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Soft systems methodology for the implementation of Advanced Manufacturing Technology (AMT) in the South African manufacturing industry

Oluwasola, Awosusi Oluwatosin

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TITLE: SOFT SYSTEMS METHODOLOGY FOR THE IMPLEMENTATION OF ADVANCED MANUFACTURING TECHNOLOGY (AMT) IN THE SOUTH AFRICAN MANUFACTURING INDUSTRY

AWOSUSI OLUWATOSIN OLUWASOLA

(Student number: **1031813**)

School of Mechanical, Industrial and Aeronautical Engineering

University of the Witwatersrand

Johannesburg, South Africa

Supervisor: Professor R. Siriram

A research report submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, in fulfilment of the requirements for the degree of Masters of Science in Engineering

Date: March, 2019.

DECLARATION

I, **Oluwatosin Oluwasola Awosusi,** declare that this research report is my own work except as indicated in the references and acknowledgements. It is being submitted in partial fulfillment of the requirement for the degree of Masters of Science (MSc.) in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University.

…….. ……..day of ……., 2019

Oluwatosin Awosusi (Day) (Month)

ABSTRACT

This research investigated the links between Soft Systems Methodology (SSM) and Advanced Manufacturing Technology (AMT) in the South African manufacturing industry. The research proposed an investigative framework linking AMT Investment and Strategic Planning, the AMT Adoption Process, Barriers and Resistance to Adoption and Benefits Realisation. The research design consisted of a survey using a research instrument and the services of a panel of experts for the verification of the results. The data were collected using electronic surveys using SPSS.

The research population was made up of South African manufacturing organisations selected from recognised authorities such as the Financial Mail Survey of the Top 100 companies in South Africa and others. Using the purposive sampling technique, 182 organisations were selected for the study focusing on individuals involved in the selling of AMTs and individuals involved in AMT implementation and operation, as well as AMT investors and decision makers.

Two hypotheses were formulated and tested using the Pearson correlation, Spearman's Rho correlation and t-tests. The findings indicated that organizations which adopt SSM have a stronger statistically significant correlation to success in adopting AMT than organisations using traditional methods.

Despite the limitations that were observed, the significant links that were found were used to discuss the findings and it was concluded that SSM presents some advantages when used for the adoption of AMT. Recommendations were made to account for these limitations and areas of improvement for further research were identified.

ACKNOWLEDGMENTS

Undertaking a study of this nature is always a collective effort and I appreciate and recognize the support and assistance of those whose expertise and assistance made this study a reality. My deepest appreciation and acknowledgement to the following:

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5. Lastly, many thanks to all the members of the expert panel, thank you for the patience all through the process of the research.

Above all, I give thanks to God for giving me the strength to see this project to completion.

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LIST OF ACRONYMS

AMT- Advanced Manufacturing Technology

SSM- Soft Systems Methodology

CAD- Computer Aided Design

CAM- Computer Aided Manufacturing

CAE- Computer Aided Engineering

MRP- Material Resource Planning

CNC/NC- Computer Numerical Controller/Numerical Controller

HAS- Human Activity System

GDP- Gross Domestic Product

CIM- Computer Integrated Manufacturing

TQM- Total Quality Management

JIT- Just-In-Time

ROI- Return On Investment

MPV- Minimum Viable Product

DCF- Distributed Coordinated Function

AHP- Analytical Hierarchy Process

DEA- Data Envelopment Analysis

MADM- Multi-Attribute Decision Making

GDSS- Group Decision Support System

NGT- Nominal Group Technique

MS- Manufacturing Strategy

CHAPTER 1: Introduction

1.1 Background statement

The emergence of the Fourth Industrial Revolution has led to rapid changes in manufacturing across the globe. The need for speed and the customisation of goods and services, etc. have made the adoption of Advanced Manufacturing Technologies (AMT) imperative in the manufacturing industry. Gunawardana, (2006) suggested that the demand for higher quality products at more competitive prices has resulted in the need for increased investments in Advanced Manufacturing Technologies (AMT). Some scholars (Lewis and Boyer, (2002); and Stock and McDermott, (2001)) defined AMTs as computer-based technologies such as computer-aided design/manufacturing/engineering (CAD/CAM/CAE), MRP, CNC/NC, additive manufacturing (3-D printing), robotics and soft technologies. (The definition and classifications of these AMTs are discussed in Chapter 2 of this research report.)

Some researchers have found direct links between the adoption of AMTs and efficiency across production with advantages such as a reduction in the time spent on product development, production line-depth and process flexibility (Kakati 1997, Beaumont and Schroder, 1997; Noori, 1997). These advantages have contributed in part to dynamic trends in manufacturing organisation strategies (Gunawardana, 2006). (The benefits presented by AMT adoption are discussed in more detail in Chapter 2.)

AMTs are without a doubt, strategic assets essential to efficient operations in the manufacturing industry, and, as a result, they act as links to the competitiveness of players globally (Singh et.al. 2007). Waldeck and Leffakis (2007) asserts that the success of AMTs is not only dependent on the level of technology, but on how well it is implemented. Researchers such as Beatty (1993), Tippet (1989) and Voss (1988) have shown that the success of AMT implementation is not only measured through technical success, but also through the achievement of manufacturing and business success.

It is important to understand how AMT success may be measured. Some examples follow: [a] Technical success in this context is the achievement of effective technological operations;

[b] Manufacturing success is the achievement of better quality, faster speed, reductions in costs, and greater flexibility by the manufacturing organisation; while

[c] Business success is the achievement of higher returns on investments and intensified competitiveness.

A survey of 40 companies conducted by Efstathiades et al. (2001) on the strategic planning, transfer and implementation of AMT, revealed that 92.3% of the companies who bought into this product achieved technical success; 41% achieved manufacturing success; while 43.5% achieved business success. Beatty (1993) in an earlier survey found that only 50% of the organisations studied realised the considerable benefits that could be accrued from the adoption of AMTs, and linked firms planning for AMT have a greater likelihood of successfully adopting this technology. In other research, Banakar et al (2010) found that many organisations adopting AMTs achieved technical success but not business success as a result of a lack-of-fit between the organisational manufacturing strategy priorities (MS) and the capabilities of the technologies. These scholars generally agreed that the adoption of AMTs in manufacturing industries provides numerous advantages, although, it is not always the case that the adoption of AMT drives competitiveness on all indices of growth and development.

Findings from these research studies (Efstathiades et al. (2001); Beatty (1993); Banakar et.al (2010)) have shown that the adoption of AMT is a complex and dynamic process owing to a variety of factors, both internal and external, that are involved. However, while there is an abundance of literature on human resources, operational structures and organisational cultures (Bourke et al., 2016; Small and Yasin., 2003), little attention has been paid to the impact of other drivers such as the type of manufacturing production system, organisational design, competition, customers, technology vendors, governmental and societal laws and regulations, company size (finances and goals) (Hall and Khan., 2003; Baily et al., 2005; Advameg., 2016; Schroder and Sohal, 1999; Gupta and Whitehouse, 2001; Sohal et al., 2001).

In conclusion, it may be argued that these factors present complexities that may create systemic faults in the process of AMT adoption owing to the lack of structure and of predictability. For the purpose of this research, further clarification is required in terms of these same faults.

Systemic faults are faults that are due to issues inherent in the overall system. The lack of structure, and the unpredictability of the factors affecting AMT adoption, such as changes in the market place, changes in customer preferences, technological compatibility, changes in government policies, insufficient knowledge, and failure to identify and remove the current or potential organisational barriers, are some such examples.

The application of SSM presents an opportunity to understand those complexities that could lead to systemic faults in the AMT adoption process. SSM is an approach which may be used to better understand AMT adoption by analysing the various factors to identify their strengths, the opportunities they present, and the threats that they might pose (Maqsood, Finegan and Walker, 2001). SSM allows manufacturing organisations and their adoption of AMT to be seen as part of a wider systems environment. The wider systems environment of a manufacturing organisation provides for the ecosystem in which the organisation operates. The environment is made up of the [A] owners and actors, [B] the competitors, [C] the global market and the consumers, [D] the demographic environment, and [E] third parties such as regulatory agencies, lawmakers, etc. Figure 1.1 gives the pictorial presentation of the wider systems environment.

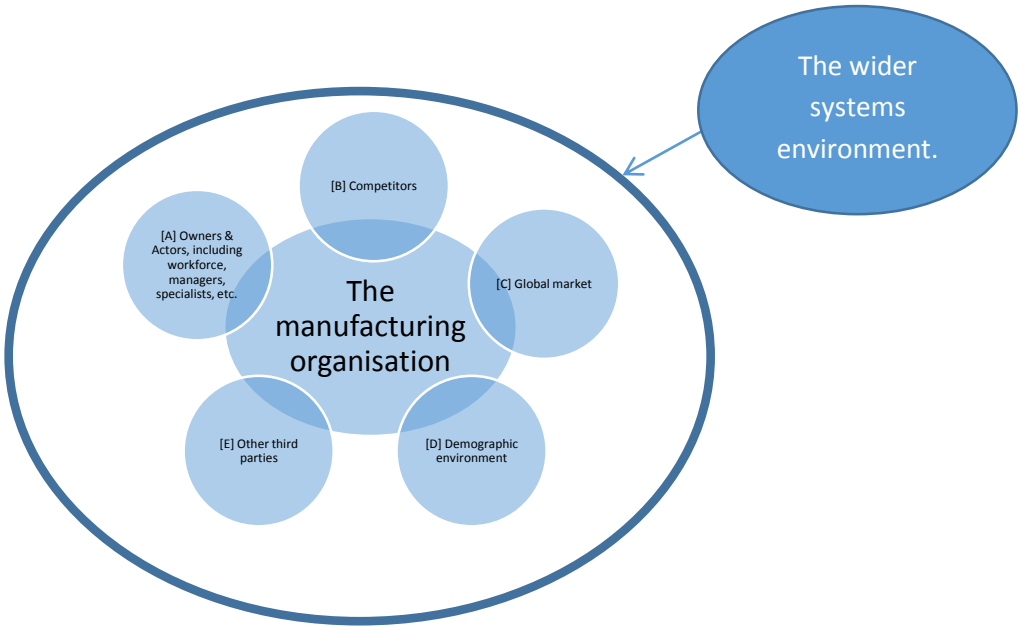


Figure 2.1: The wider systems environment of the manufacturing industry

Given the complexity of the aforementioned interactions within the wider systems environment, there is a need for a paradigm shift in terms of how we look at manufacturing organisations. A new perspective would allow for better synergy within the manufacturing systems environment that would be driven by the desire of the customers and the responsiveness of the technologies and human capital. This is the basis for applying SSM in evaluating the process of adopting AMTs.

Cavaleri and Obloj (1993) proposed SSM as an appropriate methodology and holistic process which could be designed for a better understanding of real-world problems that are typical in terms of manufacturing organisations. SSM is a specific tool in a system science which is particularly effective in analysing Human Activity Systems (HAS) (i.e. the people dimension) in a real-world context, where the values, beliefs or expectations of the stakeholders differ but where genuine compromise is possible. Foster-Fishman and Behrens (2007), while discussing methods for systems change, concluded that SSM enables stakeholders to create worldviews that incorporate diversity without forcing consensus.

The interactions within the wider systems environment of a manufacturing organisation, and deductions from previous studies (Udoka et al, 1990, Lewis et al, 2002 and Rosnah et al (2004)),

brought about the establishment of the primary factors that are considered to be central to the success of AMT adoption in manufacturing organisations, along with the applicability of SSM.

a) Alignment of the AMT to the organisation's strategic plans;

b) The AMT adoption process;

c) Barriers and level of resistance to change;

d) Realisation of the benefits identified

e) SSM applicability.

These factors were used to design the investigative framework on which this research is based. Figure 1.2 presents the investigative framework. (This framework is discussed in more detail in Section 2.13.) These central factors [A, B, C, D, and E] are also coupled with issues which are discussed in Section 2.8.

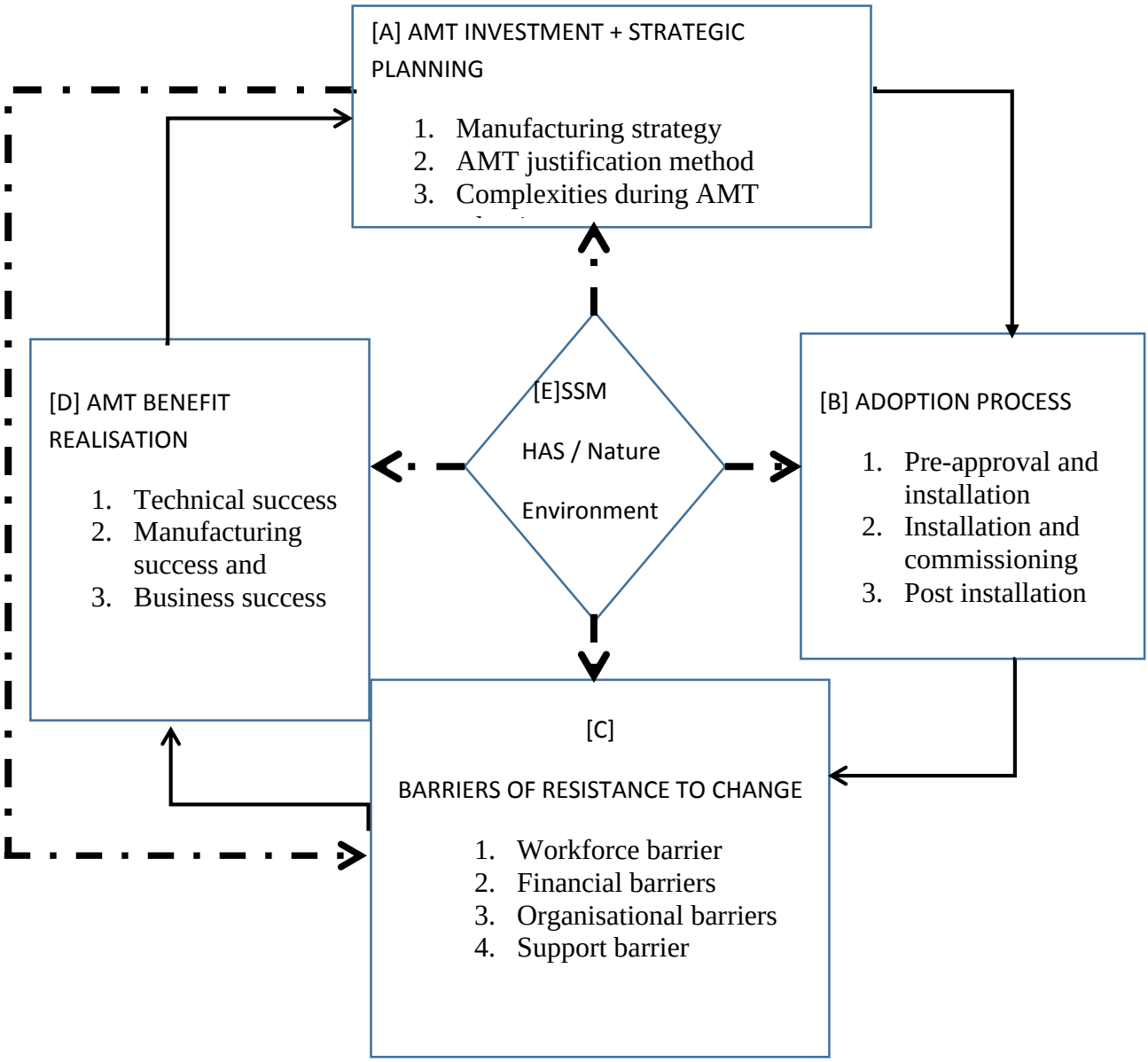


Figure 1.2: The research investigative framework

1.2 Purpose of the research.

The general purpose of this research is to investigate and analyse the links between the factors central to the adoption of AMTs by manufacturing organisations in a wider systems environment and comparing the role of SSM usage with traditional methods usage. In greater detail, this means: [A] to align the AMT in conjunction with the organisation's strategic plans, [B] to initiate or promote the AMT adoption process, [C] to identify the barriers and level of resistance to change, [D] to identify the realisation of benefits, [E] to make SSM applicable.

The research aims to compare manufacturing organisations that use SSM with those that use traditional methods for the adoption of AMTs. The comparisons are executed on the basis of statistical analysis. Furthermore, the research builds on previous studies in the field of AMT adoption and offers new insights into the prospects of SSM in the adoption of AMTs in the manufacturing industry in South Africa.

1.3 Problem statement

The full benefits of AMTs have not been realised in the manufacturing sector because the adoption of the technologies ignores the challenges of complexity and structural shortcomings which hinder the effectiveness and efficiency of AMT adoption. While there is more research evidence from studying AMT adoption (Rahardjo et al. (2010).; Kotha et al. (2000).; Elitan (2008).; Noori H (1997).; Ocampo (2017),; Pandza (2005),; Shepherd et al. (2000),; Slagmulder (1992),; Small (2006),; Stock et al. (2001),; Banakar et al. (2010),; Efstathiades et al (2001)), the focus has been on individual entities in the adoption process and hardly any research evidence is available for the systemic approach to the adoption of AMTs. Given the recorded shortcomings associated with AMT adoption over time (Efstathiades et al (2001).; Beatty, (1993).), there is a need for a holistic systemic approach that considers other factors that are related to the successful adoption of AMT as a component of the system and not to be treated in a silo.

1.4 Research Question

The research question posed by this study can be summarised as follows:

How can Soft Systems Methodology (SSM) be used to improve AMT adoption in South African manufacturing organisations?

