INVESTIGATING HOW SYSTEMS THINKING CAN ASSIST WITH THE ADOPTION OF ADDITIVE MANUFACTURING IN SPARE PART PROVISIONING SYSTEMS

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ABSTRACT

Although the adoption of Additive Manufacturing (AM) in various industries is accelerating, the adoption of AM for industrial spare parts provisioning remains slow. AM is indicated as one of the most disruptive innovations of Industry 4.0 (4IR). Innovation is defined as disruptive when it changes the way the current industry operates. This disruption challenges the status-quo and the understanding of the risks and paradigms involved when adopting this innovation. Uncertainty can cause the innovation to be perceived as complex and can prolong the adoption of this technology. A paradigm shift from linear models to integrated, networked non-linear models will be required for adoption of AM produced spare parts and provisioning system evolution.

This paper will attempt to identify how Systems Thinking can assist organisations that would like to adopt AM for spare part provisioning to resolve the above-mentioned reasons and increase the adoption of AM for spare part provisioning.

Keywords: Additive Manufacturing, provisioning system, risk, complexity, Systems Thinking, adoption.

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1 INTRODUCTION

Additive Manufacturing (AM) or 3D printing refers to the process of joining materials to make objects from 3D model data, usually adding layer upon layer, as opposed to subtractive manufacturing methodologies, such as normal milling, grinding and CNC machining [1-3]. AM is gaining more popularity as an emerging manufacturing method in various areas of the economy to produce customized components from jewellery, footwear, toys, architecture, automotive, aerospace, dental and the medical industry [3]. AM is also used for rapid prototyping where a component can be created in the Computer-Aided Design (CAD) software, modelled and then printed to test form and function before the production of the component for industrial use.

The use of AM technology is growing at an exponential growth rate year on year as indicated by figure 1.

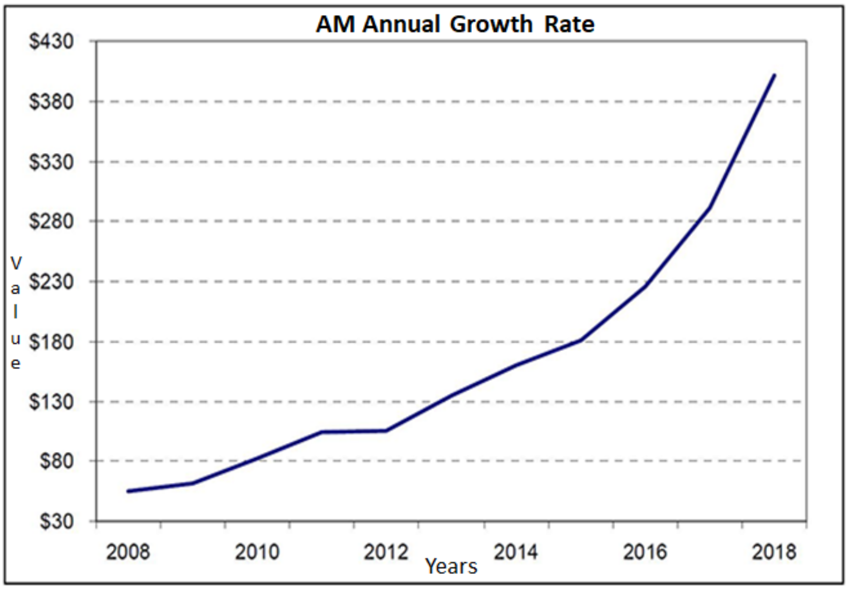

Figure 1: Annual AM growth rate - [4]

As the technology matures and moves away from rapid prototyping towards the production of spare parts [5], so does the requirement to understand and manage the uncertainty initiated by this disruptive technology [6]. Den Boer [7] contemplates that AM will not only disrupt the manufacturing and Supply Chain processes but will also fundamentally transform these activities. AM presents significant potential to enable organisations to apply new, creative, non-linear thinking to create components that can improve the reliability and process efficiency of the operations [8].

According to Olesen [9], successful organisations distinguish themselves by their willingness and ability to acquire technology and to take technology risks. AM is described as one of the most disruptive innovations of the Fourth Industrial Revolution (4IR) [10,11]. A technology is described as disruptive when it replaces current operating practices and industry norms with radical new ways [12]. This will require a paradigm shift from traditional design for manufacturing (DfM) and Supply Chain principles to new design for AM (DfAM) and network-integrated provisioning systems [13].

With DfM, and with the current spare parts manufacturing processes, complexity is expensive. One of the requirements for operating in the new business eco-system is the ability to manage complexity. When spare parts are produced with DfM, the material is removed from a block of material, layer by layer until the final component is created. This process leads to significant waste and there is little room for complexity. AM shifts the paradigm from a reductionist approach to a systemic approach. AM is a system where complexity can be accommodated, and components are built layer by layer from the bottom [14]. Figure 2 indicates the design principles for traditional manufacturing (DfM) and AM (DfAM).

