and regulatory capacity, which facilitates cohesion between the regulatory function and operations. In the context of knowledge management, decentralization facilitates the acquisition of knowledge that is diverse, deployed flexibly and promotes learning by primary activity (operations) agents; however, knowledge has to be made available for use by the whole organisation, else it creates variety imbalances between management and operations (McElroy (2003). This is particularly relevant when the business landscape is unstable and turbulent. When there exist differences between agents across PSS operations and management in their cognitive capabilities and representations of the environment, a knowledge-based mechanism that facilitates coherence in the collective representation of purpose of the system must exist to drive synergy (Kaivo-Oja *et al.* 2015).

Therefore, coping in changing environment, would require a modification of the common body of knowledge, though fed by decentralised learning processes, has to undergo some form of centralisation (Nonaka and Takeuchi 1995). Knowledge management becomes essential to organisational development, learning and innovation. At the heart is externalisation (Nonaka & Takuechi 1995), which describes the relationship between tacit knowledge and explicit knowledge.

Figure 51: Variety engineering across PSS Vertical homeostasis site



5.5.1.4 **Adaptation**

The Knowledge Management literature distinguishes explicit and tacit knowledge. The explicit knowledge is the codified knowledge and expressed in literature, writing, books, tapes, manuals. Tacit knowledge refers to the knowledge embedded within humans expressed and skills and capabilities. Nonaka and Takeuchi (1995) argued that the biggest challenge for organisations is transforming tacit knowledge in individuals to organisational knowledge. This requires a culture of continuous learning and knowledge sharing to facilitate transfer of knowledge to groups level through communication, observation and socializing events. A culture of knowledge management is one that fosters learning , which is tested and evaluated on a continuous basis.

For adaptation to occur, it requires actors within a PSS provider to build new mental representations of the environment they operate and develop new skills to exploit and exploit opportunities that environment provides. To accomplish this, the capabilities and culture must be present to in the firm.

5.5.1.5 **Knowledge Management: a Conduit Pipe for Innovation**

The findings from the analysis of the case studies reveal the role of knowledge management in driving innovation. As customers' needs and use context change, PSS operators leverage collaborative networks to create, modify and extend knowledge and competencies. One example is the use of platforms to integrate capabilities from multiple sources. Another example is the acquisition of companies to access both explicit and tacit knowledge. These knowledges were deployed to extend the functionality of existing product lines and/or deployed to creating new product lines in adjacent markets. Collaborating with third-party agents with loosely coupled links to main or parent companies by providing interoperability with platform and application creates a gateway provides access to a rich source of knowledge outside the boundaries of the PSS.

New knowledge created serve as resource to innovation process. Managing new organisational knowledge involves retaining well qualified individuals with tacit knowledge and protecting intellectual property. Company-wide culture and policies must facilitate the integration of new knowledge through knowledge management platforms, processes and

5.6 The Place of Cognition in Complexity Management

Knowledge is a cognitive process. Individual actions and decisions are often influenced by the lens which they see and understand things (Waseem *et al.* 2018). There is a whole body of research across multiple fields and disciplines which addresses the role of cognition in value co-creation (Daft and Lengel 1986, Gebauer *et al.* 2005, Payne *et al.* 2009, Gummerus 2013, Akter *et al.* 2019).

In the creation and delivery of value, managerial the ability to understand the world of the customer, understand the requirements of the business and identify unspoken needs (Ng and Briscoe 2012, Gummerus 2013). Cognition resources the ability of the manager to create a mental picture or image of his surroundings, environment, interactions (Helfat and Peteraf 2015). Contributions from the extant literature shows that digital transformation projects and organisational changes are underpinned to some extent by the degree of managerial cognitive capabilities. (Schwarz *et al.* 2019, Embriyono and Munir 2020). The role of cognition in the success of strategic alliances has also been studied (Jalali 2020). The authors found that cognitive capabilities induce some form of psychological impact, which strategic alliance and drive performance. Other study include the sustainable development of innovative ecosystem is underpinned by managerial cognitive capability (Cao *et al.* 2020).

On the other hand, customer engagement with a firm's offering entails a cognitive process of assessing the offering within the context of the individual's existing values, beliefs, and norms. To buy or not to buy, to engage or not to engage is a cognitive process if assessing emotion, beliefs and experience (Gummerus 2013, Solakis *et al.* 2017). According to (Brodie *et al.* 2011) and (Waseem *et al.* 2018), customer engagement occurs within a psychological space of cognition, emotions and interpretation. Customers are self-interested beings with preferences. They make decisions based on a set of cognitive rules and schemas to make sense of world, reality and situations (Geels and Schot 2007)

A representative fro*m CustomerLight says*.

> " *We care about the environment and sustainability. We like the idea that we can regulate our energy consumption. That explains the reason we decided to contract for the service. We searched around and we found that ….this is the best we can get".*
>
> *"they are trying to sell other solutions to us, but we are not sure we need them"*

The use of touchpoints and spaces, which explore customer cognition and decision-making capabilities have been suggested in the marketing literature (Payne *et al.* 2008, 2009, Frow *et al.* 2014, 2015). Communication encounters, interfaces, and artifacts can be used to leverage customer's cognition to drive engagement and value co-creation (Cantù *et al.* 2012, Ng, Smith, *et al.* 2012, Solakis *et al.* 2017, Taylor *et al.* 2019)

This is key and of great importance for managers. Cognition is a key player in the design of products, solutions; in the expansion of service offerings; in sensing, searching and optimising opportunities in the environment (Helfat and Peteraf 2015) as well as underpins the integration of resources by customers and other actors to co-create value.