1.5 Research Hypotheses

The following research hypotheses are formulated:

1.5.1 HYPOTHESIS 1: *Organisations that adopt SSM [E] will have a stronger correlation to success in AMT adoption than firms using traditional methods.*

1.5.2 NULL HYPOTHESIS 1: *Organisations that do not adopt SSM [E] will not have a stronger correlation to success in AMT adoption than firms adopting SSM.*

1.5.3 HYPOTHESIS 2: *Organisations that link [A] AMT Investment and Strategic Planning to [C] Barriers of Resistance to Change will have a stronger correlation to success in AMT adoption.*

1.5.4 NULL HYPOTHESIS 2: *Organisations that do not link [A] AMT Investment and Strategic Planning to [C] Barriers of Resistance to Change will not have a stronger correlation to success in AMT adoption.*

1.6 Research Objectives

This research presents the following research objectives that would be a guide to the report. The research objectives are as follows:

1. Collect quantitative data sourced from 182 sampled organisations across nine industry sectors;
2. Use Pearson's and Spearman's RHO correlation analyses to identify links in the investigative framework (Figure 1.2) to show how each construct relates to the others;
3. Validate the findings by using the services of a panel of experts;
4. Identify opportunities for further research.

1.7 Report Structure

This research report comprises of six (6) chapters. Figure 1.3 shows a detailed flowchart of the research report.

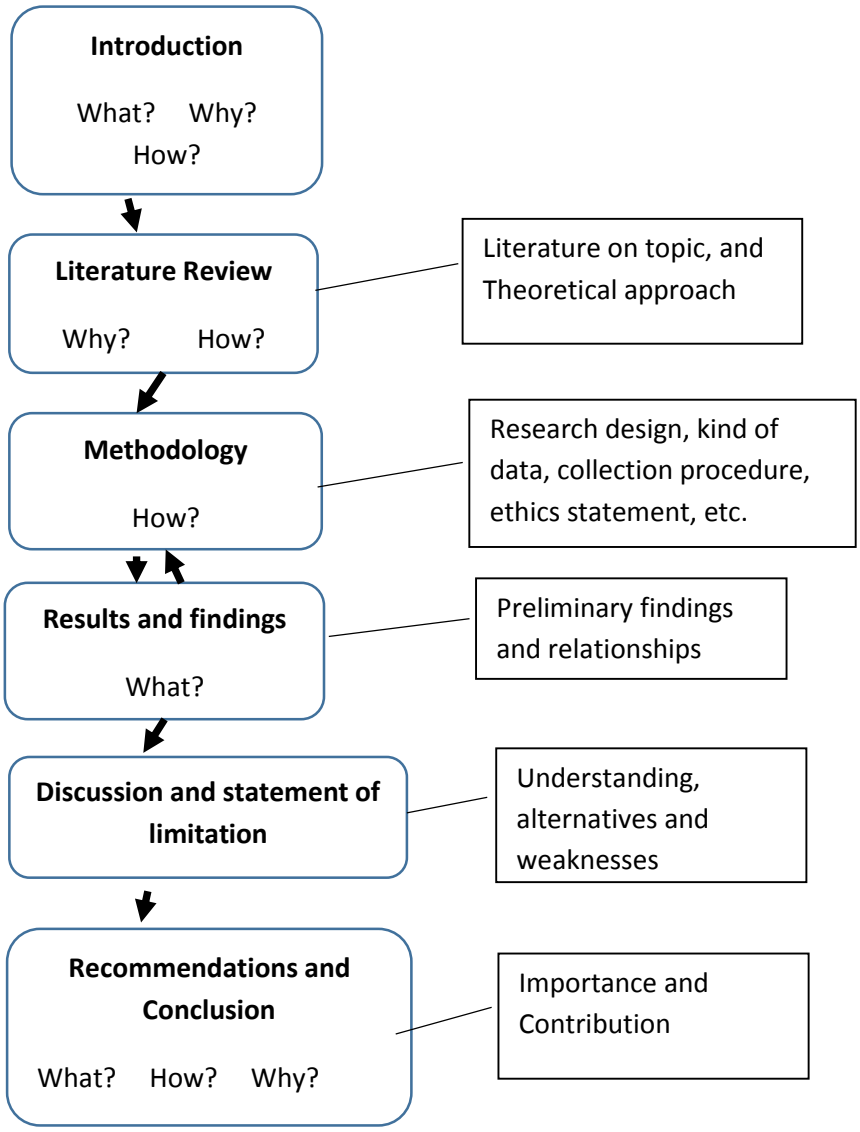


Figure 1.3: The graphical representation of the research structure

CHAPTER 2: Literature review

2.1 Introduction

A relatively large number of models and theories with respect to various organisational environments have been proposed to explain the process of AMT adoption in manufacturing organisations globally (Beatty, 1992; Frohlich, 1998; Voss, 1988; Small and Chen, 1994; Rahardjo et al., 2010 ;). Likewise, in the context of the South African manufacturing industry, analysing AMT adoption and the related concepts, such as strategy and technology diffusion, has remained fundamental to the school-of-thought, both in academia, and government policies, and to the philosophy behind organisational strategies (DST, 2003; Frost, 2010; Sohal et al., 2001; Du Preez et al., 2015.). This review gives an overview of the research related to AMT adoption and includes theories in relation to the proposed research strategy, and systems thinking, specifically in respect of soft systems methodology, for a concise understanding of the barriers to change in AMT adoption.

Fundamental aspects of AMT adoption in an organisation are explained through a process model presented by Sohal et al (2001) in Section 2.3. It describes the process of adopting AMTs in terms of four (4) interrelated components. This model complements the theories of AMT adoption by other authors, such as Voss (1988) and Welbourn et al (1994), and may also be a reference to the adoption of AMTs globally, as in the work done by Darbanhosseiniamirkhiz (2012), Cardoso et.al (2012), Marri et al (2007) and Rahardjo et al (2010).The theories presented by these authors in their separate views have been proposed to ensure improved success rates in the adoption of AMTs by organisations.

While research into AMT adoption has been conducted by different researchers, the exploration of the SSM has been sparse in the literature. Much of the focus has been on presenting theoretical models alongside limited empirical studies. An investigative framework around the use of SSM and its impact on AMT adoption is presented to provide a holistic approach, which may be used to obtain a better understanding of the different factors involved in AMT adoption.

2.2 South African manufacturing industry

The manufacturing sector in South Africa is an important sector of the economy which contributes approximately 12% to the national Gross Domestic product (GDP) (StatsSA, 2014). As illustrated in Figure 2.1, this contribution has been in a state of constant decline over the past decade,, and has been attributed to the lack of global competitiveness in products and operations. The prospects of local manufacturing depend on rapid response, adaptability to customer demands, and organisational flexibility, which in their turn are adapted to global trends. The 3.1 % decline in the manufacturing sector over an eight-year period (1994-2012) was attributed to the lower production levels of food and beverages and the processing of petroleum, chemical products, rubber, plastic products, and the manufacturing of automobile parts and accessories (Lehola, 2012). In addition to the decline in the production of the above-mentioned products, the level of production has also been grossly affected by the lack of proper management, in respect of technology and the lack of skills, and the low quality of skills and training (McCarthy, 2005).

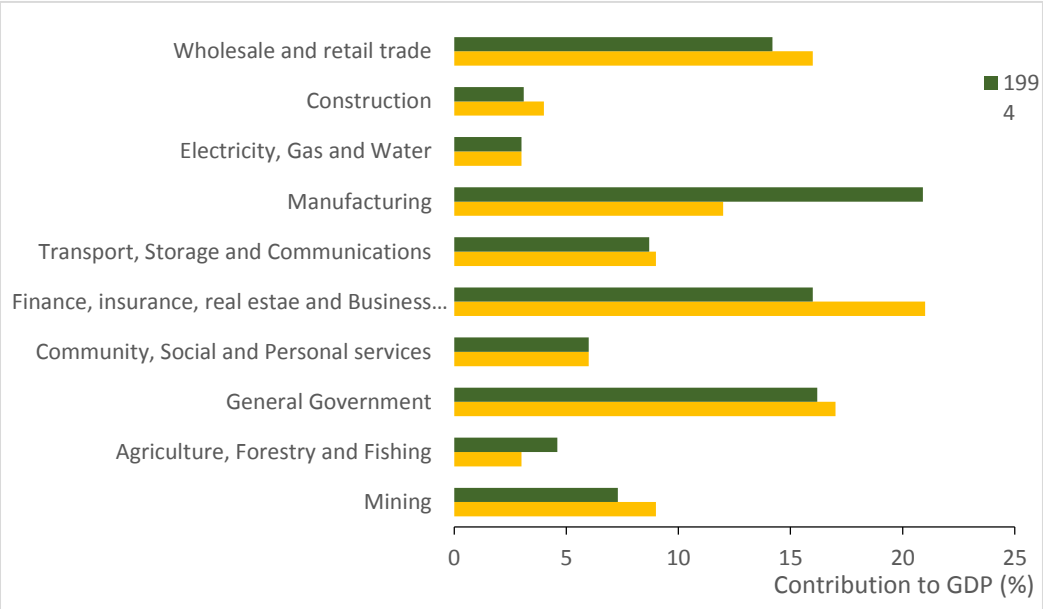


Figure 2.1: Sectors' contribution to the South African GDP (1994 & 2012) (data extracted from IDC – Research and Information – The South African economy)

The adoption of the frameworks, infrastructure and systems associated with AMT is a key approach for the modernisation and optimisation of local manufacturing platforms for improved competitiveness, productivity and customer satisfaction. Improvements in competitiveness and productivity may be achieved through better implementation processes and the adoption of advanced technologies. The establishment of these links may be interpreted for positive relationships between the adoption process for AMT and the benefits realised by the manufacturing organisations.

2.3 Advanced Manufacturing Technology

AMT includes a variety of modern technologies put together to accomplish a manufacturing goal to ensure increased quality, productivity, better working conditions, health and safety, the realisation of which may result in improved organisational competitiveness. Gunawardana (2006) defines AMT as a system of programmable equipment that is flexible enough to produce different products without losing time when changes are implemented. Bourke (2016), in agreement, also describes AMT as a series of process innovations that enables organisations to take advantage of numerical and digital technologies to optimise manufacturing processes.

Generally, the concept of AMT's as defined in the literature is the association of AMTs to computers and numerically controllable systems. This general concept regards 'manufacturing technologies' as 'advanced' on account of their flexible nature, brought about by their programmable attributes (Gouvea da Costa et al, 2000). The literature generally agrees with these conceptual views by defining AMT as a family or group of technologies introduced within the past three or four decades which occurred on account of the constant improvement and efforts in information technology. Such technologies include computer-aided design (CAD), automated handling systems, robotics, computer-controlled machines, FMS, CNC, CIM, bar-coding, and other equipment or techniques for automatic identification (Lewis and Boyer, 2002; Stock and McDermott, 2001; Baldwin and Lin, 2002; Singh et al., 201;Sun, 2000; and Pandza et al., 2005). This concept portrays the classic definition of AMTs by Rahardjo et al (2010) which describes AMTs as technologies that apply mechanical, electrical or

electronic systems controlled by programmable computers for the purpose of product design, control and execution.

These accepted definitions are vague since manufacturing is now broader than just the creation of a product from raw materials; it is a series of activities that are interrelated and that incorporate different operational components, ranging from design, material selection, planning, justification, management, etc. Looking at manufacturing from this point of view, it should be noted that there are other forms of developed technologies not accounted for by the above definitions and concepts. Technologies (generally referred to as soft technologies) such as TQM (Total Quality Management), JIT (Just in Time), Lean Manufacturing and Six Sigma, are included by some authors in their descriptions of AMTs (Swink et al, 2007; Gunawardana, 2006), as they also increase effectiveness, reduce costs, improve performance and produce a sustainable competitive advantage. Soft technologies include a wide range of process technologies that complements the generally known hard technologies. Soft technologies do not generally require sophisticated programmable computer-controlled machines but can be equally as effective in manufacturing processes and systems.

The classification of AMTs is another aspect of AMTs that has created a divide in the literature as various authors have presented different classifications for AMTs, depending on the aspect under research consideration (e.g. the functionality of AMT, the level of integration in the organisation, or the physical properties of the instrument). A well-cited and -accepted classification of AMTs was developed by the United States (US) Department of Commerce (DOC) in the late 1980s through a national industrial report (US, 1989).

AMTs were grouped into functionalities such as:

I. Design and Engineering

II. Fabrication and Assembly

III. Automated Material Handling

IV. Automated Inspection and Testing Systems

V. Communication and Control.

Sohal (1997) gave a simplistic approach to this classification by categorising AMTs as a function of the nature of the apparatus or instrument. He grouped them into three (3): (a) Computer Hardware; (b) Computer Software; (c) Plant and Equipment.

The classification of AMTs in terms of level of integration was developed by Meredith and Suresh (1986). They divided AMTs according to their level of integration in the manufacturing process. These levels are: (a) Stand alone; (b) Linked (intermediate) and (c) Integrated.

Kotha and Swamidass (2000) highlighted the need to classify AMTs according to their level of flexibility while including their information-processing capabilities. The following classification was proposed: (a) information exchange and planning; (b) product design technologies; (c) high-volume automated technology and (d) low-volume automated technology.

Small and Yasin (1997) who, while trying to clarify the misconceptions of AMTs as computing systems, divided them into two distinct categories: “hard and Soft”, “hard”, being the technologies that incorporate computing systems, in contrast to “soft” technologies, which mainly incorporate methods and consist of administrative tools.

These classifications have been the basis for classifying AMTs in the literature as other researchers have built on the above-listed classifications to further classify AMTs according to the growth in technological innovations and their introduction into the manufacturing industry.

The table below shows a detailed relationship between the types of AMTs and their classifications adopted from multiple research publications and based on the differences in the perspectives on AMT classification.

References:																										
US department of commerce (1989)				*	*	*	*	*	*	*	*	*	*													
Meredith and Suresh (1986)	*	*	*																							
Sohal (1997)														*	*	*										
Kotha and Swamidass (2000)																	*	*	*	*						
Ocampo et al. (2017)	*	*	*																							
Small and Yasin (1997)																					*	*				
Percival (2010)																							*	*	*	*
Classification (Taxonomy)	Level of Integration			Functional application										Nature of Instrument			Imbedded information processing capabilities				Type of technology		Imbedded manufacturing capabilities			
Examples of AMTs	Stand-alone	Intermediate	Integrated	Design and Engineering	Fabrication/Machining and Assembly	Logistic related	Automated material handling	Automated inspection and testing	Flexible manufacturing technology	Computer integrated manufacturing	Management and information technology	Communication and Control	Engineering management practices	Computer Hardware	Computer Software	Plant and Equipment	Product design technologies	Information exchange and planning technologies	High volume automation technologies	Low volume automation technologies	Hard technologies	Soft technologies	Design and Engineering	Management	Automated Manufacturing	Process Improvement
3D printing, direct digital manufacturing	*			*	*											*	*			*	*		*		*	
Cloud manufacturing			*						*	*								*	*		*				*	
VR (Design and Production)		*						*		*						*		*			*					*
Nano-electronics		*								*				*							*					
Self-adaptive production line			*				*		*	*									*		*				*	

Nano-manufacturing			*				*			*												*					*
Automated warehouse handling systems		*				*						*													*		
CAD	*			*						*					*						*	*		*			
CAM/CAE			*		*					*					*						*	*				*	
LAN/WAN												*		*				*				*					
CAPP	*			*							*											*			*		*
NC/CNC/DNC	*																										
Pick and place Robots, palletisers	*				*					*						*			*		*				*	
Robots with sensing capabilities	*				*					*						*			*		*				*	*
Material working lasers	*				*											*					*					
Automatic storage and retrieval systems(AS/RS)		*				*																					
Automatic material handling(AMHS)		*				*																					
Automated inspection and testing equipment (AITE)		*						*								*			*								
FMS(CIM)			*		*				*							*			*		*						
Artificial intelligence/expert systems			*																								
JIT			*										*									*				*	
MRP/MRP II						*																*				*	
TQM													*									*				*	
SIX Sigma													*									*				*	
PLC	*											*		*		*		*	*		*				*		
SCADA			*									*			*			*							*		
Sensors	*					*		*				*		*		*					*				*		

Table 2. 4 AMT classifications according to the literature

For the purpose of purchasing AMTs, Percival's (2010) classification may be the most appropriate because it is simple to understand and it appeals to managers and not only researchers. The classification also accounts for soft technologies in the form of engineering management practices. The classifications of AMTs by Meredith and Suresh (1986) and Ocampo et al. (2017) are similar but may no longer seem to be appropriate since the advancement in technologies, particularly in microelectronics and programming, is causing AMTs to be more integrated and interrelated. Because some technologies can be used as stand-alone, independent products, this does not mean that the technology is necessarily an isolated, independent or stand-alone product.

The classifications of AMTs by Sohal (1997) and Kotha and Swamidass (2000) are rather too rigid and they do not account for a number of AMTs that are being considered in this research. The classification by Small and Yasin (1997) may be too broad in that it divides AMTs into either "hard" or "soft". Although it is correct, it is not simple enough for non-researchers to understand.

Given the definition and the classifications of AMTs found in the literature, it is important to consider the constructs of AMT adoption. The investigative framework (previously presented in Figure 1.2, Chapter 1) will now be used to structure the remaining section of the literature review in the context of the research. The investigative framework is presented here for ease of reference. [A] AMT investment and Strategic Planning is discussed next.