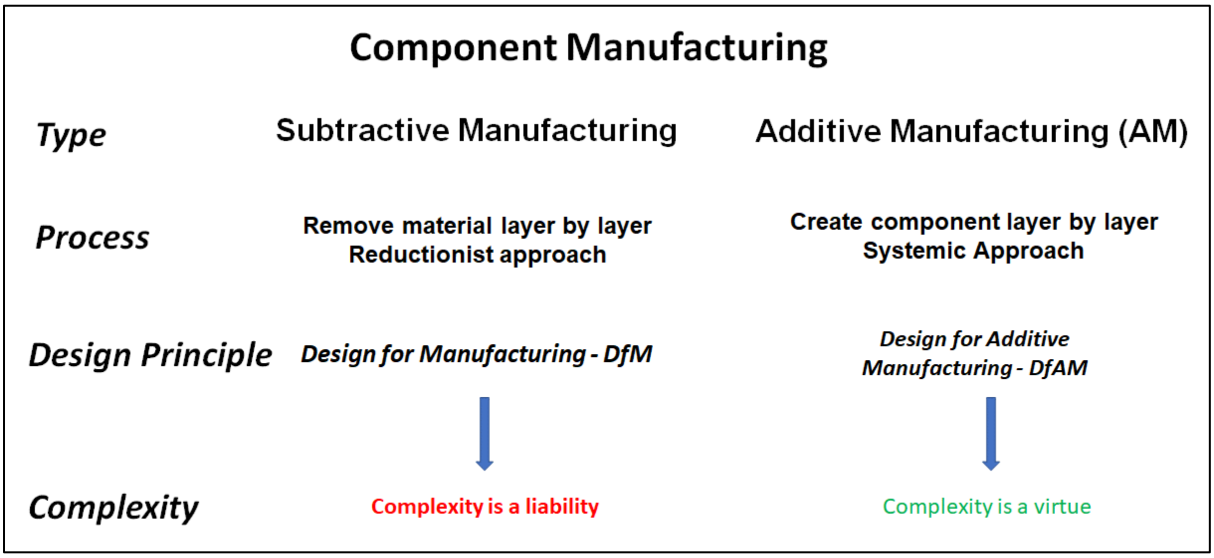

Figure 2: Difference between Traditional Manufacturing and Additive Manufacturing - Author

In order to adopt AM in spare part provisioning, a paradigm shift will be required from DfM to DfAM. This will require a disruptive change in how business risks are managed, from the traditional linear paradigm to a dynamic, non-linear, systemic network paradigm and understanding how to manage the perceived complexity created by adopting AM. Christensen [15] states that disruptive innovations are seen to be complex because their value and applications are uncertain. However, Roos [13] indicates that the strategic implications of AM across industries are significant, yet poorly understood and this attributes to the slow adoption of AM in spare part provisioning.

AM can also require a change in business model [16,17]. The process of adopting a new business model must be an agile and dynamic process. Successful companies repeatedly reinvent themselves by creating new business models that leverage these changes in disruptive technology. To translate strategies into action companies will need new tools, new talent and a new mindset [13].

When adopting a technology that will disrupt the status quo, there will all ways be resistance to change [18]. Possible reasons for the resistance to change can be contributed to some entrenched paradigms that slows down the adoption of the technology. Thomas-Seal [19] and Mellor [20] indicated that the barriers to the progression of AM for the wider adoption of AM for industrial spare parts requires attention. The focus of researchers to date was either based on broad level adoption or been highly focused on material and energy consumption. According to Douglas [21], AM is to an extent following the S-curve model of diffusion, although for wider adoption, AM will need to deviate from the current rate of adoption. In order to deviate for the current rate of adoption, organisations will have to transition from a linear paradigm to a non-linear paradigm [22].

The purpose of this paper is to investigate some of the entrenched paradigms that can contribute to the slow adoption of AM in spare part provisioning. Once these paradigms have been established, it will be investigated if Systems Thinking can be applied as a possible solution to change these paradigms that will enable the accelerated adoption of AM in spare part provisioning.

2 PURPOSE AND METHODOLOGY

2.1 Purpose of research

The research questions that will be investigated in this paper are:

Q1: What are some of the key paradigms that can contribute to the slow adoption of AM in the spare part provisioning systems?

Q2: What role can Systems Thinking play to change these paradigms in order to enhance the adoption of AM in spare part provisioning?

Figure 3 provides a layout of the research. In order to answer question 1, a Literature review, Abductive reasoning and personal experience have been used to determine the key paradigms contributing to the slow adoption of AM in spare part provision (Section 3).

Question 2 will be answered by investigating the role that Systems Thinking can play to assist in improving the adoption rate of AM in spare part provisioning. (Section 4).

The paper ends with a discussion on the findings summarizing the research outcomes and suggestions for future research will be provided.