5.7 Cognition Underpins Institutionalization

Cognition also explains the glue that drives cohesion mechanism and collaborative synergy in a PSS. In the previous section, it is argued that actors are rational beings, self-interested and use cognitive schema to assess and interpret their world. As actors interact, they interpret their tasks using their cognitive schemas (Espejo and Reyes 2011). They make sense of their interactions and construct new schemas as they adapt to new routines. As schemas converge, strong social structures arise, which may evolve to drive change and legitimacy.

In an organisation context, cohesion in the context of VSM can occur through a process of "converging perspectives" (Lassl 2019a, p. 155). It involves driving emerging schemas of individual members of the firm towards the collective purpose, values, and norms. This occurs through consensus building around the organisation's values, purpose, and strategy.

This has implications for managers in servitized companies. The operational units (system 1) actors must ***derive meaning and value*** in the task they that they do, otherwise, the ability to process variety is undermined and the viability of the PSS is undercut.

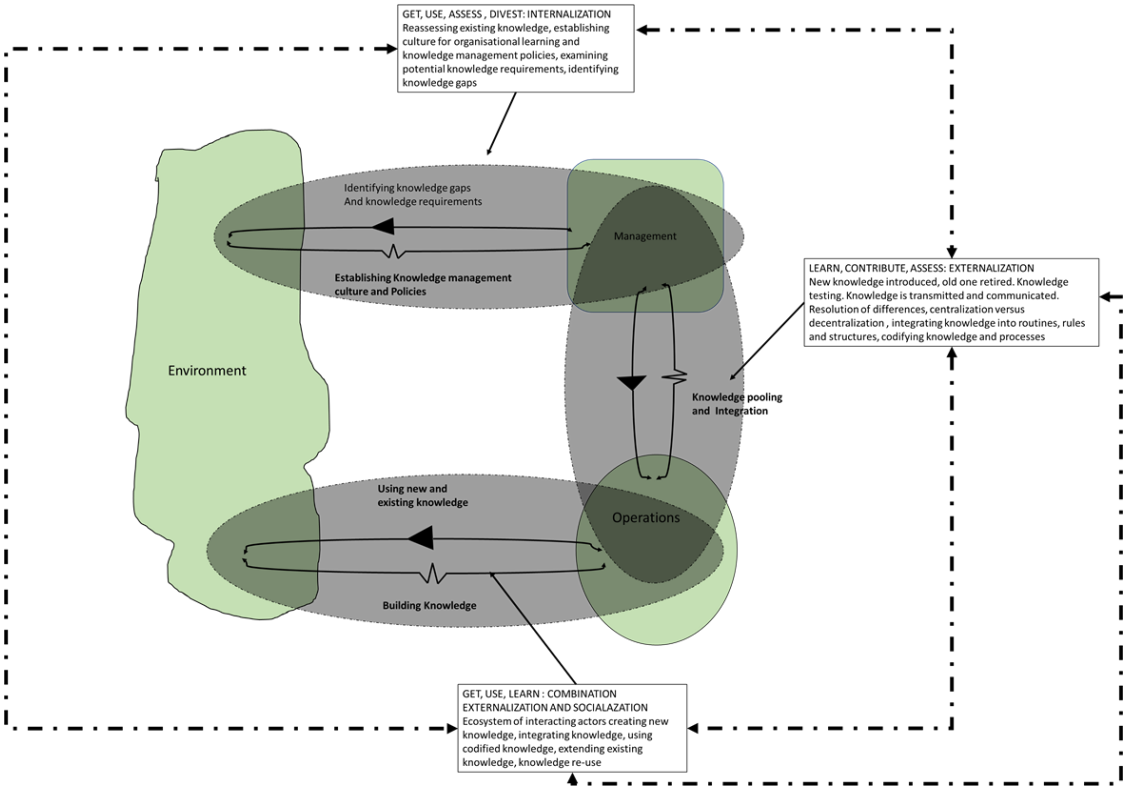
An atmosphere of "we are in this together" engenders synergistic engagement and participatory management. With this sense of agility and versatility, problems are explored within a framework of open debate , exploring multiple perspective, and embracing new change. It facilitates innovation and new generation of new ideas.

Every important here are the communication channels. The six channels of the VSM: the resource and accountability channel, the corporate intervention channel, the channel of system 2, the channel of system 3*, the interfaces between the operations of the systems 1, and the interfaces between the environments are designed to influence the capability of the

operational units to process variety. Communication channels should be constructed to facilitate open debate, bonding, and knowledge sharing.

Driving cohesion through the institutionalization has been found to modulate the behaviour of workers (Randall *et al.* 2015), facilitates the development of co-capability (Brodie *et al.* 2011), ad drive innovation in service ecosystems (Vargo *et al.* 2015, Böhm *et al.* 2016, Hein *et al.* 2019)

Figure 52: Updated VSM-based framework for complexity management in PSS



5.8 Summary

The discussion of the analysis of the results have been presented in this chapter. The relationship between complexity management and knowledge management has been discussed by drawing from complexity management and knowledge management literatures A framework has been developed to indicate this relationship.

6 Contributions, Limitations and Conclusion

6.1 Introduction

This study was motivated by the gap identified in the PSS literature regarding the concept of complexity and complexity management practices. Servitization is fraught with complexity, risks and uncertainty; all of which threatens the viability of a PSS. The PSS literature on complexity management is fragmented. Although, the literature recognises the significant role of digital technologies in driving servitization and new service-based models, there is a lack of a holistic framework for complexity management. Current studies are context specific, industry specific, address specific aspect of the PSS.