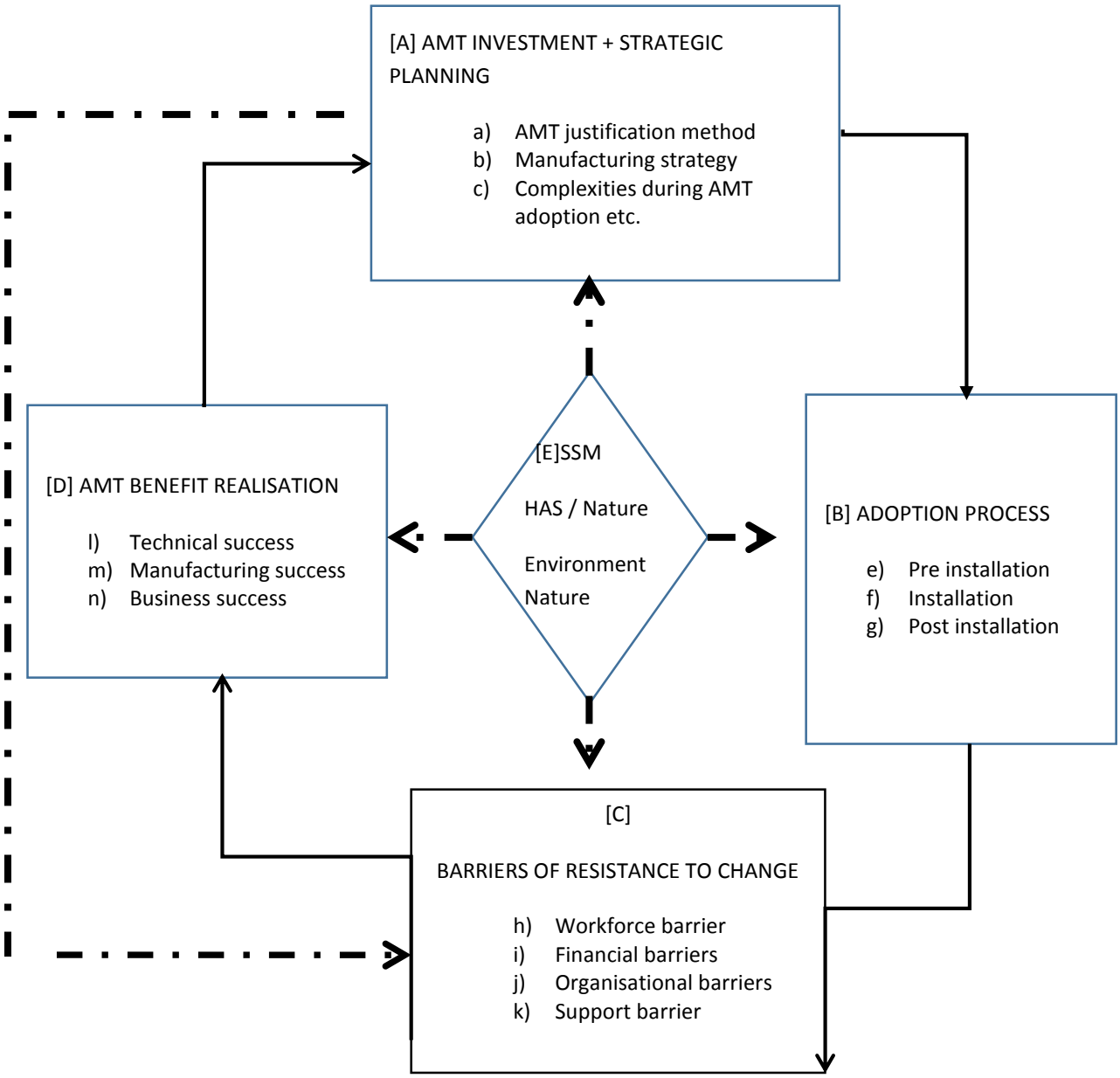


Figure 1.2: Investigative Framework

2.4 [A] AMT Investment and Strategic Planning

Modern manufacturing requires some level of transformation that is tailored for effective competition. Strategic planning is the process of providing a blueprint used to communicate the organisational goals, and the actions needed to achieve these goals (Maleka, 2014). This process is the responsibility of the senior management of an organisation. Investors in AMTs perceive strategic planning as an essential but complex process.

Strategic planning for AMTs encompasses (a) the manufacturing strategy, (b) the Justification for and evaluation and selection of an AMT, and (c) recognition of the complexities involved in adopting AMT.

Strategic planning uses a long-term and detailed view of both the technological and business aspects. In terms of AMT investment and strategic planning, Elitan (2008) reports that the probability of success is proportional to the comprehensiveness of the strategic plan. The different sub-components of AMT strategic planning are discussed next.

2.4.1 AMT justification

Studies have shown that the justification of AMTs is divided into two: (a) Evaluation and (b) Selection. Both the evaluation and the selection of AMTs are discussed in this section. Several techniques for the evaluation of the investment in AMT adoption have been well discussed in previous reports with most of the work done having grouped the AMT justification into three: (a) the economic approach, which involves the traditional financial justification; (b) the strategic approach, which involves the analysis of factors in accordance with the organisational strategy. (c) the analytical approach, which involves the risk analysis aspect of AMT adoption (Small, 1997; Tan et al, 2006; Lin et al, 2000; Efstathiades et al 2002; Gouvea da Costa et al, 2006; Elitan, 2008; Borges et al, 2018.

This classification is detailed in Table 2.2 below, alongside examples of factors considered under the different approaches.

(a) Economic	(b) Strategic	(c) Analytic
Return on investment (ROI), payback period (PP) Net present value (NPV) Discounted cash flow DCF) Internal rate of return Non DCF methods Sensitivity analysis	Technical benefits/importance Business Advantages Competitive advantages Expansion plans	Weighted evaluation methods Utility methods AHP methods Integer programming Goal programming Linear programming Stochastic methods Monte Carlo Simulation

Table 2. 5: Available evaluation approaches

However, the evaluation of AMTs is conducted differently by the different organisational departments with preference being given to their focus. A major bias is towards economic justification and the quantification of investments to benefit the organisation. It has been observed that while the costs, as a function of hardware, software, planning, procurement, training, operation, rewards, incentives, etc., are easily quantifiable, the benefits on the other hand are in most cases difficult to quantify and cannot easily be converted into a monetary value since they are intangible. The economic approach in the form of financial evaluation, using policies such as the NPV, PP, DCF, etc. was found to be inadequate for justifying AMT (Attaran, 1989.; Meredith et al, 1990.; Roth et al, 1991).

Many researchers point to the limitations in measuring intangible benefits in relation to the short-term investment in AMTs (Kaplan et al, 1986; Wilkes et al, 1991; Meredith et al, 1987). These limitations give rise to constraints which were put in place as a result of the exclusion of intangible benefits, which in themselves arose as a result of the adoption of AMTs in terms of the economic evaluation approach.

While investigating the justification for Flexible Manufacturing System (FMS), Slagmulder et al (1992) suggested that the strategic evaluation approach is more important than the economic evaluation

approach. Sullivan (1991), however, supported the practicality of the analytical evaluation of capital investments as a new paradigm in adopting AMT.

After a survey of the justification techniques in organisations that adopted AMT, Small and Chen (1995), reported that organisations using a hybrid strategy of combining the economic and strategic evaluation approaches had proved to be more successful. The report also stated that Multi Attribute Decision Making (MADM) techniques should be used to develop models incorporating the tangible and intangible benefits of AMT adoption. Small (2006) also conducted another survey on 82 organisations that showed the relationships between the types of AMTs being adopted and the specific evaluation techniques that were being used in the justification of the respective investments. The study showed that most of the organisations that had adopted more complex AMTs were using economic and strategic hybrid-evaluation approaches (Small, 2006).

The justification approaches for the evaluation and selection of AMTs present different biases by the authors contributing to the literature, as different results were presented on the different approaches to justify AMT adoption. The results of these studies reiterate that there is no bad or better approach to justifying AMTs since, as shown in Table 2.3, the different approaches pose their own individual advantages and disadvantages respectively. A combination of approaches seems ideal, therefore, for covering the areas of concern, especially in terms of the limitations with respect to accounting for the intangible benefits.

	Advantages	Disadvantages
(a) Economic	i. Easy accessibility for data collection ii. Intuitive appeal	i. Does not take non-economic benefits into account ii. Does not consider strategic benefits
(b) Strategic	i. Less technical data required ii. Uses the general objective/focus of the organisation	i. Necessary to combine it with either economic or analytical approaches as it only considers long-term intangible benefits.
(c) Analytic	i. Accounts for the uncertainty of the future ii. Incorporates multi-objectivity	i. A lot of data is required ii. Very complex

Table 2.6: The advantages and disadvantages of the justification methods for AMT adoption (adopted from Banakar et al, 2010 and Karsal et al, 2001)

This research is more aligned to the use of the strategic approach towards the justification of AMT adoption. This perspective has been emphasised in previous research studies, some of which have argued that strategic benefits are generally overlooked when AMTs are not treated as critical resources but rather as simple tools needed to perform operations (Gouvea da Costa et al, 2006). An understanding of the association (correlation) between AMT adoption and strategic justification, as documented by Pandza et al (2005), who also proposed that the latter is a necessity for a meaningful interpretation of investments in AMTs for its inherent proposed benefits. The strategic approach to

justification according to Efstathiades et al (2002) expresses two major viewpoints; (a) the strategic justification of AMTs and (b) the defensive justification of AMTs.

(a) **The strategic justification** viewpoint expresses a proactive approach, where AMT decisions must have a strategic influence on the business as a whole. In other words, AMT adoption should be centred on variables influencing the organisational strategic frameworks and business objectives. Information regarding the latter is peculiar to the respective firms but results from an assessment of the existing production platforms. (Efstathiades et al, 2002). The indicators attributed to these assessments are but are not limited to the following: a rapid increase in demand for the firm's product, an increase in the demand for innovative products, the production of a novel product, variations in customer requirements, a need for improved quality, better service delivery, etc.

(b) **The defensive justification** viewpoint expresses the occasional reactive approach of manufacturers towards AMT adoption. Here, AMT is justified based on operational concerns or problems that arise in the manufacturing process which must be tackled to avoid losses. Such concerns or problems might be, but are not limited to: labour shortages, problems with the availability of raw materials, operational safety problems, etc.

The scope of benefits (both tangible and intangible) presents challenges to the justification process. Specifically, how managers should go about the evaluation of the benefits that are more easily quantifiable (tangible benefits) and those that are hard to quantify (intangible benefits). This challenge requires a systemic approach which considers both factors in a holistic manner.

The selection of AMTs complements the evaluation process of AMT adoption. Owing to the wide range of AMTs available to manufacturing organisations, a multi-attribute decision-making (MADM) process that requires the evaluation of the tangible (economic) and the intangible (strategic) benefits and costs needs to be conducted to allow for an efficient selection of a suitable AMT package (Goyal, 2012). The selection process involves a consideration of multiple attributes, which may include the

strategic, tactical and economic aspects. It also interfaces with both internal and external factors in the environment of the organisational system. The inclusion of all factors in the decision-making process is crucial to the success of AMT adoption and the organisation as a whole. (Mohanty et al, 1998).

The selection of the right AMT and the evaluation of the adoption process are of great importance in market competition. Therefore, investments in AMTs should be justified in terms of the clearly articulated strategic attributes and the prospective benefits and not in terms of the traditional selection frameworks that depend merely on industrial trends (Mohanty et al, 1998).

There have been different procedures developed for the selection of AMTs in the literature such as the development of a procedure based on Data Envelopment Analysis (DEA) by Khouja (1995). Khouja (1995) described a two-phase model for the selection of AMT which has been used for the efficient adoption of robotic technologies. The first phase comprises of the selection of alternatives and their attributes for the purpose of evaluation, while the second phase involves the development of the selected model using Data Envelopment Analysis (DEA).

Likewise, Shang and Sueyoshi (1995) developed their procedure for the selection of FMS using both Analytical Hierarchy Process (AHP) and DEA. Their model includes three modules: (a) Analytical Hierarchy Process (AHP), (b) a simulation module and, (c) an accounting procedure using DEA. While DEA was used to unify the three modules and AHP took into account the intangible benefits, the simulation module took the tangible benefits into consideration and the accounting procedure was used to decide on the input requirements.

Mohanty et al (1998) proposed a model for the selection of AMTs in an organisation seeking strategic benefits that focused on collaborating issues confronting the organisation on different levels and in different sections. Mohanty et al (1998) proposed that a group-based participatory decision-making approach be taken to develop a MADM model for analysing the justification problem associated with

the adoption of AMT. In this context, the group decision support system (GDSS) and the nominal group technique (NGT) were proposed in the development of the AMT selection model shown in Figure 2.4.

NGT is a methodology where the ideas and knowledge of individuals who are experienced in the field are tapped, and the aim of the group consensus is focused on a desired outcome. Using brainstorming techniques, NGT has the capacity to provide iterative feedback in the form of a prioritised list of strategic initiatives. DGSS, similar to NGT, uses knowledgeable individuals to evaluate the initiatives put forward and to assist in the decision-making process.

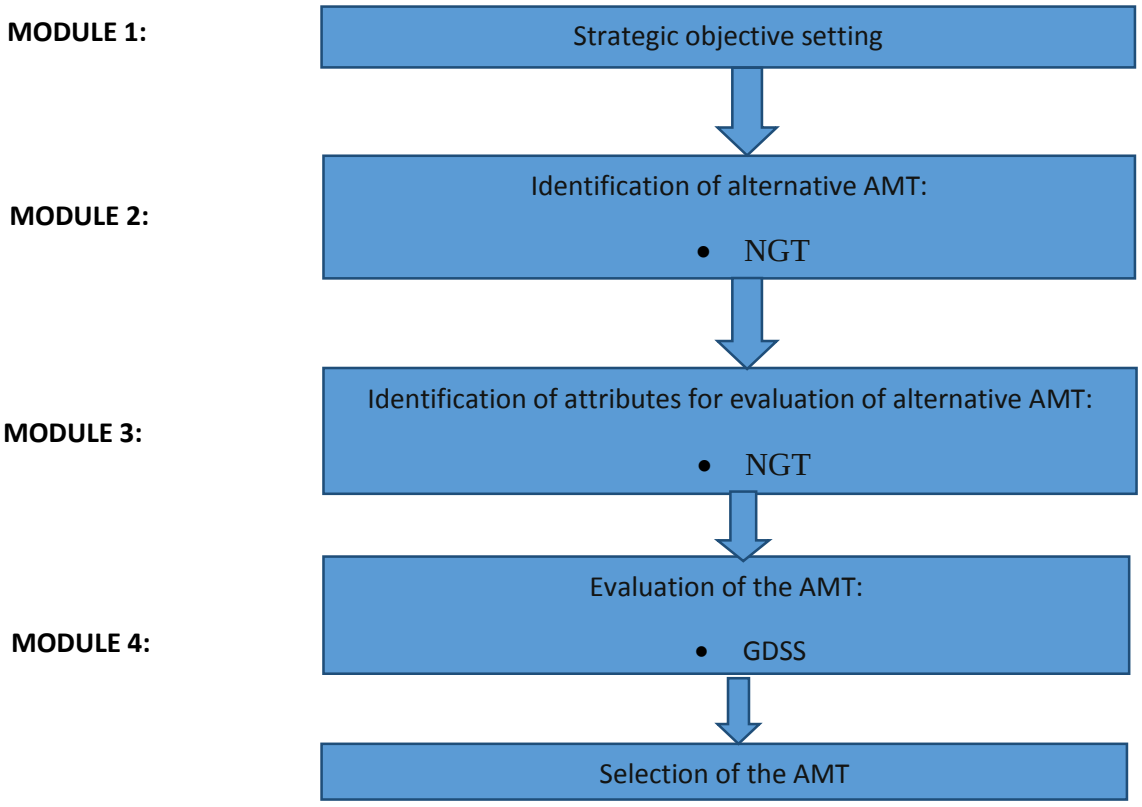


Figure 2.2: *An Integrated Framework to select Best AMT Alternative (Mohanty & Deshmukh, 1998) AMT* **selection model**

Prior to the selection of an alternative AMT, the selection model is first divided into four modules. {Alternative AMT in the model refers to the new AMT proposed to be adopted by the organisation to optimise the current production.}

- The first module defines the objectives with regard to AMT adoption. These objectives should generally be a derivation of the organisation's mission/vision statement and manufacturing strategy. It is important to involve individuals across the range of functions in an organisation such as those from management, operations/production/manufacturing, design, human resources (HR), research and development (R&D), etc. All of these groups have a stake in the decision-making process (DMP) and serve to enhance a broader reach from the brainstorming session of the NGT (Mohanty & Deshmukh, 1998).
- The second module involves the identification of prospective AMTs that are in line with the objectives set out in the previous module. This is done using NGT.
- The third module is used to identify the specific attributes of the different AMTs set out in the previous module. The attributes of the evaluated AMTs are compared, also using NGT. These attributes set forward would aid the evaluation of the AMTs, which constitutes the fourth module.
- The fourth module which involves the evaluation of the AMTs is achieved using the DGSS technique, where the individuals participating in the process evaluate various alternatives against the objectives set out in the first module, while concomitantly considering the pros and cons.
- At the end of the DGSS session, a recommendation for the AMT that serves the objectives set out previously while the tangible and intangible benefits were being considered should emerge. This recommendation will lead to the selection of an AMT agreed upon to be the perfect fit for the organisation.

Unlike the traditional techniques mentioned above which are used for the evaluation and selection of AMTs, Soft Systems Methodology (SSM) does not focus on the individual components of the system in isolation but it takes the holistic approach of viewing the situation as a whole. SSM can be applied in this justification stage to realise better results from the evaluation and selection processes. The

application level of SSM is limitless, and various authors have tailored it to fit the problems that they were trying to solve.

Hanafizadeh et al. (2017) observed SSM to have three application levels:

a. SSM as an inquiry process;

b. SSM as an action-oriented method;

c. The hybrid use of SSM.

This application of SSM would allow for the process of justifying the adoption of AMTs to be successfully implemented in that it uses the enquiry process to better understand the problem situation in a holistic manner.