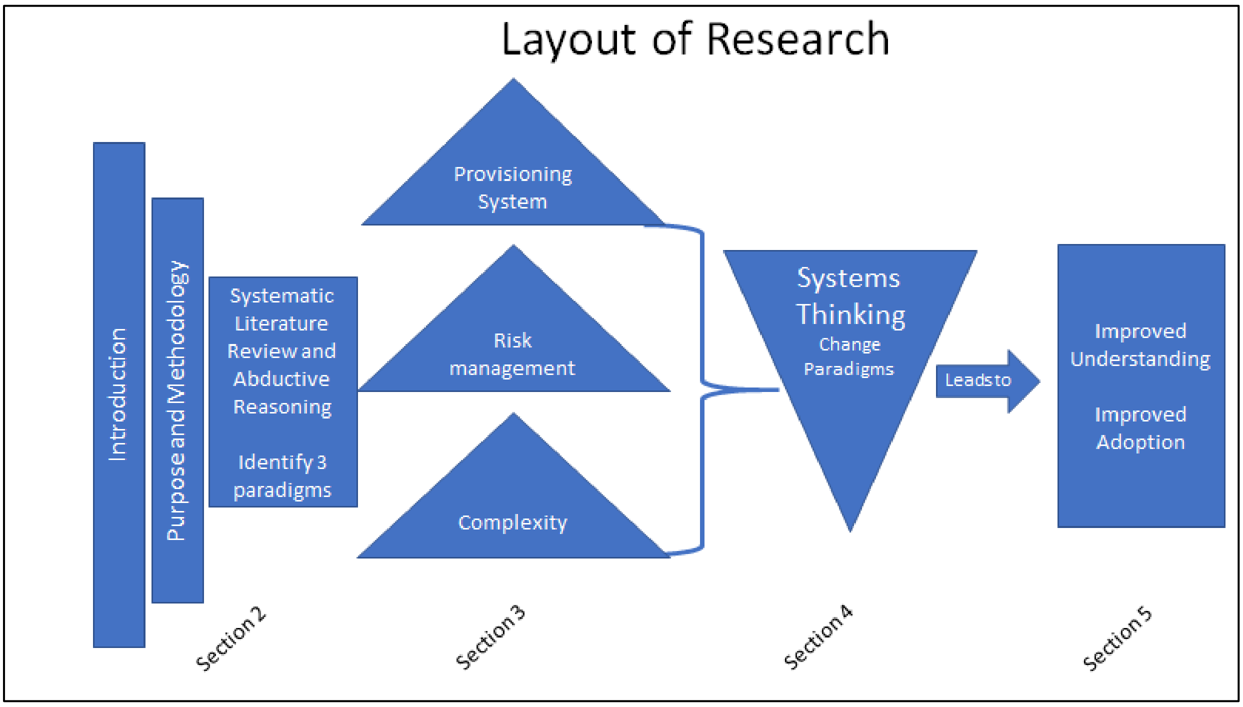

Figure3: Layout of Research

2.2 Methodology

2.2.1 Data Gathering

A Systematic literature review was conducted. Table 1 is the review protocol for the study:

Table 1: Review protocol for SLR

Purpose of the study	**To investigate how Systems Thinking can assist with the adoption of Additive Manufacturing in spare part provisioning**
Inclusion criteria:	Literature indicating Additive manufacturing and Systems Thinking in their title, abstracts or keywords. Literature on Additive manufacturing and risk Literature on Additive manufacturing and complexity Literature on Additive manufacturing and Supply Chain Literature on the business impact of Additive Manufacturing
Exclusion criteria:	Non-English literature Technical and material evaluations of Additive Manufacturing
Search databases	Searches were conducted for 5 databases EbscoHost, Emerald Insight, Science Direct, Web of Science and Scopus
Keywords	All the selected databases were searched using the following key words: “Additive manufacturing” AND “Supply Chain” “Additive manufacturing” AND “Supply Chain” AND “Evolution” “Additive manufacturing” AND “Risk” “Additive manufacturing” AND “Systems Thinking”
Quality assessment criteria	All duplicate literature was excluded Recovered literature will be checked for relevance (besides inclusion and exclusion criteria)

The bulk of the material focused on the operational performance of AM. There was an increase in the number of researchers requesting a more holistic approach to understand the impact of AM on business [11,20,23-24]

2.2.2 Data Analysis

Abductive reasoning and personal experience were applied to the literature in order to define three paradigms that can have an impact on the adoption of AM for spare part provisioning.

O’Reilly [25] indicates that Abductive reasoning is used when synthesizing complex information to generate insight and in reasoning toward creative new solutions for current problems. Creativity has always been closely associated with engineers. Due to the disruptive nature of AM, it will be required from organisations to change their paradigms and create an understanding of the systemic interrelationship that exist between different activities and processes in the business.

2.2.3 *Artefact Development*

The concept of Systems Thinking was investigated as a possible solution to assist with the creation of an integrated understanding and the relationship of the defined concepts from the literature study that plays a role in the slow adoption of AM in spare part provisioning. Systems Thinking can be defined as: Systems Thinking synthesizes systems theory and interactive design, providing an operational methodology for defining problems and designing solutions in an environment increasingly characterized by complexity [26].

3 FINDINGS: LITERATURE REVIEW AND ABDUCTIVE REASONING

3.1 Paradigms contributing to the slow adoption of AM in spare part provisioning

Three paradigms that were identified according to the literature review and abductive reasoning that can contribute to the slow adoption of AM in spare part provisioning is summarized in Figure 4 and will be discussed individually in the sections to follow.