Revisiting the research questions:

- How can a PSS be steered and governed to maintain viability against the backdrop of complexity in its internal and external environment?
- What are the conditions underlying the viability of a PSS? What conditions must PSS providers maintain to drive its viability?

In this section, the researcher discusses the contributions this research has made to theory and practice. In section 6.2, the contributions of this research, both to theory and managerial practice are laid out, Following this, areas for further research are presented. This is followed by the conclusion.

6.2 Contributions to Knowledge

The servitization literature examines complexity management with a focus on the operational system – the service delivery system. In this research a holistic perspective of complexity management is undertaken to capture systemic mechanisms underpinning self-regulation and self-organisations in service companies delivering outcomes through a product service system (PSS). Three mechanisms were found to underpin complexity management in PSS companies. The first is ***connectivity*** aimed at creating or modifying new/existing knowledge, ***collaboration,*** which is aimed at leveraging relationships to integrate knowledge to create new knowledge and activities, and third, ***flexibility*** mechanism aimed at increasing the capacity to respond (process- know-how).

Exploring complexity management using the Viable System Model reveals the centrality of knowledge management as a complexity management approach in PSS companies. For PSS companies, knowledge include knowledge repositories, information technologies,

relationships, infrastructure, procedural know-how, declarative information, functional skills, and intellectual properties. Drawing a link between complexity management and knowledge is novel in the PSS or servitization literature. These findings provide new insights into the mechanisms by which knowledge is created, shared, and transferred through processes such as socialization, externalization, and combination in firms. While existing studies has emphasized the role of relationships and relational assets in reducing variety and complexity In service contracts, the findings of this research provide a glimpse into the processes underlying the creation of shared meanings and shared mental model between interacting actors involved in a service contract.

Secondly, the research contributes to the service paradox discourse in the servitization literature. Service paradox is a situation where servitizing firms invest heavily in service provision both reaps little returns in profit. Servitization strategies fail largely due to unprocessed variety within the system. Variety imbalances arise from a dysfunctionality of system functions. To achieve viability, requisite variety is required. Information and digital technologies are not enough. Communication in the form of coordinated actions buoyed by organisational core competencies and capabilities can help service firms to absorb variety. Competences and capabilities are knowledge packages codified as routines, organisational rules and structures. Therefore, managing the creation, storage, use and sustenance of knowledge could help PSS firms address the service paradox.

6.3 Contributions to Practice

6.3.1 Complexity can be Leveraged for Good.

The findings of this research have shown that PSS providers and customers can step back to leverage variety and complexity in their environments for good rather than attempting to manage or reduce it. It is important to highlight here that complexity presents a goldmine of opportunities to explore new opportunities and possibilities. Therefore, rather than cutting back, and shrinking parts of the business, managers can adopt long-term thinking and resource integration initiatives to adapt .

This brings to fore the role of technology and digitalization on the one hand and strategic alliances on the other hand. Capitalizing on complexity as an knowledge management opportunity could underpin the viability of service firms at he precipice of collapse due to turbulent environment (Ahuja 2000, Randall *et al.* 2015, Cenamor *et al.* 2017, Sjödin 2019).

6.3.2 Beyond Information Management to Knowledge Management

This research identifies knowledge management and organisational learning as underlying catalyst for managing complexity in service companies. Managers must look beyond data repositories and digital technologies to look at how they manage knowledge in their organisations. As findings from the research shows, it might be necessary to collaborate with the competition to create new knowledge (competence and capability) to enhance organisational performance. Although technology is good and essential, it would not drive viability in itself. It is human communications system designed to create, using, assess, integrate and manage knowledge continuously and dynamically which promises the most robust approach to enhancing the achievement of requisite variety.

6.3.3 Cognition and Institutionalization are fundamental to Complexity Management.

This is important for managers. Managers in service companies could leverage cognition to manage complexity. Managerial cognitive capabilities have been found to underpin the selection of strategies, the implementation of strategies, the implementation of change, the design and development of offerings and sensing and searching the environment for opportunities. In fact, cognition underpins all capabilities. Developing managerial cognitive capabilities could help managers to learn and understand how to co-create value with their customers and network of actors.

Secondly, managing complexity is not only an operational issue but also a strategic issue as well. Understanding the need for synergy and cohesion in the implementation of the firm's purpose underscore the place of driving converging perspectives in the word place. This involves leveraging individual cognition towards the collective purpose of the company. Managers can develop the knack to promote an atmosphere, where there is open debate, participatory management, and self-reference in individual task.

6.4 Limitations

This study is not without limitations.

First, an interpretivist paradigm was employed in this research. An interpretivist perspective presents knowledge as a product of multiple perceptions, interpretations, and meanings of individuals. This research investigates complexity management using companies drawn from three industries. To this end, this research does not possess a basis for generalization as the VSM of the PSS reflects subjective interpretations of participants and industry in each case.

Although case study as a research strategy does not rely on ***statistical generalization*** like surveys, case studies rely on ***analytical generalization*** (Yin, 2003, 2014). Analytical generalization relies on generalizing results to some broader theory. In case studies, the theory "becomes the domain with which results are generalized" (p.38).