The third application level which is the hybridised use of SSM involves the incorporation of other techniques. In this case, SSM can be used to further enhance the results of the justification process by incorporating the views and results from the traditional methods approach (e.g. MCDM techniques such as the NGT, DGSS, NPV, DCF and AHP, amongst others). The adaptive management capabilities arising from the combination of SSM with other techniques might enable organisations to better understand complex situations such as the adoption of AMTs in a system such as the South African manufacturing industry (Bunch and Dudycha 2004; Cundil et al. 2012).

These respective application levels make SSM a better option for addressing the problems of AMT adoption that might arise during the AMT investment and strategic planning stages.

From this research evidence, the following research issues, which will form part of the research instrument, arise.

indicator	Issues	Source
A3	The decision to adopt AMT is properly justified and in alignment with the organisation's strategic plan.	Sohal, A.S., (1994)
A4	The compatibility of the proposed AMT is properly evaluated to align with the existing organisational infrastructure (i.e. the existing technology).	Mohanty and Deshmukh (1998)

Table 2.4: Research instrument questions with respect to AMT Justification.

2.4.2 AMT as an element of organisation: the manufacturing strategy (MS)

There are three main levels of strategy identified by Hofer and Schendel (1978), namely:

- Corporate strategy (What type of business should an organisation be in?);
- Business Strategy (How can we compete in the business that we are in?); and
- Functional strategy (How can a function contribute to the competitiveness of the business that we are into?).

The functional strategy has also been known as the manufacturing strategy (MS). This is according to the seminal work by Skinner (1969) which identified manufacturing strategy as the missing link organisational strategy with respect to corporate strategy, business strategy and functional strategy.

Manufacturing strategy can be defined in general terms to be the set of co-ordinated objectives directed at an organisation's manufacturing function for the purpose of securing a medium- to long-term sustainable competitive edge over competitors. Platts and Gregory (1990) affirms that for an organisation to experience operations effectiveness, it must have a manufacturing strategy that clearly defines how the functions of manufacturing will assist in the achievement of business objectives through the provision of appropriate structures and infrastructures.

AMTs are a function of MS content and can be viewed in two broad classifications: the decision-making areas and the manufacturing objectives (Leong et al, 1990; Slack et.al, 2011). Owing to the priorities that may be set by organisations and by the type of business which the organisation is into, the understanding of manufacturing objectives may vary slightly in the literature and in practice.

However, the popular standards include, but are not exclusive to cost, quality, flexibility, speed, time, and dependability (Hill, 1993; Slack et al, 2011; etc.). In contrast to the manufacturing objectives, there has been consensus in the literature concerning the decision areas in MS (Hayes and Wheelwright, 1984; Mills *et al.*, 1996.; Slack et al, 2011). (Figure 2.2 shows a manufacturing strategy matrix.)

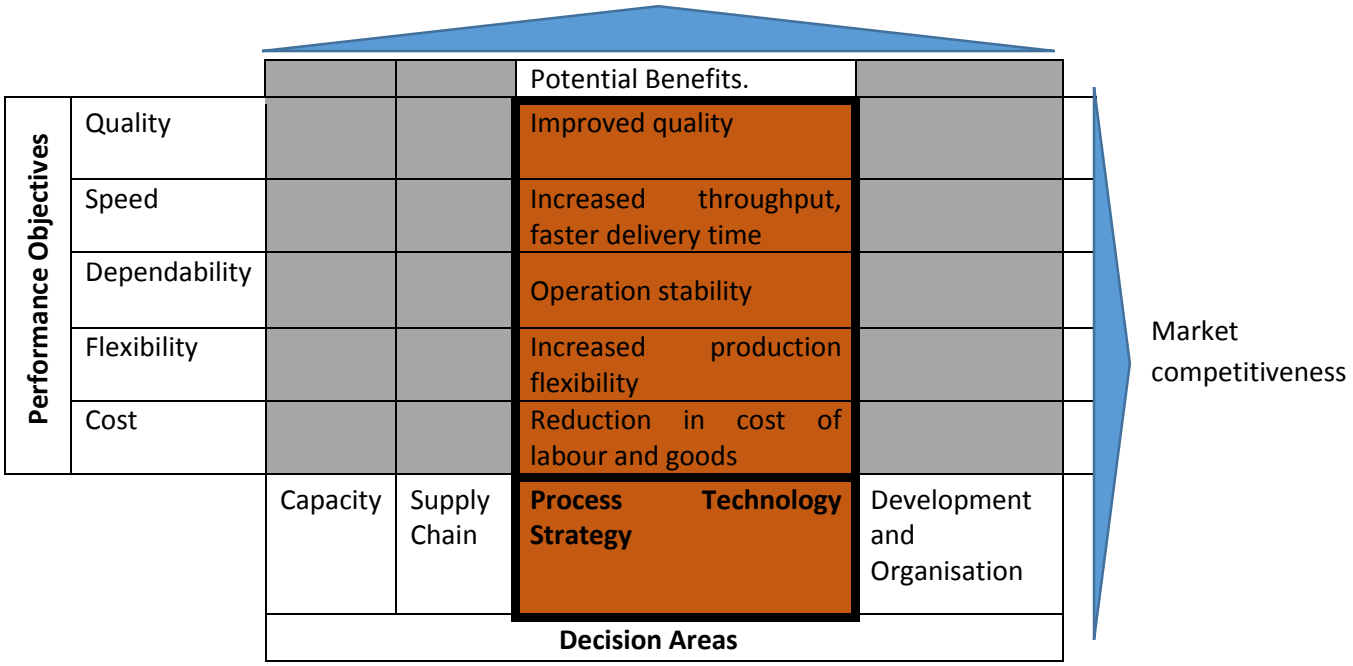


Figure 2. 3: Manufacturing strategy matrix (Adopted from Slack et al, 2011)

The adoption of AMTs affects many of the strategic decision-making areas and would also hopefully inspire and motivate the formulation of performance objectives and their attainment. For example, CAD/CAM/CAE have reduced the floor space requirements for design and engineering in the manufacturing enterprises over the years, while concomitantly producing improved and more efficient results, thereby affecting capacity positively. Likewise, additive manufacturing and rapid prototyping have also revolutionised the manufacturing industry by reducing the number of parts needed in the manufacturing of products. In its turn the supply chain has also benefited in that its capacity to provide for flexibility and quality has been raised. The implementation of lean in manufacturing processes may provide for reductions in waste which will impact on costs, while Just-In-Time (JIT) has affected the rate at which the processes operate.

AMTs have impacted on the entire range of manufacturing operations. As such, the proper strategy for adopting AMTs appears to be paramount. In fact, the effect of not adopting AMT properly could cut across a manufacturing enterprise and negatively impact on its operations. Slack et al (2011) indicates that the decision makers involved with the implementation of AMT would not necessarily need to be experts in engineering, programming or whatever the core science of the technology is. The only basic requirement is that they should know enough about the technology and about evaluating technical information in order to ask relevant questions which would help align the justifications for efficient AMT adoption. Some of these questions include:

How does the advanced manufacturing technology differ from other similar technologies?

a) How does AMT work?
b) What are the constraints that ATM would place on the operation?
c) What skills would be required from the operations staff in order to install, operate and maintain the technology?
d) What capacity does each unit of technology have?
e) What is the expected useful lifetime of the technology?

Figure 2.3 shows the three main dimensions of AMTs, namely scale, level of automation and coupling, and their effect on flexibility and costs. These aspects are often closely linked when strategising in preparation for AMT adoption: Scale concerns the level of complexity and the magnitude or scope of the AMT. The larger the scale, the fewer and larger the components of the technology, while a smaller scale gives room for many small units of the technology.

AMT adoption is discussed next.

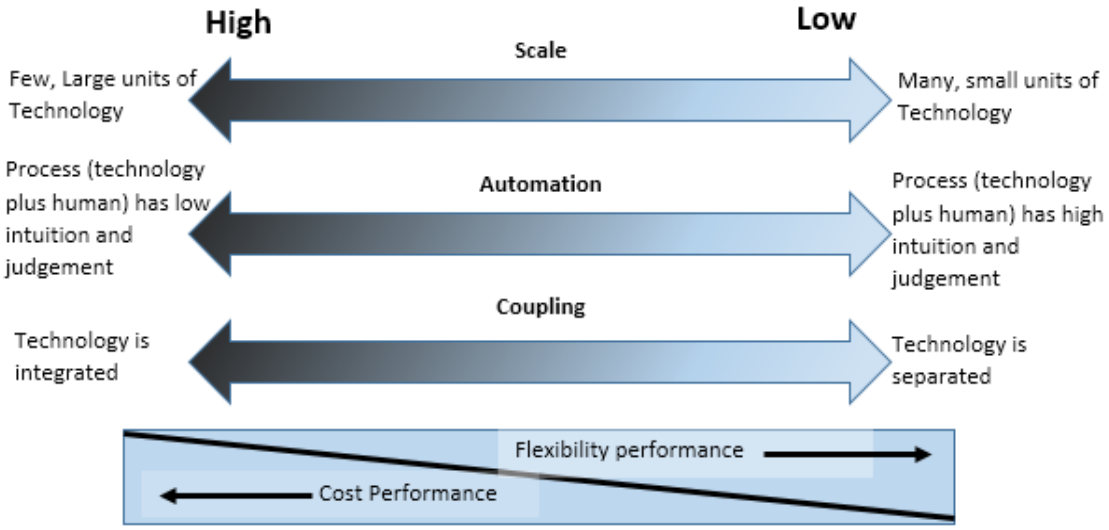


Figure 2.4: The closely linked dimensions of AMT adoption (adopted from Slack et al, 2011)

From this evidence, the following research issue, which will form part of the research instrument, arises.

Indicator	Issue	Source
A5	The level of investment by management is justified by the organisation's manufacturing strategy.	Slack et al, 2011 GDC et.al., 2000

Table 2.5: Research instrument questions with respect to organisations Manufacturing Strategy

Having discussed AMT as a function of the organisational manufacturing strategy, the complexities that may arise during the AMT adoption stage are covered under the [A] AMT Investment and Strategic Planning constructs. These are discussed next.

2.4.3 Complexities of AMT adoption

The adoption of AMTs, being a complex and dynamic process on account different factors that may either be internal or external to the organisation (Efsthiades et al. (2001); Beatty (1993); Banakar et

al. (2010);), creates complexities on different fronts. These complexities are riddled with issues that create barriers to the successful adoption of AMTs. Factors such as organisational structure, culture and size, manufacturing strategy, experience in AMT adoption, level of education, etc., are common identifiers of the issues and the potential barrier areas in AMT adoption. (Hynek & Janecek, 2010; Alvarado, 2013; Hyneck & Janecek, 2013). Also, external factors such as supply chains, government, customers, etc. also present complexities apart from the complexities that may accompany the type of technology being adopted.

A classification of Barriers to AMT adoption was carried out by Beatty and Gordon (1990). The three classifications that they presented are as follows:

(a) Structural

(b) Human and

(c) Technical.

Structural complexities are linked to organisational infrastructures, human complexities are linked to uncertainty in the resistance or cooperation of the workers, and technical complexities are linked to the compatibility of the systems. Although human resource management was described by Adler (1989), as the major complexity in AMT adoption, Chan et al. (2001) presented a more detailed list of potential complex scenarios that could lead to failure in AMT adoption. This list includes insufficient organisational planning towards the introduction of AMT, the lack of knowledge concerning the effective installation and operation of AMTs, a lack of workforce support, poor managerial support, etc.

There is an abundance of literature on the areas of complexity in AMT adoption. However, there are variations in these presentations which show that there are numerous complexities in AMT adoption. A review of these research papers has assisted in the development of an investigative framework. The research has classified these complexities into Barriers and Resistance to Change [C] , a category that

consists of four classifications, namely (a) Workforce Barriers, (b) Financial Barriers, (c) Organisational Barriers and (d) Support Barriers. (These are discussed in more detail in Section 2.6.)

Complexities were found in all of the stages of AMT adoption. Rahardjo and Bin Yahaya (2010) found a direct link between the management of the complexities during the AMT adoption process and the success and failure of AMT adoption. They suggest that these complexities may pose problems that are greater than those that AMT was meant to resolve. From the research evidence mentioned in this section, the following research issues, which will form part of the research instrument, arise. .

Indicator	Issue	Source
A7	There are strategic plans to account for possible barriers and resistance that might occur during the AMT adoption process.	Winter and Steinfort (2006)
A6	People are involved in a variety of functions in the proposal formulations and decisions pertaining to the technology	Researcher's interpretation
A8	Investment in AMT is complemented by investment in operator training.	Elitan (2008)

Table 2.6: Research instrument questions with respect to AMT adoption Complexities.

Having discussed the complexities that may arise during the AMT adoption stage as an element of [A] AMT Investment and Strategic Planning (discussed under point 2.4 from p 24 to 38), the [B] AMT Adoption Process construct of the investigative framework is discussed next.

2.5 [B] AMT Adoption Process

AMT adoption is defined by Gunawardana (2006) as the interrelationship between planning, investment and the implementation of AMTs towards the realisation of the benefits of AMTs. The performance of an organisation using AMTs depends to a large extent on how well the AMT adoption process was managed and not wholly on the efficiency of the technology itself. The success and limitations of AMT adoption are well discussed in the literature. Research shows that there are different models and phases for the AMT adoption process. For example, Beatty (1992), described AMT adoption to be a three-phased process: (a) institutionalisation/initiation, (b) acceptance, and (c)

routinisation and infusion. Likewise, Frohlich (1998), while studying how to successfully adopt AMT, adopted the Kwan and Zmud's model for AMT adoption which comprises of six stages; (a) initiation, (b) adoption, (c) adaptation, (d) acceptance, (e) use and (f) incorporation.

In the context of this research, the model presented by Sohal et al (2001) and then by Darbanhosseiniamirkhiz (2012) is used on account of its simplicity and the ease with which it can be understood. The model presents AMT adoption in four areas under consideration.

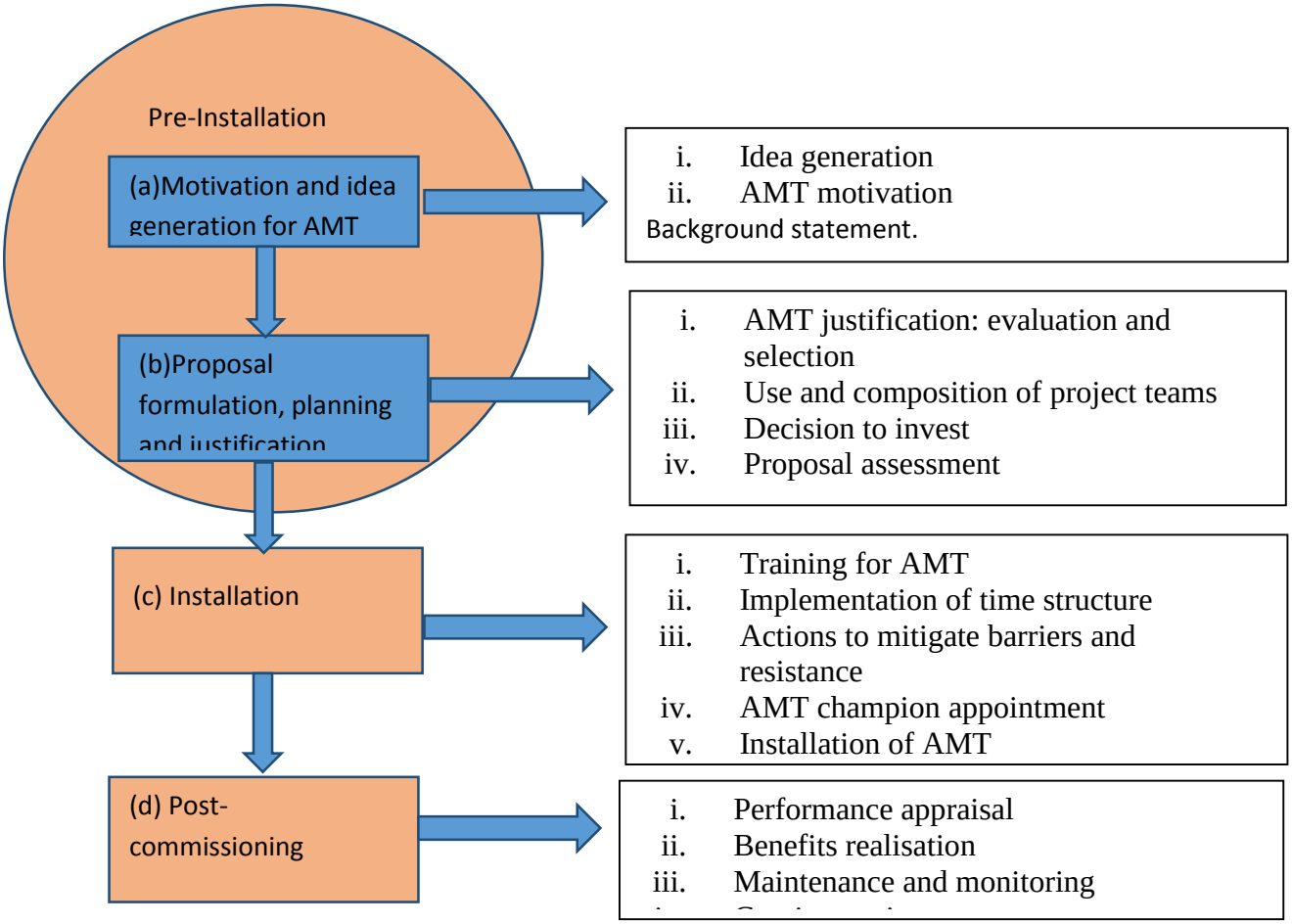


Figure 2.5 : Process model for the adoption of AMT (model adapted from Sohal et al (2001) and Darbanhosseiniamirkhiz (2012)

2.5.1 Pre-installation Stage (a,b)

The first third of the AMT adoption lifecycle proposed by Voss (1988) and adapted by Sohal et al (2001) and Darbanhosseiniamirkhiz (2012) is the pre-installation stage of AMT adoption, which consists of

the motivation, planning, proposal formulation and justification for AMT. The pre-installation stage starts with the generation of the idea of using AMT, followed by the motivation to work on this idea prior to the approval. After the decision to adopt the AMT has been approved, the AMT justification and project planning processes occur before the decision is made to invest in the project.