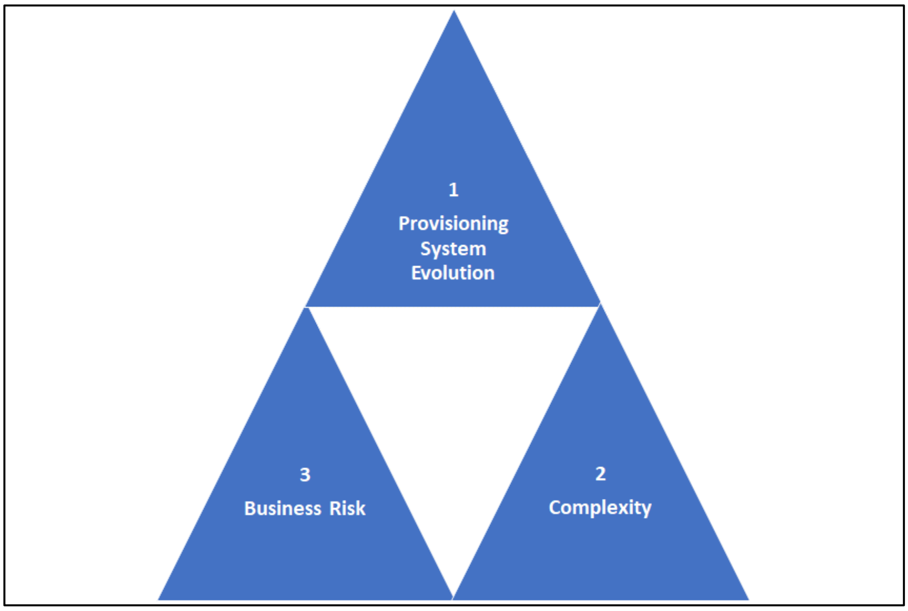

Figure 4: Paradigms contributing to the slow adoption of AM - Author

3.1.1 *Provisioning system evolution*

Apart from the exponential growth of AM, the adoption and provisioning systems for the use of AM for spare parts is not developing at the same rate [27]. With the advent of the 4th Industrial Revolution (4IR), provisioning systems must evolve from a linear perspective where the sum of the parts makes up the whole, to a holistic systemic view where the interrelationship in the system needs to be managed and understood [23,28]

One of the risks that remains inherent in the current Supply Chain, is that it re-enforces traditional linear thinking. Gattorna [29] states that the term Supply Chain Management was never a good term because it emphasizes the supply side of the enterprise. The chain descriptor implies, participants are dealing with linear chains or strings of enterprises, when in fact the provisioning systems are involved in multi-dimensional, integrated networks or eco-systems. 4IR necessitates that organisations move away from static, linear provisioning systems to dynamic eco-networked non-linear systems [30].

Disruptive technologies change the attributes required to manage the business and the nature of the provisioning systems which is sometimes ignored by companies [15,18]. The business is not operating in a linear supply chain any more but will become part of the global network or eco-systems [31]. Harmse(a) [32] in their study on the evolution of business models from supply chain to demand networks contemplates that the focus in the provisioning system has to transcend from a supply culture to a demand culture understanding the dynamic requirements of the integrated networks or eco-systems.

Moore [33] defines the eco system as:

> *“an economic community created from interaction between individuals or groups, with the emphasis on the networks between the actors within the ecosystem and the dynamic interaction between these networks.”*

Choi [34] indicate that eco-systems are complex adaptive systems that can function in a dynamic business environment.

Figure 5 is a summary from Mellor [20] of the model that they propose for adoption of AM. This model indicates the integrated nature of the different activities when embarking on the adoption of AM for spare part provisioning. Although Supply Chain is part of the model, it still presents a linear view with the emphasis on the supply side of the business.

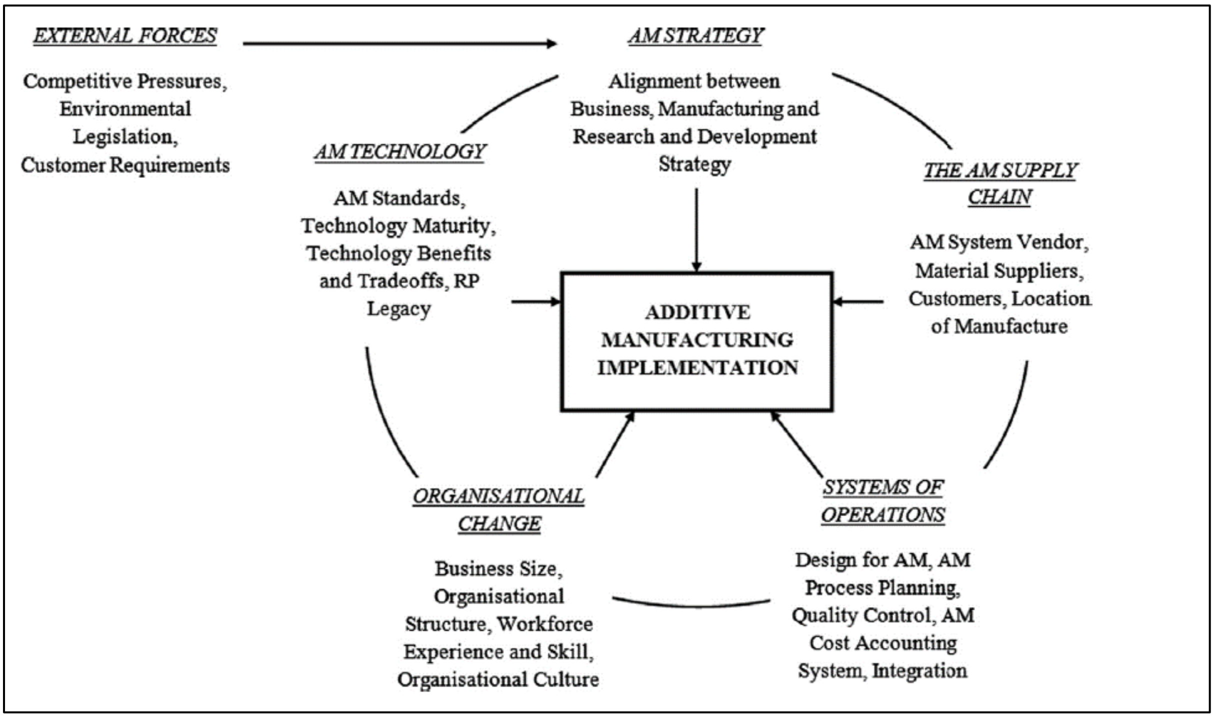

Figure 5: Model for AM adoption – [20]

McCarthy [35] contemplated that a new Supply Chain evolution is needed to adapt to the requirements of 4IR. There should be a transition from Supply Chain to Supply Networks to incorporate the multitude of different actors in the operating environment. Harmse (a) [32] indicated that due to the disruptive nature of AM, it will also require a disruptive view of Supply Chain that will focus on the integration into the eco-system.