In this research, findings show the link/relationship between complexity management and knowledge management. This finding could be generalized to the theories relating to knowledge management, organisation learning and competitive performance. A learning organisation is one that learns, creates new knowledge, and utilizes the knowledge to achieve competitive advantage. By competitive advantage, it means the firm is viable, possess requisite variety (capabilities and competence) to process and absorb variety.

In their seminar book titled "the Core Competences of the Corporation", Prahalad and Hamel (Prahalad and Hamel 1990), prevailing in global competition and achieving competitive advantage rest on the ability of corporations to create, identify and exploit their core competencies that make growth and viability possible. These core competences are nothing but a company's collective knowledge about how to coordinate diverse production skills, capabilities, and technologies. Therefore, it seems very logical to generalize the findings of this research to the theory of core competences proposed and developed by Prahalad and Hamel.

6.5 Further Research

This research used cases chosen from the lighting industry, printing industry and payment processing industry. These companies are multinational companies with a presence in many countries. And possess well-developed knowledge management systems. They are heavily resourced to contain variety using their recursive architecture and reach. Small and Medium Enterprises (SME) do not possess the same characteristics. Therefore, future research could expand the exploration of complexity management using a VSM to Small and Medium Enterprises (SME).

Combining VSM with a hard systems-thinking methodology is another area that can be explored. Multi-methodologies can leverage the capabilities of each methodology to provides insight, where a single method has failed. Some research works are currently on-going in that regard (Haslett and Sarah 2006, Iandolo *et al.* 2018, Vahidi and Aliahmadi 2019).

Furthermore, the viability of a PSS is dependent on relationships. Relationships reflect coordinated actions to align shared expectations, shared meaning and mental image of the system purpose and objectives. Further research could look at the mechanisms underlying the externalization of knowledge in group relationships.

6.6 Conclusion

The literature on PSS managing complexity has been explored and a gap was identified. PSS complexity models lack a holistic touch. Complexity is considered as an objective property, where underlying forces of cause and effect can be used to predict a PSS behaviour. In addition, existing models strips a PSS of its wider components and limit the boundary of the system to its product and service component.

In this research, an exploration of complexity management in the context of a PSS has been undertaken. The Viable System Model developed by Beer (1979, 1984, 1985), alongside associated principles like variety engineering and Law of Requisite Variety were used as epistemological lens and meta-language to explore complexity management practices in PSS providers. Adopting a cybernetic lens enables the exploration of a PSS as a human communication system, where people are observer participants engaging in recurrent communication network producing their systems.

These communication systems represent coordinated actions.

Revisiting the research questions:

1. How can a PSS be steered and governed to maintain viability against the backdrop of complexity in its internal and external environment?
2. What are the conditions underlying the viability of a PSS?

The research finds complexity management involves managing knowledge in a PSS across operations and management functions. Whether it involves maintaining repositories and databases of data/information or nurturing and growing relationships or building infrastructure,

knowledge occupies a central position in the creation and renewal of new capabilities, competencies and learning opportunities.

Knowledge relies on cognitive abilities of individuals. For PSS companies, cognition and institutionalization represent critical factors of an effective complexity management practice. These factors underpin how a PSS is steered (via its value creating and delivery processes and mechanisms) and governed (through the cohesion mechanism). Cognition and institutionalisation drive actions and cohesion and influences results generated from those actions. Both cognition and institutionalization has been found to drive actor engagement and co-creation of value in ecosystems. **This satisfies the first research question.**

Furthermore, the findings show connectivity, collaboration and flexibility as the core mechanisms underlying the viability of a PSS . Connectivity to know, collaboration to leverage knowledge to create new knowledge and flexibility, pockets of knowledge which increases the speed of response ensure that a PSS provider is is stable and capable of evolving as the environment changes. **This satisfies the second research question.**

7 References

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8 Appendices

Appendix 1:Consent form

Aston Business School

Consent form

Full title of Project: PSS Complexity – A Viable System Perspective

Name, position and contact address of Researcher: Emmanuel Musa, PhD Student, South Wing/11th Floor Aston Business School, Aston University, Birmingham, B4 7ET, UK

	Please initial box
I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions.	☐
I understand that my participation is voluntary and that I am free to withdraw at any time, without giving reason.	☐
I agree to take part in the above study.	☐
I agree that my data gathered in this study may be stored (after it has been anonymised) in a specialist data centre and may be used for future research.	☐

	Please tick box	
	Yes	No
I agree to the interview / focus group / consultation being audio recorded	☐	☐
I agree to the interview / focus group / consultation being video recorded	☐	☐
I agree to the use of anonymised quotes in publications	☐	☐

Name of Participant _____ Date _____ Signature _____

Appendix 2: Invitation to Participant Letter

Aston Business School

Dear Sir,

Participation in PhD Research Survey

I am Emmanuel Musa, a PhD student at Aston University Birmingham, majoring in Operations and information Management. I am researching complexity in PSS offerings. Therefore, I will like to invite you to take part in this research study.
Prior to deciding whether you would like to take part, it is essential that you understand the purpose and the procedure of the study.

What is the purpose of the study?
The aim is to understand the mechanism by a product service system manages complexity and to develop a viable model

Why have I been invited to participate?
You are invited to participate in this research because you work for a firm providing an integrated product-service offering or by virtue of your job description you hold information relevant to the research.