This pre-installation stage is where organisations focus on the organisational issues instead of the technical issues. The pre-installation stage, as described by Beatty (1991), is an all-encompassing phase of AMT adoption; therefore, the need for careful management is required during this stage. This is to avoid the reactive, unplanned and disruptive adaptation cycles highlighted by Lindberg (1992) in a research study on the management of uncertainties in AMT adoption. The disruptions caused by the uncertainties that riddle this stage are much more difficult to manage in the other thirds of the AMT adoption life cycle. These disruptions may result in increased costs, restricted flexibility, delays in production, and changes in the strategic aims of the AMT adoption process (Lindberg, 1992). Ford (2002) calls for a properly managed and well-organised AMT adoption process with strong management guidance focusing on future potentialities to cater for these factors.

2.5.2 Installation Stage. (c)

The second part of Voss (1988)'s model which is the installation stage comprises of the acquisition, installation, integration and installation of the AMT. Using the foundation of the pre-installation stage, action is taken in this, the project stage, during which the implementation of AMT occurs. The relevant organisations involved should focus on technical issues, such as training employees to operate and manage the AMT, the implementation of a time structure for the project, as well as supervision by an AMT adoption champion to manage the successful installation of the said technology.

2.5.3 Post-commissioning stage. (d)

The third part of Voss (1988)'s model is the post-commissioning stage. This stage of AMT adoption is considered in conjunction with the realisation of the benefits that were used for its justification during the pre-installation stage, in mind. Building on the previous two stages of AMT adoption to

maintain a successful process, the monitoring and regulation processes of the AMT are carried out at this stage. In doing this, there should be plans to ensure that the AMT stays aligned to the proposed objectives of the organisation. This can be achieved by using performance appraisals, continuously improving on the technology, and through proper maintenance of the AMT. The critical success factors for these stages of AMT adoption are further discussed in this section.

All three stages presented by Voss (1988) have been considered to be essential in order to elicit the necessary benefits from the AMT adoption and to prevent the underutilisation of such technologies which in turn leads to sub-optimal business performance.

The different stages of AMT adoption as proposed by Voss (1998) are associated with different levels of success, all of which are important to the overall successful adoption of AMTs. Lists of these critical success factors (CSF) for AMT adoption are numerous in the literature, but the five, presented by Rahardjo et al (2010) and as highlighted in Table 2.5 better reflect the scope of this research work and have already been standardised for the Voss model.

Rank	Pre-installation	Installation	Post-commissioning
1	Good leadership	Good leadership	Support and involvement of top management
2	Involvement and support of top management	Financial availability	Interdepartmental cooperation and coordination
3	Financial support	Teamwork	Communication with supplier
4	Organisational culture	Involvement and support of top management	Expertise availability
5	Training and education on AMT	Interdepartmental cooperation and coordination	Collection and analysis of AMTs data

Table 2. 7: Ranked critical success factors for AMT adoption process at each of the stages

There is little evidence supporting the use of SSM for AMT adoption. However, there is evidence from the research that supports the use of SSM in project as well as performance management (Doloi, 2011; Behera et al., 2015; Walker and Steinfort, 2013 ;). Given that AMT adoption may be seen as a complex project to be implemented by organisations, it is expected that SSM may be of benefit to organisations in terms of the simplification of the complexities and being an enabler of success in the adoption of AMT. Doloi (2011) recorded the impact of SSM in the initial stage, also known as the pre-installation phase, of project management in terms of its effects on the estimation of the precise costs of the project in question. SSM has also been associated with better conceptualisations and analyses of the project situation (Joham et al., 2009; Behera et al. 2015; Walker and Steinfort, 2013; Small and Walker, 2011).

SSM recognises that projects such as AMT adoption are initiated typically from a point where systems owners and stakeholders lack a detailed understanding of the scope and nature of the project. This lack of understanding has the potential to lead to a clash in worldviews or holistic views of the system amongst systems owners, stakeholders and actors. By using SSM, such clashes or conflicting views may be mitigated by initiating a lining up of the “building blocks” leading to an understanding of the project situation. The use of SSM has resulted in improvements in the scheduling of projects (Sankaran et.al. 2009) and the structuring of projects (Winter 2006).

The usage of SSM in project management is not restricted to the pre-installation and installation stages of AMT adoption, but rather researchers have also implemented SSM in the optimisation of the post-commissioning phase of projects in the form of monitoring, control and management of change (Crawford et al. 2003; Sankaran et al. 2009).

Based on the available research evidence, a project such as the adoption of AMTs is considered to be a complex system, embracing a multitude of human actions. The management of these changes requires a true understanding of the contexts within which the system is viewed. The SSM approach

not only provides for a precise understanding of the complex system. It also allows stakeholders to take a holistic view of it, thus facilitating an action plan.

From this evidence, the following research questions that will form part of the research instrument, arise.

Indicator	Research instrument questions	Sources
B1	The adoption of AMT is supervised by an AMT champion.	Researcher's interpretation
B2	Tasks are strategically planned and allocated towards the success of AMT adoption.	Rahardjo and Yahya, 2010. Cardoso et.al., 2012
B3	Interdepartmental work teams are on board in the AMT adoption process.	Rahardjo and Yahya, 2010
B4	Best practices are developed to manage the AMTs	Voss 1988
B5	There are good channels of communication between management and the employees.	Researcher's interpretation

Table 2.8: Research instrument questions with respect to AMT adoption process.

Having discussed the AMT adoption process in terms of the model by Sohal et al. (2001), the Barriers and Resistance to AMT adoption [C] are next discussed.

2.6 [C] Barriers and Resistance to Change

The construct of the investigative framework discussed in this section, namely barriers and resistance to AMT adoption, focuses on the relevant factors that may actively constitute such barriers. Several studies have identified issues such as a lack of managerial know-how, the lack of a proper infrastructure, the lack of training and skills, poor communication channels, etc. as barriers to AMT adoption. The negative effects of these barriers to change in the relevant organisations have attracted much attention in the literature (Beaumont and Schroder, 1997, Kakati, 1997, Swink and Nair, 2007, Milen and Sohal, 1998, Stock and McDermott, 2001, Efstathiades et al, 2002, Dangayach and Deshmukh, 2006, Elitan, 2008, Noori, 1997). This has led researchers to various issues which must be

addressed prior to AMT adoption to avoid the risk of impeding the success of its adoption. This research proposes a categorisation of possible areas of resistance to change in AMT adoption in such areas as (a) the workforce, (b) finances, (c) organisational issues, and (d) support systems. The barrier categories are discussed next.

2.6.1: Workforce Barrier

Workforce barriers refer to the challenges faced by organisations with regard to AMT adoption within the organisation's workforce. These barriers are usually as a result of the resistance of the workers to the process of AMT adoption and are internal to the organisation. They can be further categorised into owner/manager barriers and employee barriers. Owner/manager barriers are those arising as a result of a lack of commitment from top management to the idea of AMT adoption, while employee barriers are those linked to the resistance raised by the lower-level workers.

2.6.2: Financial Barriers

Financial barriers are those that occur in organisations adopting AMTs as a result of the situation regarding the availability or the allocation of funds. Examples could be improper justifications for making investments, a lack of discretion in dealing with the funds for rewards and incentives and with the funds for training employees, and whether the organisation is financially ready to purchase AMTs.

2.6.3: Organisational Barriers

Organisational barriers are those that are associated with the functions of the manufacturing organisation. Negative attributes in terms of such factors as infrastructure, organisational culture, technological readiness, and organisational changes are relevant.

2.6.4: Support Barriers

Support barriers are those resulting from the situation in respect of available facilities and resources that support the AMT adoption processes. These support barriers could either be internal or external to the organisation adopting the AMTs. Internal support barriers include the challenges faced within

the environment of the organisation, financial support from top management, and technological support from the AMT vendors, etc. External support barriers are barriers that are external to the organisation's systems environment such as governmental support barriers and societal support barriers.

A detailed list of some of the barriers that dominate in the literature concerning AMT adoption are listed in Table 2.5. These have emanated from a survey of 12 research papers and the high frequency of citations is indicated.

Authors / **Issues**	A	B	C	D	E	F	G	H	I	J	K	L	NO OF CITINGS
Improper justification of investments	*	*	*	*	*	*	*		*		*		9
Training for maintenance personnel		*	*	*		*	*		*	*			7
Top management support			*			*	*	*	*	*	*	*	8
Workers/employee support			*	*	*	*		*	*	*		*	8
Training for operations personnel		*	*	*	*				*	*			6
Training for technicians and engineers			*	*			*		*	*			5
Relationship with vendors/suppliers			*	*	*			*					4
Lack of knowledge of the benefits	*			*	*					*			4
Improper communication channels					*	*			*				3
Lack of interdepartmental cooperation				*			*	*		*			4
Integration of manual and automated processes			*		*			*					3
Availability of AMT team and adoption champion			*				*			*			3
Availability of client support by vendors/suppliers			*		*		*						3
Global technological uncertainty	*					*		*					3

Global economic uncertainty	*					*		*				*	4
Lack of required infrastructure					*		*		*				3
Availability of an AMT adoption team			*				*			*			3
Incomplete economic analysis	*					*					*		3
Incomplete strategic analysis	*					*					*		3
Government regulations	*			*					*				3
Software management of the AMT			*	*									2
Lack of a continuous-improvement culture		*							*				2
Interface between software and hardware			*										1
Incapability to evaluate strategic benefits											*	*	2
AMT skills deficiencies												*	1
Acquisition and delivery of AMT hardware			*										1

Table 2. 9: AMT adoption Barriers and resistance to change: a survey or 12 academic papers.

Sources:Shehabuddeen et al, 2006; B: Mital and Pennathur, 2004; C: Low-Lock and Seetharaman, 2003; D: Baldwin and Lin, 2002; E: Efstathiades et al, 2002; F: Kotha and Swamidass, 2000; G: Hynek and Janeček, 2006; H: Shepherd et al, 2000; I: Efstathiades et al, 2000; J: Noori, 1997; K: Canada and Sullivan,1990; L: Elitan, 2008.

From Table 2.5, the prominent areas of concern, as identified in the surveyed literature, are (a) improper justifications for investments, and negative attributes in respect of (b) training of maintenance personnel, (c) top management support and (d) worker/employee support. These major issues, shown in Table 2.5, are categorised under the heading barriers and resistance, outlined by the investigative framework. As can be seen from Table 2.5, the most quoted problem refers to the justification of investments which is commonly related to a lack of financial resources and authority or power to manage AMT adoption. This can be classified as a financial barrier. This issue was quoted nine times out of the twelve surveyed research papers. Other main issues commonly encountered in these research papers were the training of maintenance personnel and top management support, which can be classified under organisational barriers, and worker/employee support, which is classified under workforce barriers.

The issues that may impede AMT adoption are not only limited to the list identified in Table 2.5. An assessment of the context in which South African manufacturing organisations operate would also present new insights into issues that are peculiar to the localised environment. These issues can be identified and targeted using systems techniques such as SSM to better understand the unique issues that face the manufacturing industry in South Africa.

Having discussed the barriers and resistance to change in the adoption of AMT, the benefits of AMT discussed under the AMT's Benefits Realisation [D] section, now follows.

The following research issues that have arisen as a result of this research evidence discussed above, will now be discussed. These issues will form part of the research instrument.

Indicator	Issues	Source
C1	The lack of financial justification owing to the high cost of equipment	Efstathides, 2002
C2	The high costs involved in integrating the new technology.	Kuilman 2017
C3	The shortage of available skills in the organisation.	A.S Sohal et al. (2001)
C4	Workers' resistance.	A.S Sohal et al. (2001)
C5	Lack of proper technological/technical support or service (from vendors or consultants)	Researcher's interpretation
C6	The resistance by management to the introduction of the new technology.	Elitan 2008, Efstathiades et.al(2002)
C7	The inability by management to evaluate the new technology	Researcher's interpretation
C8	The cost to develop and maintain software for the new technology	Researcher's interpretation
C9	The cost of ensuring cyber security	Elitan 2008

Table 2.10: Research instrument questions with respect to Barriers and resistance to AMT adoption.

Following on the discussion of the barriers and resistance to AMT adoption, the next section discusses Benefits Realisation associated with AMT adoption [D].

2.7 [D] AMT Benefits Realisation

The prospects of increased economic performance present a strong motivation for most organisations to adopt AMTs, while the increased capabilities of AMTs with regard to global technological trends and the intensified competitiveness between manufacturing organisations continue to impel the adoption of AMTs across the manufacturing sector (Hynek and Janeček, 2006; Saberi and Yusuff, 2012). Several works have established that AMT adoption presents opportunities for manufacturing organisations to realise the benefits that directly translate into improved marketability of their brands. On the other hand, it is not unusual for organisations to realise the unexpected areas of application of AMTs and their benefits, which open up enormous opportunities in respect of, amongst others, (a) production flexibility, (b) reductions in production costs (c) improved product quality, and (d) faster production speeds.

Following on the results from Efstathiades et al. (2001); Banakar et.al (2010), which suggest that manufacturing organisations generally achieve technical success rather than manufacturing and business success, it would therefore be appropriate to describe AMT benefits realization [D] in terms of these factors.

2.7.1 Technical success

Technical success is described in context by Efstathiades et al. (2001) as a situation that is attained in the operations of organisations when there are low downtime and high mean time to equipment failure for the adopted AMTs. The attributes of technical success have been found in literature to be easily achieved by manufacturing organisations as Efstathiades et al. (2001) found that 92.3% of the organisations that have adopted AMTs realise these benefits. This compares well with the results of Voss (1988), who found that 100% of the organisations that introduced AMTs achieved technical success.

2.7.2 Manufacturing success

Manufacturing success is described as the realisation of attainable benefits in relation to the level of importance of the manufacturing parameters, the latter including as amongst others product quality

and production flexibility. Efstathiades et al. (2001) recorded a manufacturing success rate of 41% in organisations that had adopted AMTs.

2.7.3 Business success

Business success is the realisation of organisational goals which are in line with the manufacturing strategy. Organisational goals spelling out success include, amongst others, an increase in revenue and improved competitiveness. Efstathiades et al. (2001) recorded a business success rate of 43.5% in organisations adopting AMTs.

The success rates discussed above are complemented by the findings from Voss (1988); Beatty (1993) and Banakar et al. (2010), which show that organisations generally realise technical benefits; however, in over 50% of these cases, success is not realised in the manufacturing and business fields. These findings have led this research into focusing more on the requirements for attaining success in both the manufacturing and the business sectors as these would be better suited to the application of SSM. (Table 2.8 shows a list of the benefits of AMT adoption grouped into either manufacturing or business success.)

AMTs are said to have an effect on organisational competitiveness in two main ways (Bessant, 1993; Vinas et al., 2001). Firstly, they can have an effect on the price structure by producing outputs more efficiently through an integrated process which better utilises raw materials, reduces waste, optimises energy consumption, etc. Secondly, AMTs may also have an effect on other structures besides price, as in the development of better-quality products, improved designs, a shorter lead time, customer satisfaction, etc. Even though price factors remain an important factor in global competitiveness, it is now becoming clear that owing to globalisation, factors other than price are becoming major considerations in the global markets. Where organisations from previous generation adopted AMTs to reduce their labour costs, the Fourth Industrial Revolution is now placing competitiveness on factors such as customisation and delivery speed.

There have been studies in the literature aimed at ranking according to importance the benefits to be expected from AMT adoption. Such studies include the research conducted by Hynek and Janecek (2013), which focused on the importance of the benefits arising from the adoption of AMTs in the manufacturing industry in the Czech Republic. Also, a similar study was conducted by Sohal et al (2001) to evaluate the main benefits targeted by manufacturing organisations in South Africa when adopting AMTs. (The top six ranked benefits for each study are presented in the Table 2.7.) It is evident that both studies show a level of agreement on the type of benefits targeted by the manufacturing organisations, with the exception of increased flexibility and increased sales, which are not commonly featured on the top six rankings. It can also be observed that increased throughputs and increased quality both feature in the top three categories of both study rankings.

Ranking	**Studies**	
	Hynek and Janecek, 2013	**Sohal et al, 2001**
1	Reduced costs	Obtaining a competitive advantage
2	Improved quality	Increased throughput
3	Increased throughput	Improved quality
4	Obtaining a competitive advantage	Reduced costs
5	Increased sales	Better management control
6	Better management control	Increased flexibility

Table 2. 11: The rankings of the targeted benefits of AMT adoption (a comparison from past studies)

The potential benefits of AMTs are limitless and not bound to the list in table 2.7 above since the prospects of AMT adoption are reminiscent of applications in the manufacturing sector and development on scope promises which result in new advantages, especially over traditional manufacturing. These benefits are further emphasized upon in table 2.8. Table 2.8 highlights some current quantifiable benefits, focusing to a slight extent on the level of agreement between the studies as to the benefits. As shown in Table 2.8, the list of benefits correlate with the perspectives across the

list of reviewed research evidence with potential variations owing to factors such as type of industry, type of AMT adopted, organisational need, justification criteria, etc.