Harmse (a) [32] compiled a model for the Supply Chain evolution from Supply Chain to Agile Demand Networks. This model can be seen in figure 6.

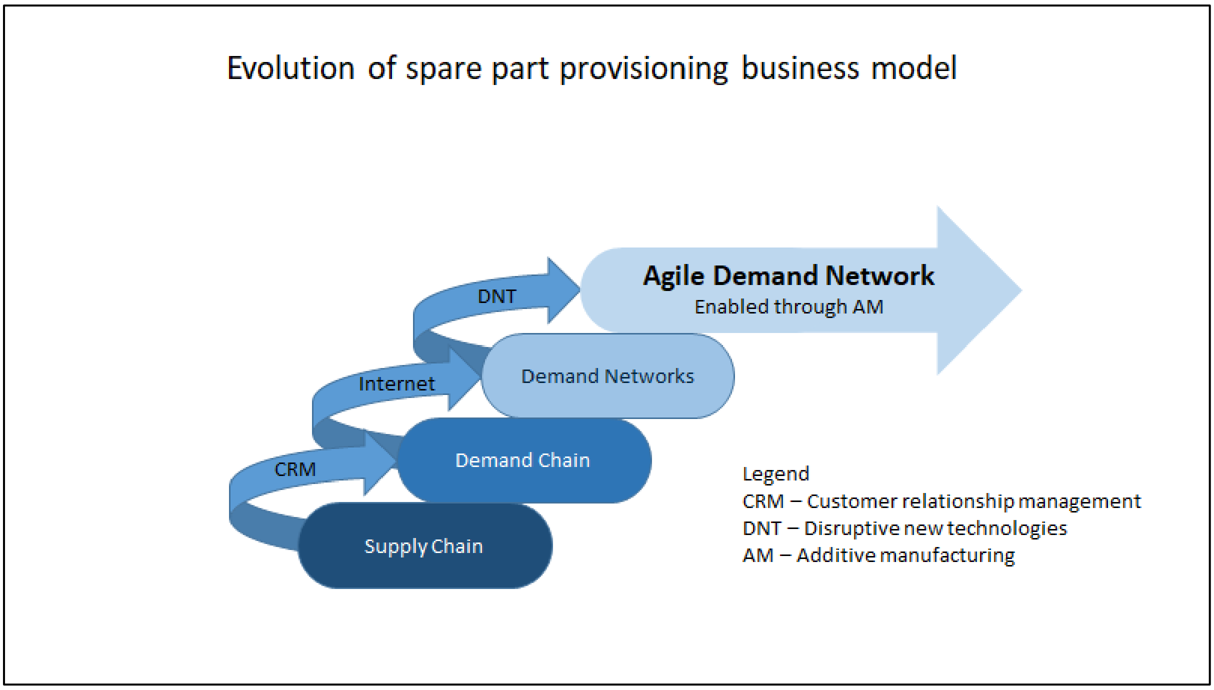

Figure 6: Provisioning system evolution model - [32]

The evolution from Supply Chain to the Demand Chain has been initiated by the implementation of Customer Relationship Management (CRM) software and a focus on the demand side of the business. The next evolution was initiated by the advent of the global internet. The internet allowed many different networks to be connected and created more real time visibility. 4IR, introduced new disruptive technologies and the requirement for agility became sturdier. With the proliferation of these technologies, where AM is the most disruptive, an improved systemic understanding of the provisioning system and how to function in turbulent, agile and complex, non-linear business networks will be required to fulfil the dynamic demand [32].

3.1.2 Complexity

Organisations are facing unprecedented levels of change and the ability to adapt to and manage the change should be well understood [36]. As the world becomes more interconnected as part of the participation in the eco-system, so does the need to understand and manage complexity [37].

Gartner [38] indicates that AM is still perceived to be a single technology whereas AM consists of a whole manufacturing paradigm and a wide range of different processes and techniques that integrate across boundaries and networks adding to the complexity of the global eco-system.

Rogers [39] published the Innovation diffusion theory (IDT), an influential work which helps to explain the adoption of innovation. The IDT indicates that an innovation's adoption rate is influenced by five specific innovation attributes. Table 2 is a summary of these attributes.

Table 2: Innovation adoption Attributes – [39]

Innovation Attributes	Definition
Relative advantage	Perceived superiority of an innovation to existing practices
Compatibility	Perceived consistency of an innovation with existing values, past experiences and needs of potential adaptors
Complexity	Perceived difficulty to understand and use the innovation
Trialability	Perceived degree to which the innovation can be experimented with
Observability	Perceived degree to which results of an innovation are visible to others

The IDT indicates that a high degree of relative advantage, compatibility, trialability and observability of an innovation is positively associated with its adoption, whereas complexity is negatively related to an innovation's rate of adoption. Rogers [39] further indicated that the idea about a disruptive innovation can cause some uncertainty by possible adopters and that some degree of risk is involved in the adoption that exacerbates the uncertainty and fear of complexity.

Gartner [38] indicated in their study on the construction of a theoretical framework to explain the disruptive potential of Additive Manufacturing that the complexity of AM technologies has been underestimated. According to Oettmeier [40], this can be attributed to the insecurity about the how, where and why to deploy additive technologies.

Burnes [36] contemplates that organisations are like complex systems in nature, they are dynamic, non-linear systems and that their actions can be unpredictable as part of the integrated network environment.

Table 3 indicates the difference between complicated (traditional linear) systems and complex (eco-based systemic, non-linear) systems. This summary is derived from Sammut-Bonnici [41] and author own inputs.