Do I have to take part?
Only if you want to. Taking part in this research is completely voluntary. You may skip any questions that you do not want to answer in the questionnaire. There are **no risks** in taking part

What will happen to me if I take part?
This research has been approved by the Aston University Research Ethics Committee. This means all rules and regulations guiding the conduct of a PhD research at Aston University will be followed to the latter. **All information and data** collected including your responses to questions in this survey will be kept confidential. The name of the company, participants' names or title, company brands, marquee product names or services and artefacts will be fully anonymized and unidentifiable in my thesis report.

What are the possible benefits of taking part?
To advance our knowledge on what drives costs in performance-based service contracts over time
To support effective decision-making in organizations

Any concerns or questions?
If you have comments, questions, concerns regarding any ethical issues related with this research at any point, you can contact me, Emmanuel Musa at musaeo@aston.ac.uk or my supervisors, Dr Andrew Greasley at a.greasley@aston.ac.uk and Dr Pavel Albores at p.albores@aston.ac.uk. I have attached a consent form, which can be emailed to me at musaeo@aston.ac.uk . I hope to hear from you. Thank you

Appendix 3: Interview questions

System/Channel	Questions / *Sub-questions*
S1	What are the main operations of the system? E.g. Growing, hauling, milling – are there any others? And you as a grower/haulier/miller how dependent are you on the overall system?
C3	How do the operational units relate and work together? How are the relationships, connections and interactions between the different operations in the system? Does it work well or not? Why? Tell me more….
S2	If you look at the operations you mentioned, how do you coordinate them? What mechanism do you have that things run smoothly? Do you experience fluctuations in the system and what do you do about it? E.g. every morning there was a long queue at a special intersection and cars waited over half an hour. Then the build a traffic light, cars still wait, but less.
S3	What are the important committees, procedures and structures that facilitate a good operation of the entire system? To what extent do they influence you, what do they determine? If you look at the system as a whole, who is managing it and through what mechanisms? Where do the instructions come from in relation to the operational groups you mentioned and how? Who is the "boss"? Who gives instructions for what needs to happen across these groups and how? What is determined? What is expected from you? If there is conflict between the main players how does it get sorted? Where does committee/group xyz fit in?

	What resources do you get (from the system as a whole/from your "boss")?What do you get from being part of the system? What resources does the xyz provide? What is expected from you in exchange for these resources? How is it checked that you deliver what is expected? How does the System you work in affect your operation? What mechanisms are in place to support internal stability, synergies and an overall optimum among the units? To which extent does upper management intervene in your day to day activities?
S3*	Who is controlling you and how? How do you or the others check that you deliver what is expected on a sporadic basis? What kind of internal audit processes do exist?
S4	Who is looking at future trends and the environment, and investigates their impacts on the system in the long-term? Where do you see your system in 5 years? Which future trends and external impacts are likely to affect the system and how do you plan to deal with them?
S5	Why does your system exist in the way it does, as collective whole? Please describe to me in one sentence why the system does exist! Why can't you just farm and do your own business? What binds this system together?

System/Channel	Questions / *Sub-questions*
S3	Can you tell me more about measurements in regards to ensuring rateable delivery and delivering appropriate quality and no foreign matters. Who determines, monitors and implements them? Are they followed? If not what would be appropriate measurements to achieve that?
C3 & S2	Can you tell me more about the issue of the lack of two way communication
S3*	Are there any sporadic controls in the system ?
C3 & S5	Can you tell me more about the working relationship between the different stakeholder groups? We were told it is great and then we were also told that everyone has its own agenda and there is no understanding and appreciation of each other.
S2	How could the coordination of the different activities in the system (cane growing, harvesting, transport and milling) be improved? What would it need?
S4	Is there a group that initiates projects or special initiatives to improve the system and adapt to the future? In what ways? Who defines and implements the strategy for the whole? Who is looking at the risk of decreasing cane supply or other future developments?
Environment	What do you consider as the environment? Who are your customers and who are your suppliers? How does the environment affect your operation and the operation of the entire system? What external rules and regulations do you have to comply with? How do you interact with your environment?

Appendix 4: Case 1

CASE 1

Operational Unit	Processes	Recursion & Autonomy or Complexity
Management of Operations	1. Maintenance services – to increase availability of MFD (multi-function device) and other devices 2. Timely and prompt supply of consumables like toners and cartridges to avoid business disruption. This is an automated process. 3. Updating software – to fix bugs and malware. This is to prevent security breach and loss of data. 4. Customer Service/Advisory – Answering queries and questions is a major part of managing the relationship between *Partner1* and *Customer1*. This occurs via phone call, office visits, emails. Questions relates to how to resolve one issues relating to the operation of the MPF device, how to perform a task such remote printing, scanning to the cloud, scanning multiple pages simultaneously, Follow-me printing. 5. Recycling and end of life processes – Partner1 handles the disposal of a MFD following its removal	***Potential flashpoint*** for Complexity – Shortage of spare parts, multiple devices breaking down at the same time, waste of consumables Obsolete materials, hardware downtime, poor communication between field technicians/contractors and Partner1 Disruption to *Customer1*'s business ***Recursion*** – The app helps all parties to view what the state of things. It helps to alert every party to their responsibility. Through the app, consumables are arranged, the performance and usage of the hardware can be viewed, any anomality is corrected. Software update was carried out on weekends. The new machines are equipped with Do-it-yourself help messages that enabled *Customer1* employees to solve little problems without calling *Partner1.*