Type pf Benefit	Authors	A	B	C	D	E	F	G	H	I	No
	Benefits of AMT adoption										
Manufacturing Success	Increased flexibility	*		*	*	*	*	*		*	7
	Production line and depth expansion		*	*		*	*	*	*	*	7
	Faster response time	*	*			*	*	*			5
	Enhanced operational stability	*		*					*		3
	Reduced change over set-up times									*	1
	Reduction in lead time		*							*	2
	Increased productivity/ volume throughput	*	*			*	*				4
	Time reduction in product development		*	*		*	*	*		*	6
	Increased product quality	*	*	*			*			*	5
	Faster delivery time		*	*			*	*	*		5
	Reduction of work-in-progress inventories	*				*	*		*	*	5
	Better manufacturing integration process			*	*	*		*		*	5
Business Success	Reduction in labour cost	*			*		*		*	*	5
	Organisational competitiveness	*	*				*	*			4
	Better working relations		*		*	*	*		*	*	6
	Positive ROI							*		*	2
	Waste reduction				*					*	2
	Overcoming skill deficiencies	*		*		*		*		*	5
	Better management control	*	*	*		*	*	*	*	*	8
	A better working environment	*	*	*	*	*	*		*	*	8
	Enhanced company image		*	*	*	*		*	*	*	7
	Improved attitude of workforce	*				*	*	*	*	*	6
	Widening of product range									*	1

Table 2.12: Benefits of AMT adoption (Code of authors: A : Kakati, 1997; B: Beaumont and Schroder, 1997; C: Noori 1997; D : Swink and Nair, 1997; E: Millen and Sohal, 1998; F: Stock and McDermott, 2001; G: Efstathiades et al, 2002 ; H: Dangayach and Deshmukh, 2006. I: Elitan, 2008)

The following research issues, which have arisen as a result of the research evidence discussed above, and which will form part of the research instrument, will now be discussed.

Indicator	Issues	Sources
D4	Reduction in lead time	Elitan, 2008
D2	Increase in business growth	Efstathiades et al, 2002; Elitan, 2008
D3	Enhancement of company image	Researcher's interpretation
D1	Organisational competitiveness	Sohal et.al 2001, Hynek and Janecek, 2013
D5	Increased productivity/volume of throughput	
D7	Increase in product quality	
D10	Reduced labour cost	
D8	Better working conditions	Borges et.al, 2018
D9	Increase in manufacturing flexibility	Sohal et.al 2001
D6	Positive ROI	Elitan, 2008
D11	Identification of new business opportunities	Borges et al. 2018
D12	Employee satisfaction with AMT adoption result	Researcher's interpretation

Table 2.13: Research instrument questions with respect to Benefits realisation constructs.

Having discussed the literature relevant to the constructs of the investigative framework fig 1.2. (i.e. [A] AMT Investment and Strategic Planning , [B] AMT Adoption Process, [C] Barriers and Resistance to Change and [D] Benefits Realisation), the holistic systems thinking approach [E] SSM applicability is discussed next.

2.10 [E] Systems thinking

Systems thinking is a holistic approach to understanding how things work (O'Connor and McDermot 1997). Traditionally, the technique for problem-solving involves the isolation of the components, elements or parts of a system and their subsequent analysis in isolation. Bertalanffy (1972) discussed the concept of interdependency between the output of any system and the interaction within its parts

and that an accurate image of a system cannot be seen when the parts are studied in isolation. Waldman (2007) agrees with this concept by putting forward a theory that one must understand the multiple-level interactions over time to grasp the idea of the functionalities of a system. The complexity of a system is driven by the number of elements in the system (Van Eijnatten, 2008); hence, an increase in the number of elements in a system leads to an increase in the arising complications and the overall multi-dimensionality of the interactions between all of the components or elements (Tyson, 1998). As such, the complexity of a system is directly correlated to the possibility of an array of non-defined and difficult-to-resolve process issues (also referred to as "wicked problems") (Becker, 2002).

The human system (families, organisations and countries are systems) is characterised by an infinite number of complexities and the challenges that most of them experience have an effect on their functionalities, which generally transcend the constitutive components or elements. These problems often involve a dense connection of interrelated factors across different sub-systems, making it a difficult task to assume the effect of decisions and the impact that these decisions might have in other areas of the system. These types of problems often occur in complex, dynamic and uncertain environments.

Senge (2006) addressed "wicked" problems in a complex system by proposing a conceptual framework which addresses the system as an entity to assist in understanding and eventually solving the "wicked" problems.

In the context of AMT adoption and its integration into an organisational design, the systems thinking approach assists in the formulation of an investigative framework (fig 1.2) to better understand the system and manage AMT adoption. The development of a holistic methodology, which functions on the basis of active participation from the different parts (components) of the manufacturing organisation towards a better understanding of the complex problems, promises to be an effective tool.

The use of soft systems methodology (SSM) stems from recommendations by several important previous works done in the scope of system science to make sense of characteristics tagged as "wicked" problems and the complexities evident in AMT adoption (Sankaran et al, 2009; Cavaleri and Obloj, 1993; Checkland, 2000; Foster-Fishman and Behrens, 2007; Maqsood et al, 2001).

The layered administrative and operative hierarchy of humans and machines in manufacturing organisations has caused the organisation to become a dynamic system. Senge (2006) described organisations as a network of functional, multi-subsystems in a larger, complex system, with a large potential to be riddled with "wicked problems". The application of systems tools such as SSM seeks to promote a better understanding of the interrelationship between the components or elements of an organisation and its adoption of AMTs.

The following research issues, which have arisen as a result of the research evidence discussed above, and which will form part of the research instrument, will now be discussed.

Indicator	Issues	Sources
E1	The involvement of SSM will improve the AMT adoption process	Researcher's interpretation
E3	Through the use of SSM, a better understanding of the environment and the relevant agents helps improve the justification and strategic planning behind investing in AMT	Researcher's interpretation
E4	Increase in growth rate owing to AMT adoption	Researcher's interpretation
E6	Exposure of the organisation to SSM enables it to realise the full potential of the benefits of AMT adoption.	Researcher's interpretation
E7	Systems thinking enables faster responses to customer preferences and requirements	Flood, R. And M. Jackson (1991).
E9	SSM and other innovative tools can help reduce barriers and resistance that arise during the AMT adoption process.	Researcher's interpretation

Table 2.14: Research instrument questions with respect to SSM applicability.

CHAPTER 3: Research Methodology

This research investigates whether SSM methods will better benefit those South African manufacturing organisations that adopt SSM for adoption of AMT as opposed to those that use traditional methods. The research consisted of a research instrument for quantitative data collection, and through an extensive survey of the literature, an investigative framework was developed. The investigative framework was then used as the guide for the development of the research instrument. The instrument was tested using a pre-test and a pilot study to ensure acceptable validity and reliability levels. (These tests are discussed in section 3.4.) The data obtained from the survey were analysed statistically and the results were then validated by a panel of experts. (The panel discussions are also discussed in this report.)

3.1. Research Design

Yin (2009) defines "research design" as a logical sequence connecting the empirical data to the research question specified by the research. "Research design" for Durrheim (2004) is a strategic action framework that serves as a link between the research question and the execution of the research objectives. The research design consists of a literature review which leads to the development of an investigative framework and a research instrument design. The detailed research design for this research is shown in Figure3.1.

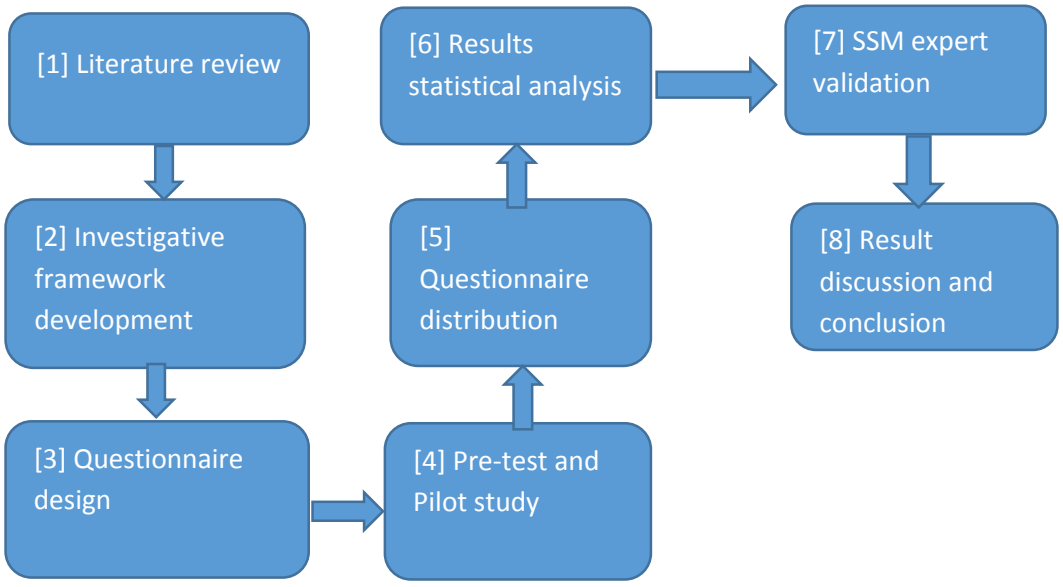


Figure 3.1: Research design graphical representation

3.2. Research instrument and data collection techniques

The research instrument used for this study is based on a Likert point scale deployed via email using REDCap, an online platform used for the development of surveys and electronic data collection. The questionnaire, with a five (5)-point ranking scale is used (where 1= least likely and 5= most likely). (The research instrument can be found in Appendix B.)

To obtain a greater response rate, individuals targeted by the survey were identified in terms of their roles and job description in the organisation. Secondly, initial contact was made via email to solicit participation and consent before the research instrument was then deployed. Thereafter, a bi-weekly reminder was sent via email to all participating individuals or organisations.

Saunders and Lewis (2012) suggests that the following information be included in the communication with the potential respondents of the research: a brief description of the research/questionnaire, the estimated time for the completion of the questionnaire, an undertaking that the confidentiality of the information would be protected, and an expression of gratitude. These recommended aspects were incorporated in the questionnaire's introduction to the survey for this research, as can be seen in APPENDIX B.

3.3. Population, Sampling and Response Rate

Zikmund (2003) defined population as any complete group of individuals, organisations, stores, or similar, that has a specific characteristic in common. The selected population on which this research was focused included individuals who were experienced in using AMTs, namely, individuals acting on behalf of their employer organisations in the selling and buying of AMTs, in the implementation of AMTs, and also in making technology investment decisions. The population of the study was limited to organisations that operate in South Africa. To ensure that the organisations selected for the

research were appropriately chosen, the organisations participating in this study were selected on recommendations from the following recognised authorities:

- The Financial Mail Survey of the Top 100 companies in South Africa, 2015 edition;
- The Top 500 of South Africa's Best-managed Companies (8th edition);

This resulted in a total sampled population size of at least 182 firms. The list of the proposed organisations that fall into this population sample is attached with this proposal (Appendix B).

The purposive sampling technique was the technique used for the selection of the participating organisations. The process of selecting a sample was described by Saunder and Lewis (2012) as a non-probabilistic approach by the researcher to judge the participant's ability to correctly answer the questions related to the research. The benefits of such a technique were identified by Zikmund (2003) as those that include an allowance for a large number of completed surveys that could be obtained quickly and economically. This sampling technique is therefore justified in terms of the access that it offers for a larger sample size and thus a greater response rate.

The variance in response rates to specific sample sizes in operations management research has been observed across the literature. Specifically, in relation to AMT adoption, the following response rates were recorded by these researchers:

- Amoako-Gyampah et al (2001) used 78 firms operating in Ghana and recorded a response rate of 78%.
- Udoka et al (1990) recorded a response rate of 50% from 97 manufacturing organisations in the United States.

In view of these differences in sample sizes and response rates, the sample size of 182 manufacturing organisations selected for this research was considered adequate according to the scope of the research as it allows for generalisability in the South African manufacturing industry context since it cuts across all of the major arms of manufacturing.

3.3.1 Pre-test, pilot study and response rate

A pre-test was conducted to test the validity of the questionnaire. This consisted of a sample of nine participants who were selected for the purpose of testing the instrument. The aim was to determine whether the questionnaire was properly structured so that the respondents could understand and interpret the questions correctly. The participants of the pre-test consisted of academic staff, doctoral students, industrial workers and other specialists involved in the use of AMTs. Comments on the language, clarity and structure of the questionnaire were used to improve upon the research instrument prior to the pilot study.

The pilot study was conducted using six firms and 22 respondents. The firms were selected from the sampled population and the results were tested for reliability. The results showed very low values for reliability (0.338) in one of the constructs of the questionnaire relating to barriers and resistance to AMT adoption. This led to a restructuring of this section and a re-run of the pilot study. The pilot study re-run consisted of 11 respondents, including managers and AMT users, and the reliability of the results thus gained were acceptable for deployment to the general population of the research study.

A total of **568** individuals were invited to participate in the online survey. Although the invitations were directed towards individuals who were thought to meet the criteria for selection, only **109** responses were received. This equates to a response rate of **19%,** which is justified in that an electronic survey was used. Nulty (2008), on studying the adequacy of response rates of online surveys and paper surveys, concluded that as opposed to paper surveys , electronic surveys are usually lower in their response rates,, claiming a 23% difference in average. With this supportive information, the response rate was found to be adequate for the scale of the research.

3.4. Validity and reliability

This section of this research report addresses the validity and reliability of this study. Validity and reliability are used on the basis of the criteria used to measure the quality and trustworthiness of a

research study. The criteria for validity can be divided into two classes: internal validity and external validity. Both are evaluated in this research report.

3.4.1. Reliability

Reliability is the criterion that measures the repeatability, dependability and consistency of a study. The reliability of all of the factors that were established in the investigative framework was also checked and described in this section. Cronbach's alpha coefficient method, which is one of the most commonly used methods in testing for internal consistency (DeVellis, 2011), was used. Cronbach's alpha coefficient method, recommended for the calculation of internal consistency for empirical research in operations management, was developed by Forza (2002). Previous researchers in operations management have presented variations in their selection of acceptable Cronbach alpha values. Some researchers present the following views:

- Gang et al (2008) cites Hull and Nie (1981) when they claim that Cronbach alpha values of 0.70 or higher are considered to be acceptable.
- Nunnally (1994) suggests that a Cronbach alpha value of 0.70 is often considered to be the criterion for internal consistency for the established scale although permissible alpha values can be somewhat lower; thus suggesting the use of a minimum alpha value of 0.60 for newly-developed scales.
- Hinton (2004), while explaining the acceptability of Cronbach's alpha values, presented a guide with segmented scores as set out below:
    - ✓ 0.90 and above shows excellent reliability
    - ✓ 0.70 to 0.90 shows high reliability
    - ✓ 0.50 to 0.70 shows moderate reliability
    - ✓ 0.50 and below shows low reliability.

In view of the data provided above, a Cronbach alpha value of 0.60 was therefore used to operationalise the minimum value in this research study to assume the reliability of the constructs. The Cronbach alpha reliability test for the research is discussed next.

The final questionnaire consisted of 59 items and 109 responses. In an attempt to obtain Cronbach Alpha results, the items were divided into multiple scales based on the constructs of the investigative framework. The scales consisted of a number of items for each scale. Using the guidelines presented by Hinton (2004), the Cronbach alpha values for all the scales were found to be acceptable. The Cronbach alpha coefficient for the entire survey was measured at 0.923, indicating a very high internal consistency for the scales used. The Cronbach alpha coefficient for the scale for SSM applicability recorded the lowest score at 0.686, which shows moderate reliability. Table 3.1 shows the results of the Cronbach alpha reliability test for the questionnaire and the multiple scales for the investigative framework.

Groups	Reliability for retained items
Whole group	0.903
[A] AMT investment and strategic planning	0.724
[A] AMT Adoption process	0.714
[C] Barriers and resistance to AMT adoption	0.844
[D] Benefits realisation	0.782
[E] SSM Applicability	0.686

Table 3.1: Cronbach alpha test for the AMT adoption constructs

3.4.2. Internal and external validity

Validity is defined by McNeil and Chapman (2005) as the level to which data collected for a purpose is a true reflection of what is being studied. Internal validity is the criterion that accesses whether the instrument of the research is measuring accurately what it is designed to measure in order to evaluate the credibility of the study. External validity, on the other hand, measures the extent to which the

findings of the research are applicable to the real world. External validity addresses the transferability and generalisability of the results and conclusions of the study.

As the data collected in this research were collected via questionnaire, as distinct from a direct interview, the data needed to be checked for validity before assumptions of validity could be made. The researcher used the Delphi method to check the internal and external validity of the study (Thangaratinam and Redman, 2005). The Delphi technique involves the use of a panel of experts in a multiple iteration of analysing the research instrument and rating its ability to check what it is meant to check. There are no hard and fast rules in selecting the size of the panel. Therefore, for the scale of this research, a panel consisting of three experts, namely two lecturers and a doctorate researcher, was selected.

3.5. Representativeness of data

The manufacturing organisations sampled for the research were from a wide range of manufacturing industries. They include organisations operating in the chemical, textile, pulp and paper, automotive, metal and steel industries, and Fast Moving Consumer Goods (FMCG), etc. By selecting a broad range of individuals from different manufacturing organisations in different industries, the researcher argued that the recommendations and conclusions drawn from the research would give a more detailed picture of the system construct of the South African manufacturing industry and that the insights gained could be relevant for use by other people or organisations involved in the process of adopting AMTs.

3.6. Data analysis

For the statistical analysis, SPSS for Windows was used for the descriptive statistics, t-tests and correlational analyses. The objective of the research was to find how SSM could be used to improve AMT adoption and to test both hypotheses put forward, linking SSM, AMT strategic planning, barriers and resistance, and benefits realisation in respect of AMT adoption. Testing these hypotheses was done using the respective t-tests, while the correlation analyses were done using Pearson's,

Spearman's and Kendall's correlation tests. Each correlation analysis was tested at a 0.05 level of significance.