Table 3: Difference between complicated and complex systems - [37, Author]

Complicated (Traditional systems)	Complex/Complexity (AM Eco system)
Complexity is a burden	Complexity is a challenge
Attention to detail	Investigate behaviour of whole system
Rich in detail	Rich in structure
Getting task done	Action in one-part affect other
Problems are broken down into small parts	Activities shift and adapt according to situation on hand
Experts solve parts	Agile, multi-disciplinary teams create solution
Management hierarchy	Evolves and adapt with internal systems and external environment

Complicated (Traditional systems)	Complex/Complexity (AM Eco system)
Rules established – linear processes	Operations framework
Organisations viewed as complicated and static	Organisations viewed as complex set of self-organizing components
Mass production and division of labour	Economic and organisational phenomena are like those observed in science and nature
Attributes: Diminishing returns, rules based regulated environment, stagnation, linear dynamics	Attributes: Increasing returns, self-organizing system, continuous adaptation, sensitivity to initial conditions, non-linear dynamics
Component design Methodology: Design for manufacturing (DfM)	Component design methodology: Design for Additive Manufacturing (DfAM)

Table 3 indicates that an organisation must move from complicated, linear systems to complex, non-linear systems. There needs to be a clear understanding of how to manage the complexity introduced by adopting AM as part of the spare part provisioning systems.

3.1.3 Business risk

Roos [13] and Christensen [15] contemplates that disruptive, innovative technologies that replaces current industry platforms, can have a significant impact on the structure of the industry. It is therefore important to understand the systemic nature of the structural changes and the risks associated with such a disruptive, innovative change. Disruptive technologies also require new structures and capabilities of the organisations where they are implemented [15]. The philosophy of management towards new technologies will also influence their decision to adopt disruptive technologies [42,43]. Managers needs to understand the systemic impact that these new technologies introduce in the business and the risks associated with them.

Matinaro [43] contemplates that the diffusion of a new technology is linked to the propensity of the organisation to adopt innovation and change. According to their study, the key to the adoption of new innovation in an organisation, is much more linked to the attributes of the organisation and their propensity for risk and not so much to the new innovation. Table 4 is a summary of the list Matinaro [43] prepared of the business attributes required for adoption of an innovation.

Table 4: The innovation process characteristics and explanations - [43]

Innovation Process characteristics	Explanation
Braking industry traditions	Willingness to change traditional approaches
Communication	Increased communication between organisations and its employees including clients and subcontractors
Co-operations	Increased co-operation between organisations from company level to projects and from projects to other projects. Increased cooperation in top and middle management and with stakeholders
Leadership skills	As general, identifying innovators, and strengthen innovators, positive messengers, skills and competencies, with clients, with design etc. Leading the people.

Innovation Process characteristics	Explanation
Knowledge management	Sharing the knowledge throughout organisation and project boundaries, the spread of know-how.
Organisational learning	Support of all functions of learning. In project-based industry learning must happen in a project itself and across inter-organisational boundaries.
Organisational culture	Positive and supporting. Positive towards innovations and changes
Management acceptance	Open mindset, resource allocation, investment in technology, supporting innovations, leadership
Top down – bottom up approaches	Emphasises organisational learning and breaking the barriers that project based industry have.
Vertically integrated organisations	Increased ability to spread needed information to organisations, learning aspect, decrease internal barriers.
Human resource management	Need of changes compared to traditional approaches, emphasis leadership kind of features on management, work circulation, creating an open atmosphere, social skills of management and project management, willingness to change, changing career paths.
Stakeholder integration	All stakeholders should take part in developing industry, better cooperation, common ways of doing designs
Standardization	Common and accurate standardization to integrate stakeholders and making models more usable, accurate designs.

Thomas-Seal [19], Oberg [16] focus on risks relating to the implementation of disruptive new technologies like AM. The authors focused on risks that are related to the production of the components i.e. the operational risks. Harmse (b) [24] contemplates that one of the most important business risks is the adaptation of AM by the leadership of the organisation. AM is not only a disruptive innovation but is also a disruptive strategic intervention impacting a multitude of processes and structures inside and outside the organisation. Leadership is also identified in table 4 as an important component for the adoption of an innovation.

Schniederjans [44] indicate in their study on the adoption of AM that there is limited focus on the impact of the required change in leadership of the organisation as a risk for the adoption of AM in spare part provisioning and successful functioning in the eco-system. In Christensen [15] the author reasons why great companies fail. The conclusion is that they don't fail because there are changes in the market that they don't understand, but because the leadership in the companies did not understand the specific requirements of disruptive technologies. This denial of the business impact of disruptive technologies where AM is implied as the most disruptive is one of the most significant risks of any company.

Some of the other business risks that will be impacted when adopting AM is a required change in the culture and the structure of the organization when adopting AM for spare part provisioning [43] (b) [24]. Due to the disruptive nature of AM, it will require significantly different skills than what has been prevalent in most traditional organisations [15].

Oettmeier [40] indicates in their study on AM technology adoption that it is important to focus not only on the intra- but also on the inter-organisational factors. Gartner [38], Oetmeier [40] and Matinaro [43] emphasise that there are external factors outside of the organisation that plays an important role in the successful adoption of an innovative new technology, in this case, AM that requires careful attention. These external factors and the systematic interaction of these factors as risks to the organisation must be well defined and understood.

Oberg [16] contemplates that companies don't have a clear understanding of how to manage the risks involved in venturing into AM. One of the key risks that traditional organizations are faced with, is the risk of changing from linear processes to non-linear, network-based processes with constantly changing competitors [43].