		Partner1 operates a 4 hours response time following the first contact or reporting a fault. It tries to ensure faults are resolved within 24 hours to prevent downtime. While the machine is down, all data or print jobs can be re-routed to other printers Repairs and maintenance were carried out without causing disruption to the business processes of the customer. Availability of hardware was high, response time for inquiry and queries were within service level agreement, consistent updating of software, timely supply of consumables.
Assessment and Monitoring	Assessing customer's print needs and requirements to understand business needs is a regular and routine practice for Partner1. This was carried out at the outset of the contract to understand the business requirements of *Customer1*, the office architecture, distribution of workload, volume of print jobs per period, and current usage. During the contract, some of the assessment activities include assessing print volume and moving devices and hardware and scheduling training where necessary. Regular meetings were held between *Partner1* and *Customer1* to review the contract and assess new requirements.	***Complexity flash point***: Lack of consumables like toners, wastage of papers, printing personal stuff. Badly behaving staff from *Partner1* Customer requirement changing mid way into contracts **Recursion** Managed Prints service provides visibility to managers in *Customer1* and appropriate action can be taken locally to correct the problem and if not, the problem is escalated to Partner1 Areas generating waste is identified and dealt with accordingly without resorting to *Partner1* Reviewing service performance routinely to identify improvement opportunities.

Regular Update of Apps on Apps Studio	The release of new apps and software is a regular feature of MPS contract. Although, this happens behind the scene. Partner1 has a software development capability in-house, however no app has been created or developed specifically for this contract. Most of the apps created have been done by other actors within the network.	The risk of malware is low since *CompanyDoc* certifies aeach app before it is listed in the app store
Training	Training is an important part of an MPS relationship to bridge gaps in knowledge, provide information relating to the use of new devices or apps and software tools to increase staff productivity..	**Complexity -** The training has a low level of discretion as this is decided at System 3 (Operation Manager), who decides the type of training *Customer1*'s staff need. However, there was flexibility on the part of the trainer to make changes to plan and content if necessary. So the the activity had requisite variety to absorb any changes in schedule, training content

System : 2 COORDINATION The function of the coordination function (System 2) is to ensure the harmonic functioning of System 1, by preventing uncontrolled oscillations from happening (Beer 1981b, 1995a)	○ The payment function – this is very important as the failure to pay print charge could generate some problems between Partner1 and *Customer1* ○ Dispute Resolution Mechanism – Partner1 assigned an Account Manager to *Customer1*. When a discrepancy in the charge for a period was identified, *Customer1* informed the Account Manager, who investigated and got the matter resolved. ○ The supply of consumables is automated. When the lower limit is reached, Partner1 is notified and a box of consumables is dispatched. However, Partner1 does not supply printing papers. The administrative desk in collaboration with the IT department handle the procurement of printing papers. ○ Automatic updates for apps and software drivers	**Complexity** -Rude and automcratic Ops Manager. Poor relationship management **Steps taken by system actors** An essential element of the coordination subsystem is communication and monitoring of activities to maintain the standard of excellent service. Communication is not only between Partner1 and *Customer1*, but with the wider network of actors across the chain . Regular communications take places between Partner1 and *CompanyDoc*. *CompanyDoc* maintains a relationship management portal for all partners. Each partner has an account where they can procure supplies, request for new devices,

	○ Communication via the portal – *Customer1* use the customer portal to communicate with Partner1, to lodge a query and ask questions. Alternatively, this can be achieved via phone calls and emails. ○ Monitoring Function - MPS provides visibility to the usage of devices across *Customer1*. Improper use of devices, wasteful use of paper and toners, printing non-work-related documents were some of the issues identified by the manager in *Customer1*. ○ The dashboard is accessible to both Partner1 and *Customer1*.	request for rebates, request for refunds and ask questions about new products and solutions. Logging all communication and issues on the portal Customers can chat directly with agents/experts on app for solutions to problem There a partner's portal when discussion and communication between partners and *CompDoc* takes place. Partners can request for supplies, make payment, settle disputes, make queries. Other support materials include videos, playbook, marketing toolkits and customized workflow manuals. A user-iD required hotspot for partners in the elite category, where they can access business development reports, industry insights, news and resources Conflict resolution – a more democratic structure rather than the autocratic mode of the Ops manager. The monitoring of revenue – a criteria for placing partners into gold, silver and bronze categories
System 3: Control and Synergy	Upstream, *CompanyDoc* has created tiers of partnership and each partner belongs to one of the levels or tiers. Each tier has some criteria as well as rewards/benefits attached to it. The tiers include 'Gold, 'Silver', 'Platinum' and 'Member'. Partners move up and down tiers when they meet the criteria of each tier. *CompanyDoc* offers marketing support,	Complexity – the pressure to cut cost is driving risky behaviour Conflict between members of staff at ***Customer1*** Fake products - use only certified product supplied by *CompanyDoc*

	training support, business development support and the use of its logo and badges to every partner. Since all partners are connected to the main portal, the sales performance of all partners is visible to *CompanyDoc,* who rewards partners who have exceeded the targets for their respect tier. The tier system allows all partners to operate at a level that is suited to their business model, industry peculiarities and internal capabilities. Partners are free to set their prices and operate independently. The revenue values on the portal for each partner provides a form of accountability report to *CompanyDoc* on the quality of value creation at the micro level. The tier-system incentivize partners to explore legitimate ways of increasing value with their customers, as this reflects in the revenue generated. In addition, all customers such as *Customer1* are a part of the global network created by *CompanyDoc.* On this forum, customers across the world ask questions, share ideas and cultivate friendships around product lines, service offerings and new technologies. This create synergies through collaboration and communication among actors at the micro level. In fact, System 3 is built on a robust digital platform that provides easy access to information for all actors, facilitates collaboration and communication, sharing of information and ideas and working together toward achieving mutual benefits.	Training for inexperience staff
System 4: Intelligence	At the provider-customer interface, *Partner1* gathers and collects information on industry news, trend, technology trends and competitor activities. Partner1 hold regular meetings with *Customer1* on a regular basis to collect information about the customer's changing needs, latest	**Complexity**: new technologies emerging, sophisticated malware and information theft. Price pressure, competitors There is a lot of collaboration and relationship building in thesystem. This has