The results of the descriptive and correlational analyses were then discussed with the panel of experts to create a base for the SSM analysis conducted in order to compare the applicability with that of traditional method usage for AMT adoption in the manufacturing industry.

3.7. Ethical considerations

As defined in section A.4 of the Senate Standing Orders on Higher Degrees of the University of the Witwatersrand, the research and researcher commits to:

- Ensure that the subjects or informants studied had consented to the research without coercion;
- Communicate the aims and possible implications of the research to all of the subjects or informants;
- Do everything in his power to protect the subjects'/informants' social and psychological welfare and to honour their dignity and privacy.
- Ensure that the relevant people understood the use of tape recorders and cameras.
- Ensure that the questions posed to the subjects/informants were not insulting or embarrassing.
- Ensure that there would be no exploitation of the subjects or informants for personal gain.

3.8. Summary

With this chapter, the researcher outlined the philosophy adopted and the methods used for data collection and analysis. Matters regarding reliability, validity, correlation and representativeness of data were also discussed, alongside the ethical considerations.

A tabular summary of the research methodology is presented in Table 3.1 below.

Research philosophy	Research Direction
Research design	Literature survey, questionnaire design and panel of systems experts
Research question and hypotheses Data analysis	Descriptive, correlational, independent sample t-test and systems analysis
Data reliability	Cronbach's alpha
Data validity	Delphi technique
Data: correlation analysis	Pearson's, Spearman's and Kendall's tests.
Representativeness of data	Over five different industries studied
Ethical Approach	The ethical standards of the University of the Witwatersrand respected

Table 3.2: Tabular representation of the research methodology summary

CHAPTER 4: Results and analysis

The results gathered from the quantitative research, alongside the selected statistical analyses carried out on the data, are presented in this chapter. The statistics describe the general profile of the respondents who participated in the research in terms of their involvement with AMT adoption, and their knowledge of SSM and other factors related to AMT adoption.

This presentation is followed by a graphical representation of the descriptive statistics showing the frequencies of the scores of the entire body of respondents on issues that impact on AMT adoption, with comparisons being made between the respondents from different organisations that are aware of SSM and other system techniques as compared to traditional method users.

Following on this, the reliability assessment was reported for the collective final result and the results for the different sections identified in the investigative framework in Figure 2.9. The correlation analyses conducted on the data gathered were presented in this chapter and were also used to show the links between the respective sections of the investigative framework. The links thus provided were then used to discuss the research question and to test the hypotheses presented in Section 1.5.

4.3 Descriptive statistics of respondents' profiles

4.3.1 Role in AMT adoption

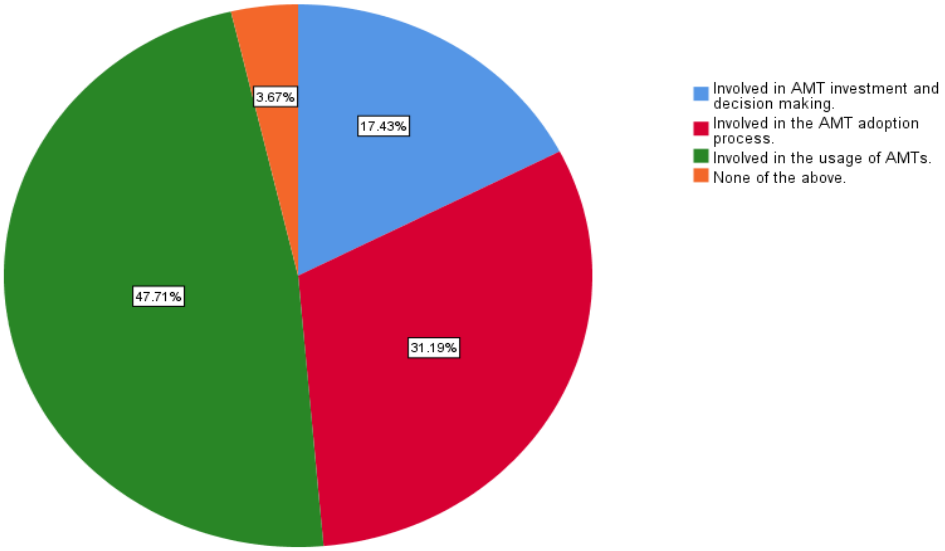


Figure 4.1: Respondents by role in AMT adoption

Figure 4.1 is a proportional display of the respondents of the survey according to their roles in AMT adoption in their respective organisations. A larger proportion of respondents (47.71%) was involved in the adoption of AMTs, while 31.19% were involved in the implementation of AMT adoption and 17.43% participated in the decision-making stage of AMT adoption. A minimal percentage of 3.67% specified that they were not involved in any of the afore-mentioned functions.

4.3.2 Organisational footprint

The manufacturing organisations represented in terms of their organisational footprint are featured in Figure 4.2. This figure represents the different organisational sizes, which were dominated by the national local companies (56.07%), followed by the multinational companies (27.10%); , 13.08% of the respondents, who accounted for joint ventures, mergers or strategic alliances; and 3.74% of the respondents who were classified into the category defined in the questionnaire as "others".

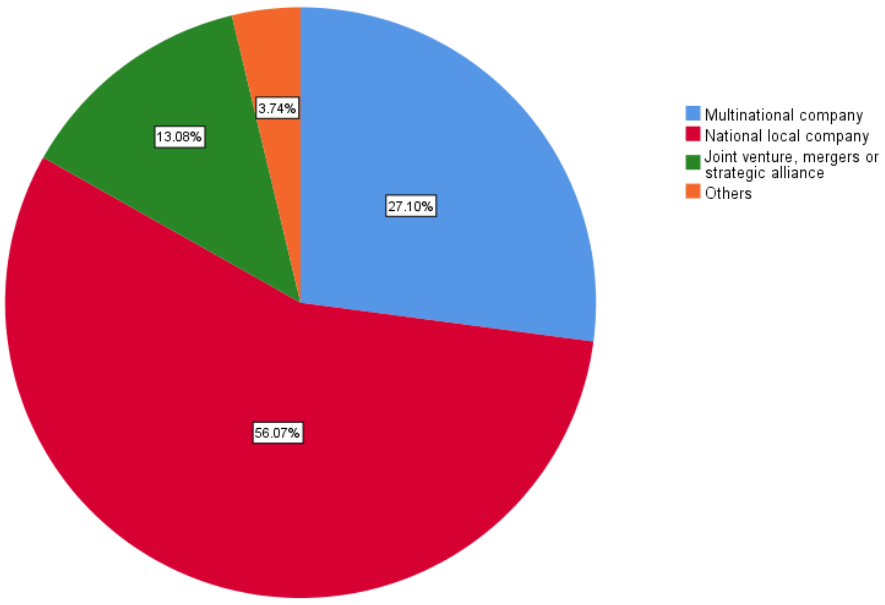


Figure 4.2: Respondents by Organisational classification

4.3.3 Company size

Figure 4.3 shows the respondents by company size with respect to the estimated number of employees in the respective organisations.

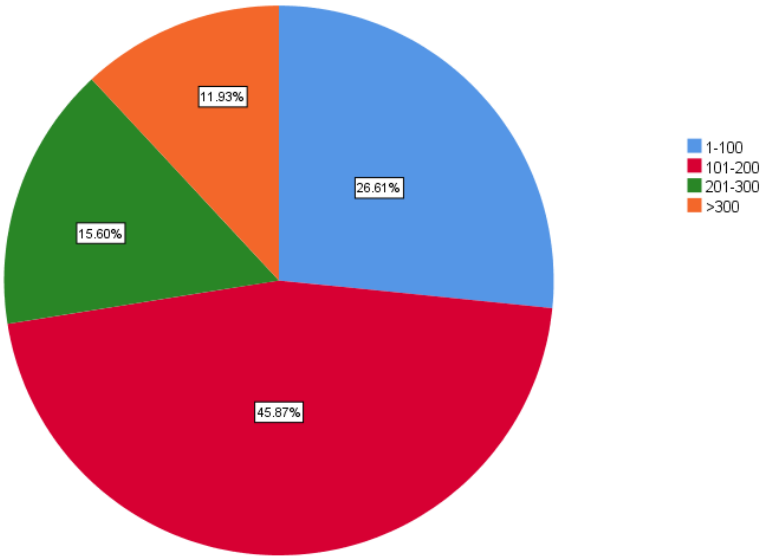


Figure 4.3: Respondents by organisational size.

Organisations with an estimated size of 101 to 200 employees were represented by the bulk of the respondents (45.87%), followed by 1 to 100 employees at 26.61%, and 201 to 300 employees at 15.60%. The least represented in the defined organisational size were those organisations with more than 300 employees, at 11.93%.

4.3.4 Type of manufacturing

The manufacturing system types represented by the respondents to the survey are displayed in Figure 4.4.

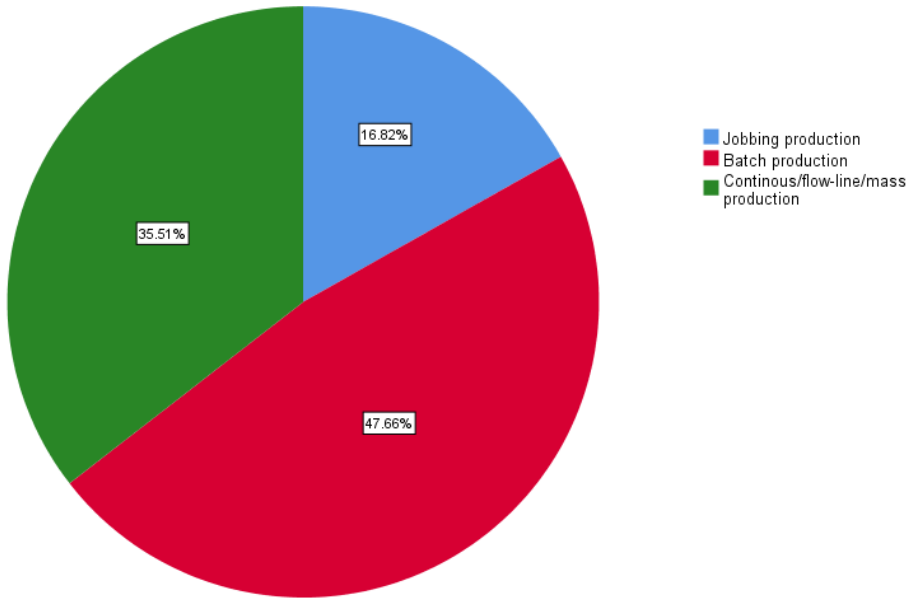


Figure 4.4: Respondents classification by manufacturing systems.

The majority of the respondents were represented in terms of batch production as the method of manufacturing at 47.66%. They were followed by those involved in continuous/mass production and in jobbing production manufacturing systems respectively at 35.51% and 16.82%.

4.3.5 Manufacturing Sector

The manufacturing sectors represented by the respondents of the survey are illustrated in Figure 4.5 below. The fast-moving consumer goods companies dominated at 32.11%; the chemical industry, metal and steel and automotive industries showed a presence of 19.27%, 14.68% and 11.01% respectively, while the textile and pulp and paper industries were the least featured according to the classification of the survey at 7.34% and 2.75% respectively. Some of the respondents that fell into the sectors not defined in the survey accounted for 12.84% of the respondents.

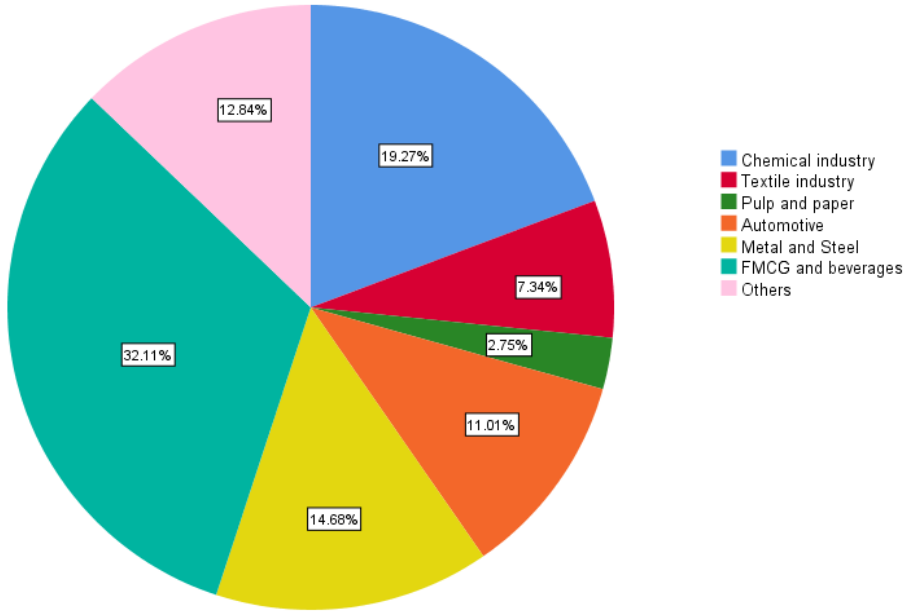


Figure 4.5: Respondents classification by manufacturing sector

4.3.6 AMT adoption experience

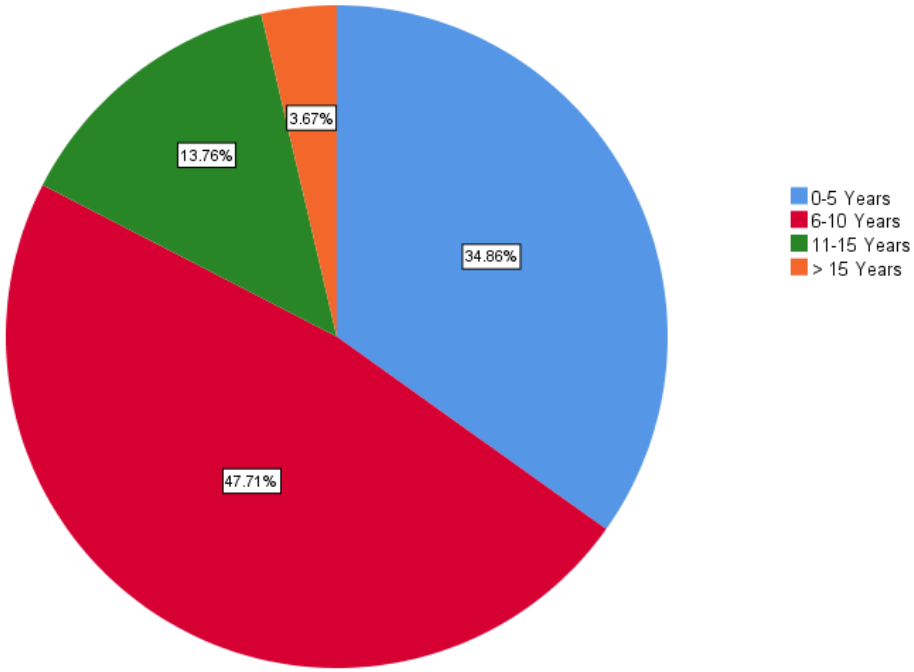


Figure 4.6: Respondents classification by AMT adoption experience

The respondents were also asked to indicate their estimated experience in years of involvement in AMT adoption. It was found that 47.71% had six (6) to 10 years of experience in AMT adoption,

34.86% of the respondents claimed to have less than five years of experience, 13.76% with 11 to 15 years of experience, and 3.67% with over 15 years of experience in AMT adoption.

4.3.7 SSM awareness

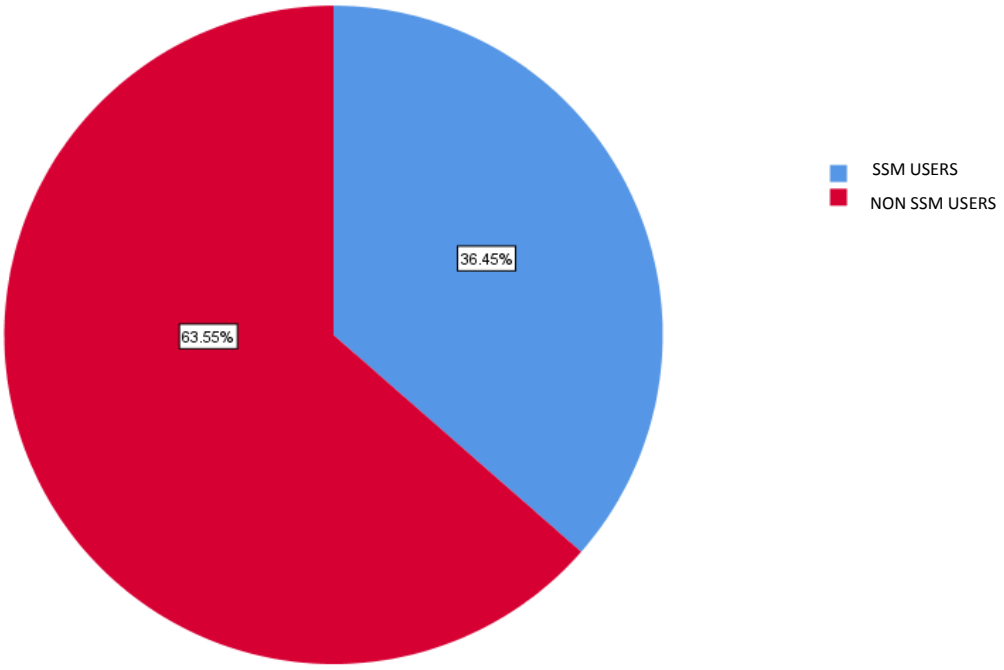


Figure 4.7: Respondents by SSM usage

Figure 4.7 above shows that there is a higher percentage of respondents who are not aware of and who do not use SSM in their organisations, as only 36.45% of the respondents agreed that they were aware of the role of SSMs as opposed to the 63.55% who were not aware of SSM.