In a study by Oettmeier [40], they concluded that the adoption of a new technology, in this case AM, will be emphasized by three groups of variables or risks in table 5:

Table 5: Variables for the adoption of Innovative new technology - [40]

	Adoption Variable
1	Technology related factors – relative advantage and ease of use – complexity.
2	Firm related factors – how adaptable is the company to embrace change.
3	Market structure related factors (Eco system) – external pressure and perceived outside support.

To reduce the risk of slow adoption of AM in spare part provisioning, the variables in table 5 needs to be well understood and managed.

Organisations are still trapped in a mindset where risks can be avoided by removing the complicated activities from the processes and therefore create a stable, manageable and linear environment where they can control the behaviour [33].

White [45] summarized in a study on risk management, that most of the current models are based on a reductionist approach see fig. 7.

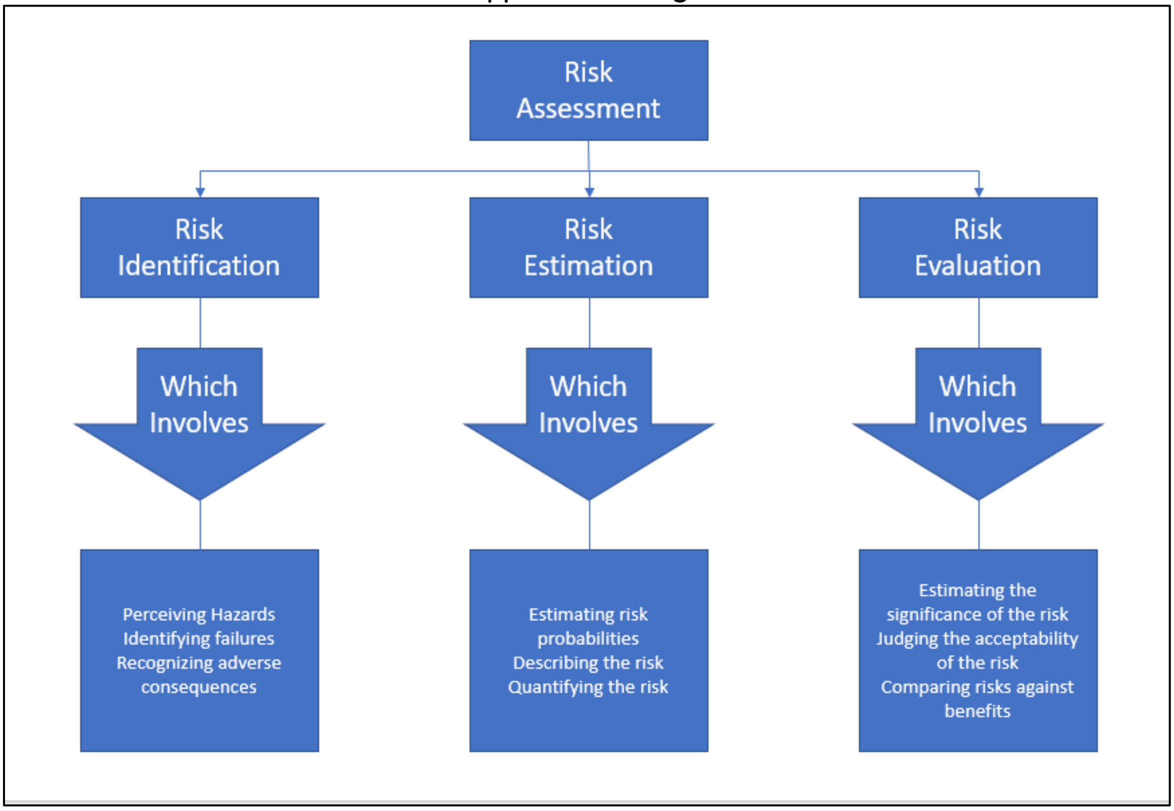

Figure7: The process of risk management - [45]

This way of managing risks is to identify the risks, breaking it down into its smallest components and then use experts to identify the criticality of the components. The risk factors are then multiplied, and a hierarchy of risks is established that is seen as the total risk exposure. This linear approach fails to recognise the interrelationship of the components of the whole system and that the identified risks can be affected by components surrounding the identified risk as part of the global eco-system [22,46].

Table 6 is a summary of the key differences between the linear approach and the holistic approach of risk management derived from [45].

Table 6: Difference between Reductionist and Systemic approach to risk management - [45]

	Reductionist Thinking - Linear	**Holistic Thinking - Systemic**
Method	Systemic	Systemic
Issue tackled by	Reducing problem into smaller and smaller parts	Investigating the problem's environment
Approach characterized by	A downward movement	An upward movement
Simplifies by	Breaking down problems into simplest parts	Taking multiple partial views

When adopting AM, the organisation will have to transition from the traditional reductionist thinking and business management to a holistic and systemic culture. In the next section, an understanding of Systems Thinking will be investigated as a possible solution to assist with the adoption of AM and the required change in thinking from reductionist, linear thinking to non-linear, systemic thinking.

4 THE ROLE OF SYSTEMS THINKING TO IMPROVE AM ADOPTION

In section 3, three paradigms that can contribute to the slow adoption of AM in spare part provision have been discussed. In section 4 the role of Systems Thinking will be discussed as a possible solution of how to manage these elements and to create a culture that will allow organisations to improve the adoption of AM for spare part provisioning as indicated in figure 8.