	information about the client's industry and new business development opportunities. Often this information is passed on to *CompDoc*. (in System 5), In recent times, issues raised via the intelligence system include i. Security threats – hardware malware, hacking ii. Follow me printing iii. Cloud printing iv. mobile printing v. Paperless scanning vi. Digital signature vii. Remote printing, scanning viii. Scanning to web ix. Competitor pricing and charges x. Repair and response time for maintenance in the market	help to identify subtle or passive indication about the customers' worries, interest and objectives. Through meetings and communication with *Customer1*, partner 1 was able to identify the future plans and goals of the *Customer1*, which has enabled it to plan accordingly via systems 5
System 5: *Policy*	The highest decision point of the organisation. In the context of this case, this corresponds to the *Customer1* as well as *Partner1*. Both parties jointly set the rules – the terms and conditions, the deliverables, the responsibilities of each party and penalties. Although Partner1 is an independent organisation, however, since it receives support from *CompanyDoc*, there is input from *CompanyDoc.* The contract terms and conditions govern the behaviour of both parties. It also spells out the responsibilities of both parties. The contract specifies ○ Deliverables ○ the minimum number of pages per period, ○ charge per copy (based on volume) – one for colour and one for mono, A3, A4 ○ the payment dates, ○ the breakdown of activities - covered in charge per copy ○ consumables – coloured and black toners ○ maintenance ○ service ○ spares ○ calls	Complexity~: Slow decision making, inflexibility to change policies to meet today's challenges, bikering at the board level The exclusivity contract can be a problem as Partners can't sign an contract with any other print manufacturer.

	○ Length of the contract – 5 years ○ Termination and penalty ○ Call escalation procedure Exclusivity	

Appendix 5: Case 2

SYSTEM	Processes	Complexity
System 1: Operational Activities	Maintenance services – this involves routine preventative maintenance designed to reduce downtime, failure, card errors, and network problems. Cash Management – This is aimed at keeping the cash machine afloat with cash and to prevent cash-out. Repairs – This relates to a repair of the machine or a complete replacement when the machine fails. Processing of transactions with banks – This is handled by *ATMComp* who facilitates the routing of transactions between ATMs and banks through the ATM controller network Security – CCTV on site and on ATM to monitor nefarious activates and prevent hacking Software Update of ATM – to prevent hacking and ensure security of cash Facilitate cash withdrawal - Customer usage	- Resolution of customers' complaint is problematic as customers are directed to their cash issuer - - Issues are not solved locally at the store. No autonomy for shop keeper - Poor connection of the ATM can be a problem, leaving the ATM unavailable - Only specific denominator note available - Theft - Slow software update - Poor communication between *ATMComp, CustomerATM,* LINK Network, Banks
System 2: Coordination Activities	***Monitoring Systems -*** There is a live monitoring system set up to monitor ATM usage, detect fault, raise tickets and alert the technical teams. A customer support team from *CompATM* is always available to attend to reported fault that may not be reported by the monitoring system. Contractors handle repairs and maintenance.	Poor communication between *ATMComp, CustomerATM,* LINK Network, Banks

	Processing Transactions: Membership of LINK is Mandatory- The operations of independently managed ATM are governed by LINK Network. LINK Network is the UK largest cash machine network as every ATM in the UK is connected to LINK. LINK consist of banks, card issuers and ATM card issuers. LINK sets the ***rules*** for ATM operators whose ATMs are connected to the UK ATM network. ***Sources of Conflicts-*** Conflict resolution and stability are the objectives of System 2. Issues that have generated conflict include customer's card trapped in the ATM, network issues, customer bank accounts debited without the dispense of cash. According to the interviewee from *CompanyATM:* ***Fraud reporting and Investigation -***Issues relating to fraudulent activities are investigated by the fraud investigation unit. Store owners like *CustomerATM* are encouraged to report and escalate suspected criminal activities around the ATM. ***Rules, Terms and Conditions of use*** This covers the terms of the contract and terms underlying the use of the cash machine. The rules were heavily tilted in favour of *ATMComp*. It had the right to modify the terms without the consent of the store owner. It also has the right to increase or decrease the charge customers pay for using the machine. This caused a lot of friction between ATM Comp and *CustomerATM.*	
System 3: Control and Audit	*ATMComp* solely deals with the control of the operational units and captures hardware faults and usage pattern remotely. The overarching goal is ensuring the profitability of the contract. When the number of users decreases, *ATMComp* thinks the viability and profitability of the arrangement is threatened. Hence, it either introduces a charge for the use of the machine or reduces the share of the revenue due to the store owner. This undermines trust and	Poor communication between *ATMComp, CustomerATM,* LINK Network, Banks Indiscriminate changes in ATM fees

	breeds conflict, which more often than not, get escalated to the Payment Systems Regulator.	
System 4: Intelligence	Anticipating problems in the environment and dealing with it Renegiatting existing contracts – profits Ceastion of ATM operation Changing ATM operator	1. The sudden increase in business rates, which led to a suit in the courts. 2. Changes in the rules from LINK, which threatens the viability of the business. LINK outlines how much banks (card issuer) pays ATM operators when card holders use their cash machine. When LINK reduces the charge banks pay ATM operator, ATM operator compensate for the loss in revenue by increasing the charge they ask customers to pay. 3. The growth of fintech – pay wallet, mobile payments, contact less cards 4. Theft and burglary 5. The falling number of ATM users
System 5		