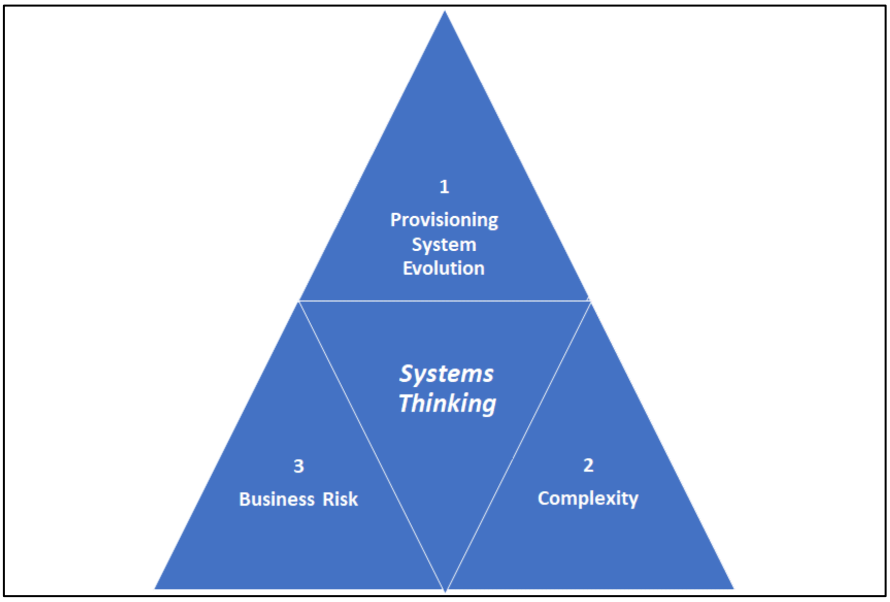

Figure 8: The role of Systems Thinking in the adoption of AM - Author

Behl [47] defines Systems Thinking as the ability to think holistically about a system, rather than only considering the parts individually. Senge [48] defines Systems Thinking as a discipline for seeing wholes and as a framework for seeing interrelationships rather than things, for seeing patterns of change rather for seeing snapshots. Systems thinking can be defined according to [49] as:

> *"a set of synergistic analytical skills used to improve the capability of identifying and understanding systems, predicting their behaviours, and devising modifications to them in order to produce desired effects. These skills work together as a system".*

A sub section of Systems Theory is Complexity Theory. Sammut-Bonnici [41] indicates that Complexity Theory provides an understanding of how systems, grow, adapt and evolve. Complexity Theory explains how the relationship between the members give rise to collective behaviour and how to understand and utilize complexity for adopting disruptive innovation [37].

The principles of Systems Thinking and Complexity Theory enables the user to create an understanding of the systemic nature of the system and how to manage the perceived complexities. Behl [47] specify that companies are faced with increased complexity due to the nature of the integrated networked business environment and dependencies. Critical to systems theory is firstly the recognition that because of dependencies, the properties of components cannot behave independently but must obey certain rules and secondly, it is their

relationship that provides for emergence and can create complexity. In order to successfully managing this transition and understanding how to embrace complexity, it is imperative that

there is a comprehensive understanding of Systems Thinking and Complexity Theory and the inter-relationship of all the components in the eco-system [37].

Provisioning systems requires an evolution from Supply Chain to an Agile Demand Network as can be seen in figure V. This evolution will allow practitioners to focus on the dynamic interaction and the agility required for success in the global networks or eco-system. This evolution will transcend the Supply Chain from a linear system to a non-linear system where it is important to understand the interrelationship and cross-functional effect of the different components of the network. Systems Thinking will assist with this to create an understanding of the total system in a non-linear complex network.

Complexity can be daunting especially if a myriad of activities requires different understanding away from the stable status quo. AM is a system that moves spare part provisioning from a complicated, linear environment to a complex, non-linear environment. Understanding complexity, allows companies that adopt AM not only to fulfil the immediate requirement but to use complexity to improve the efficiency of the total system. An understanding of Systems Thinking and Complexity Theory will assist in understanding and managing the complexity in the global network or eco-system. Complexity creates new risks and alters activities that were not seen as risks to become risks due to the new requirements in the global eco-system.

Risks are identified and broken down into small manageable components. This is a reductionist approach the same as traditional manufacturing where the material is removed until the final component is created. AM is a process where components are manufactured layer by layer from the bottom up and an integrated view of the risks is required for an optimized solution. An understanding of the principles of Systems Thinking will contribute to understand the risks and to define the interrelationship between the different risks. Figure 7 indicates how Systems Thinking can influence each of the three elements identified as possible contributors in the adoption process of AM in spare part provisioning.

5 CONCLUSIONS AND FUTURE RESEARCH

The adoption of AM as part of the spare part provisioning system, will not only disrupt the business or the eco-system but also requires fundamental new ways of operating and managing business risks and complexity and new paradigms are needed. Normal business processes can become business risks if the systemic relationship between the different processes are not well defined and understood. Participation in the global eco-system, will introduce complexity in the organisation that will require innovative and creative solutions. Both risk management and the provisioning system needs to transcend from a linear system with a functional view to a non-linear system with a systemic view. The role of Systems Thinking is to assist organisations to create an understanding of the true value that AM can deliver by eliminating the fear for complexity and to see risk as an opportunity.

To complete this process, future research can focus on a maturity model with which organisations can plot their current position on the provisioning system evolution against the key business risks. This maturity model could then assist organisations to understand the systemic relationship between the key business risks and what is required to manage these risks for the adoption of AM as part of spare part provisioning. The maturity model could serve as an evolutionary road map that will allow organisations to remove the perceived complexity on their journey to adopt AM for spare part provisioning.

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