Appendix 6: Case 3

System	Processes	Complexity, Recursion, Autonomy
System 1: Operational processes	***Capturing Energy Consumption*** **-** This includes the use of energy by *CustomerLight* and the simultaneous capture of energy usage, thus giving *CustomerLight* visibility on their energy consumption ***Maintenance*** **-** This involves carrying out repairs, maintenance work, replacement of fittings and light bulbs. LED lights are easy to maintain, last longer and saves money. *LightComp* takes care of repairs and replacement tasks in short order. They called this annual health check. ***Optimization*** **-**This includes identifying where more savings can be achieved. Upgrading the system with new technologies. These upgrades comply with facility maintenance legislations. This also include recycling and re-use ***Training and the Provision of Manuals*** **-** *LightComp* provides training to clients as well as documentation manuals	**Complexity** – maintenance delays (this rarely happens since the state of the hardware and appliances is monitored via the app). - Sudden change in energy consumption by CustomrLight (CustomerLight always has the capacity to control its energy consumption using the control system provided by LightComp – example online app) - Disruption in the supply chain - - Low quality LED (this rarely happens since the LED lights are tested and verified in the lab before they are deployed for use). - Obsolescence (LightComp is a technology company and innovative) - - *LightComp* has an effective maintenance culture that ensure problems are spotted or identified before they occur.

System 2: Cordination	***Accounting and Finance - Payment process*** The contract is financed through a credit facility and payments are made quarterly, depending on energy consumption. The payment process ensures that *CustomerLight* pays the energy consumes and *LightComp* is paid for the service it has offered. **Monitoring process** This serves as a coordination function in that regular meetings between LightComp and CustomerLight to assess the value created. *LightComp* monitored the activities of contractors contracted to maintain and optimize the lighting system. ***The supply of resources*** The supply of resources is an essential part of the coordination function. Repairs and maintenance in System 1 need to be carried out by ***LightComp.*** The scheduling of tasks, technician visit, and other administrative processes constitute the coordination function. ***Resolution of Dispute*** ***Sensor system*** At the heart of the coordination function is the sensor which detects motion and turns lights on and off respectively. This way, only when there are people in a room, energy is consumed. This allows *LightComp* to control their consumption of energy 'on their own terms' as opposed to the flagrant consumption of energy. Recently *LightComp* standardized its sensor drivers in line with the standard certification. According to ***LightComp,*** standardization helps to ensure all different elements of the system controls, sensors and luminaries work together seamlessly.	Complexity- The finaning arrangement can be rigid sometimes giving no room for flexibility. Therefore, Customerlight can be stuck on a contract it might not like, for several years The rule of game guides the actions of individuals involved in the performance of the operational tasks. *CustomerLight* expects *CompLight* to do the right thing (cost savings and reduction in energy consumption) and *CompLight* expects Customerlight to do the right (make payment for the services offered)

System 3: Regulation and Control	*LightComp* takes charge of all the processes behind the scene that ensures all operational processes work together to create synergy between the operational units. According to *LightComp,* each contract is unique in terms of customer requirements and operational delivery. The data captured by the sensor and monitored via an app on PC or mobile device provides a control system to regulate actions and decisions that facilitates the achievement of synergy. *CustomerLight* can increase/decrease the light level, review and monitor its energy usage on the app. The remote monitoring system also help *LightComp* to schedule technician visit for replacement, maintenance and repairs..	The Pay-per-lux have clearly outlined key Performance Indicators relating to Energy Savings, Uptime and Light Level. *LightComp* coordinates with suppliers and contractors to ensure key performance indicators are met. Regular meetings are held between *LightComp* and *CustomerLight,* to explore and exploit ways of exploring new technologies that would drive cost savings. Routine inspection is carried out by *LightComp* to ensure contractors have provided the right quality of job..
System 4: Intelligence and future planning	*LightComp* operates in the technology industry, which is susceptible to technological disruption. Although *LightComp* collects data from its customers – business organisations, facilities managers, building developers around the world, it moves ahead of the curve to exploit new emerging technologies that creates superior experience for users	Innovation and research is the norm in the industry . the pressure to develop energy saving bulb is huge **Complexity –** **Provider Side :** fluctuating price of fittings and bulbs (provider side), poorly done work by contractors, need to adhere to legislation, competition. Response: CompLight has built a network of relationship with a large number of organisations across multiple industry to leverage knowledge which enables it to respond very quickly to changes in the external environment. Development of new knowledge, new skills and new relationship give CompLight

		enormous advantage to create new products which deliver superior value and cost savings. **Customer side** - Energy consumption target not met. Affordability problems, uncooperative employees. Moral hazard **Response :** regular assessment of needs (both current and future needs) and integrating plans into operational processes. Operational activities are assessed against the backdrop of increases in utility bills, service costs and affordability potentials
System 5: Policy	Commitment to sustainability by all companies across the PSS network and value network.	It drives sustainable behaviour and aligns expectations across the value network. It drives investment and the growth of the circular economy.