The next section considers those respondents who showed that they were aware of SSM-related systems tools.

4.3.8 Usage of other system tools in AMT adoption

The possibility of other systems tools such as systems thinking, systems dynamics modeling, value management/engineering/analysis, etc. was considered for those respondents who responded negatively ("No") to their awareness of SSM. This is illustrated in Figure 4.8 below, which shows the differentials between those aware of SSM, those aware of other systems techniques, and those who are not aware of the systems techniques. Fifty-one percent (51.40%) of the respondents who said

"NO" to their awareness of SSM responded "YES" to the use of other systems tools similar to those of SSM, and the other 48.60% showed that they were not aware of these tools.

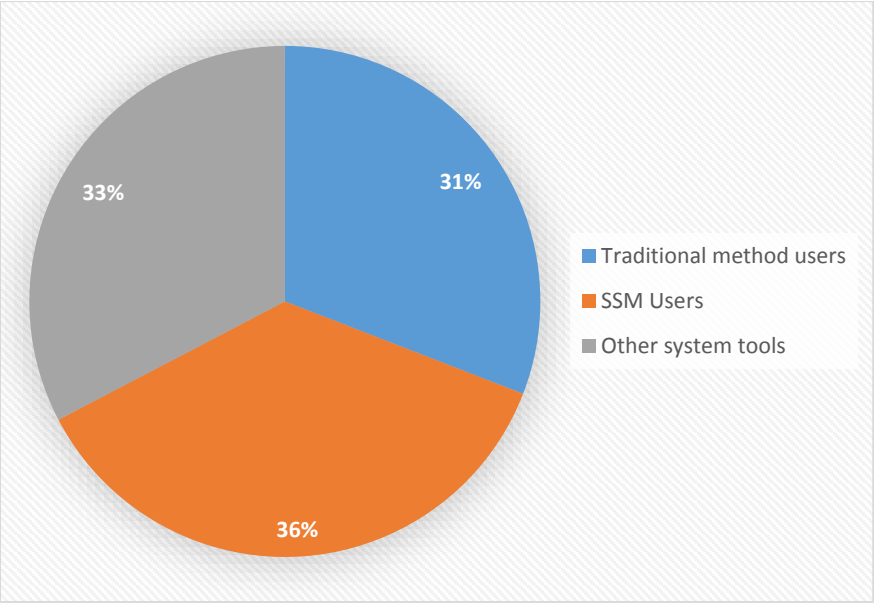


Figure 4.8: Respondents' classification by SSM alternatives awareness.

4.4 Descriptive statistics of AMT adoption factors

The following section presents the descriptive statistics for the factors used in defining the various sections of the investigative framework to drive the research and to impact upon a successful AMT adoption.

The Cronbach's alpha coefficient was measured at 0.923 for the entire survey, indicating a very high internal consistency for the scales used. The Cronbach alpha for the scale for SSM applicability recorded the lowest value, at 0.686, which shows moderate reliability. Table 4.1 shows the results of the Cronbach alpha reliability test for the questionnaire and the multiple scales for the investigative framework.

The lowest Cronbach alpha value of 0.686 was found in the SSM Applicability [E] construct, thus making it an acceptable measure for reliability, as recommended by Hinton (2004), it exceeds the moderate reliability level. Other researchers such as Siriram and Snaddon (2005) have also used values above 0.6.

Constructs	Indicator	Cronbach's alpha	Cronbach's alpha standardised items	Mean	Standard deviation	Cronbach alpha if item deleted
Over 54 items in the instrument		0.903	0.921			
Constructs:	Indicator	Corrected item: total correlation	Cronbach's alpha	Mean	Standard deviation	Cronbach alpha if item deleted
[A] AMT Investment and Strategic Planning		0.724	0.671			
Planning for AMT investment	A1	-0.078		1.05	0.214	0.751
AMT evaluation	A2	0.019		1.07	0.251	0.746
AMT justification	A3	0.474		4.00	0.340	0.695
Compatibility with existing infrastructure	A4	0.564		4.07	0.576	0.663
Alignment with MS	A5	0.652		4.11	0.698	0.635
Involvement of employees during decision making	A6	0.543		4.17	0.700	0.667
Strategic plans for barriers and resistance	A7	0.511		4.25	0.585	0.675
Investment in training	A8	0.428		4.18	0.568	0.694
[B] AMT Adoption Process		0.768	0.769			
AMT champion supervision	B1	0.605		4.23	0.721	0.701
Tasks allocation	B2	0.603		4.17	0.693	0.702
Teamwork	B3	0.578		4.24	0.580	0.715
Best AMT management practice development	B4	0.480		3.99	0.575	0.745
Good communication channels	B5	0.442		4.12	0.669	0.759
[C] Barriers and Resistance to Change		0.844	0.847			
High cost of equipment	C1	0.691		4.19	0.729	0.812
High cost of integration	C2	0.692		4.20	0.706	0.812
Skills shortage	C3	0.683		4.21	0.610	0.815
Workers' resistance	C4	0.473		4.07	0.743	0.839
Lack of technological support	C5	0.598		4.11	0.691	0.823

Management resistance	C6	0.248		4.23	0.667	0.860
Inability to evaluate new AMTs	C7	0.652		4.21	0.640	0.818
Software cost and maintenance	C8	0.702		4.28	0.510	0.817
Cyber-security	C9	0.361		4.26	0.555	0.846
[D] Benefits Realisation		0.782	0.757			
Organisational competitiveness	D1	0.390		4.00	0.343	0.774
Business growth	D2	0.532		3.97	0.692	0.755
Enhanced company image	D3	0.580		4.21	0.636	0.750
Lead time reduction	D4	0.604		4.14	0.728	0.745
Increased productivity and volume	D5	0.427		4.26	0.542	0.767
Positive ROI	D6	0.428		4.15	0.663	0.767
Increased product quality	D7	0.473		4.32	0.660	0.761
Better working conditions	D8	0.328		4.09	0.702	0.778
Manufacturing flexibility	D9	0.371		4.19	0.525	0.772
Reduction in labour costs	D10	0.380		4.13	0.518	0.771
Identification of new opportunities	D11	0.151		1.04	0.194	0.795
Overall satisfaction	D12	0.503		4.07	0.899	0.761
[E] SSM Applicability		0.686	0.738			
AMT adoption improvement through SSM application	E1	0.477		4.22	0.633	0.639
Use of traditional method	E2	0.179		3.58	1.234	0.748
Understanding the systems environment	E3	0.426		4.21	0.511	0.654
Organisational growth as a result of SSM	E4	0.533		4.20	0.608	0.630
Improvement of AMT investment and strategic planning	E5	0.466		4.19	0.732	0.637
SSM application and potential benefits	E6	0.154		4.24	0.670	0.698
Systems thinking and customer satisfaction	E7	0.625		4.19	0.619	0.612

Continuous growth requirement by the industry	**E8**	**0.487**		**4.27**	**0.625**	**0.637**
Role of SSM in barrier reduction	**E9**	**0.244**		**4.25**	**0.582**	**0.680**

Table 4.1: Reliability test for the research instrument.

4.5 Correlational analysis

The research objective was to link SSM to the investigative framework for the adoption of AMT. Figure 4.9 presents the links in the investigative framework, consisting of the following:

- [A] AMT Investment and Strategic Planning,
- [B] AMT Adoption Process,
- [C] Barriers and Resistance to AMT Adoption, and
- [D] Benefits Realisation.

On account of the scale of this research, the respondents, and the number of links explored, the correlational analysis was conducted using Pearson's and Spearman's tests for correlation.

The statistical correlations are represented by **r α, β,** where **r** represents the correlations for the associations or links between the relevant constructs in this survey, namely:

- **rα** represents the correlations between the links for SSM users, and
- r**β** represents the correlations between the links for the traditional method .

The results for the correlational analysis are discussed in this section, while the links in the investigative framework are illustrated in Figure 4.9. The pie chart in Figure 4.8 shows that the population of respondents that agreed to using SSM for AMT adoption amounted to 36.45%, while those that were aware of the SSM-related system tools amounted to 32.66%, and those not aware of SSM and the other related systems tools amounted to 30.89%.

The sample was broken up into two groups for analysis:

i. Those who used SSM for AMT adoption
ii. Those who used traditional methods for AMT adoption.

This was done in order to compare the links between the adoption constructs for AMT between the two groups.

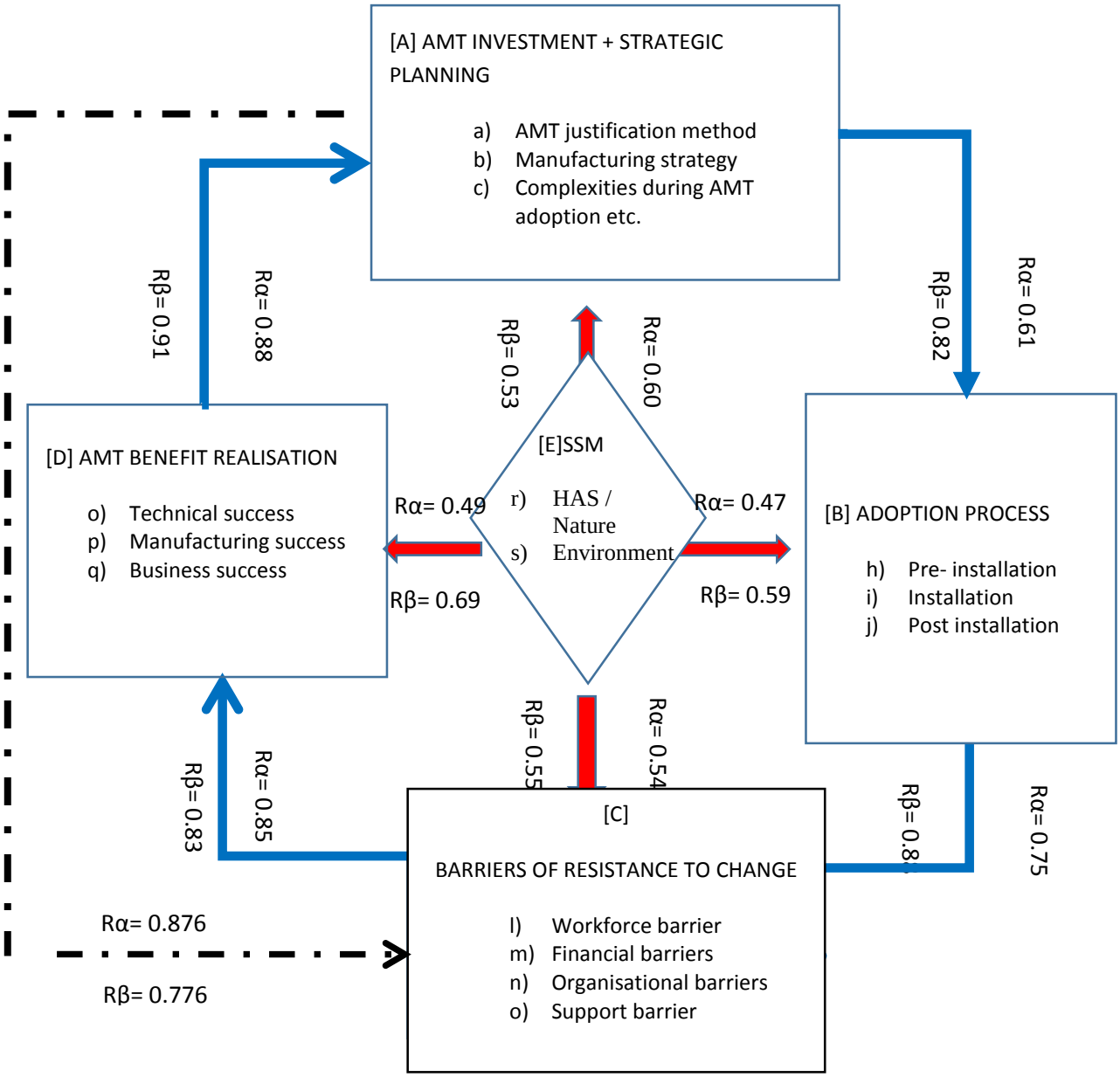


Figure 4.9: Links between the constructs of the investigative framework. All links are significant at a 0.01 level of significance.

AMT Investment and Strategic Planning [A] and the AMT Adoption Process [B] were found to be significantly linked. Using the Pearson's correlation test, this association was found to have a significant correlation for **r α** at **0.61**, while **r β** was at **0.82,** at a 0.01 level of significance. This link is

also supported by an inter-variable correlation within the AMT Investment and Strategic Planning [A], and the AMT Adoption Process [B] constructs. These correlations indicate a stronger significant correlation for traditional method users for the adoption of AMTs as opposed to the correlation for SSM users.

4.5.2 AMT Adoption Process [B] and Barriers and Resistance to AMT Adoption [C]

The links between the AMT [B] Adoption Process and [C] Barriers and Resistance to AMT Adoption were computed using Pearson's correlation test. Significant links were found between the two constructs: **rα** was significantly correlated at **0.75**, while the correlation for **rβ** was at **0.88** at a 0.01 level of significance. The results indicate a stronger correlation for the use of the traditional method for AMT adoption as opposed to that for the SSM users.

4.5.3 Barriers and Resistance to AMT[C] and Benefits Realisation [D]

The links between [C] Barriers and Resistance to Change in respect of AMT and [D] Benefits Realisation were analyzed using Pearson's correlation test, and a positive correlation was found between the two constructs: **rα** was at **0.85**, while **rβ** was at **0.83** at a 0.01 level of significance.

These correlation results indicate a stronger correlation between Benefits Realisation [D] and Barriers and Resistance to AMT [C] for SSM users as opposed to that for the users of the traditional method for the adoption of AMTs.

4.5.4 AMT Investment and Strategic Planning [A] and Benefits Realisation [D]

The links between AMT Investment and Strategic Planning [A] and Benefits Realisation [D] were analyzed using Pearson's correlation test, and a significant correlation was observed between the two constructs since there was an **rα** of **0.88** value for SSM users and an **rβ** of 0.91 for traditional method users at a 0.01 level of significance. These results indicate a stronger correlation for traditional method users as opposed to that for SSM users in respect of AMT adoption.

The links between these four show that the users of the traditional method have a stronger links with the different constructs of the investigative framework. A graphical representation of these links is displayed by means of the blue coded links in Figure 4.9.

4.5.5 Links between SSM applicability and the investigative framework:

In this section, the relationship between SSM and the other constructs of the investigative framework [Fig 1.2] are discussed.

Table 4.2 shows a summary of the significant links between SSM applicability and the investigative framework for both SSM and traditional method users. The correlation analysis was carried out using Pearson's correlation test at a 0.01 level of significance. The results of the analysis showed that the SSM users had a higher level of correlation in respect of AMT Investment and Strategic Planning [A] only, as opposed the traditional method users who presented with higher significant correlation levels in respect of the other three constructs in the investigative framework.

In summary, Table 4.2 shows the comparison between the links between the SSM users and the traditional method users. The test shows a stronger link for SSM users at **$r\alpha=0.60$** as opposed to **$r\beta=0.53$** for the traditional method users between [E] SSM Applicability and [A] AMT Investment and Strategic Planning. This represents one link out of the four links l of the investigative framework that displays a higher level of correlation to [E] SSM Applicability. A graphical representation of the links between [E] SSM Applicability and the four constructs of the investigative framework is shown by means of the red coded links in Figure 4.9.

Constructs	[E] SSM applicability			
	SSM users (rα)	Traditional methods users (rβ)	Stronger Correlations	
			SSM Users	Traditional method users
[A] AMT Investment and Strategic Planning	**0.60** **Sig= 0.01**	**0.53** **Sig= 0.01**	✓	
[B] AMT Adoption Process	**0.47** **Sig= 0.01**	**0.59** **Sig= 0.01**		✓
[C] Barriers and Resistance to Change	**0.54** **Sig= 0.01**	**0.55** **Sig= 0.01**		✓
[D] Benefits Realisation	**0.49** **Sig= 0.01**	**0.69** **Sig= 0.01**		✓
			1	**3**

Table 4.2: Correlation matrix for SSM applicability and the other constructs of the investigative process

4.6 Results related to the research question and the hypotheses

This section expands on the descriptive statistics and correlation analyses conducted on the data from the survey data and also on the outputs of the discussion with the SSM panel to address the research question and test the hypotheses.

4.6.1 Research question:

The research question: "**How *can Soft Systems Methodology (SSM) be used to improve AMT Adoption in South African Manufacturing Organisations*?"**

The aim of this research was to assess the role that SSM plays in the adoption of AMTs in South African manufacturing organisations, based on the participation of respondents from the qualifying companies listed in Appendix B. This research question was answered by judging the nature of the links in the investigative framework and through what emerged from the panel discussion, all the detail being summarised in Table 4.3.

The results from the survey display a significant correlation between SSM users and AMT adoption even though stronger correlations were observed between the links for traditional method users and the adoption of AMTs than in the SSM users. These results are presented in Table 4.3, alongside the views of these links by the panel of experts. These links show that the correlations of the SSM users constituted 25% of the total of the stronger correlations for the investigative framework links, while those for the traditional method users constituted 75% of the stronger correlations.

Links	**Correlations**		**Higher Correlation**		**Expert Panel views**
	SSM users, Rα	Traditional method users, Rβ	**Rα**	**Rβ**	
[A]AMT Investment & Strategic Planning and [B] AMT Adoption process.	Rα= 0.61 0.01	Rβ= 0.82 0.01		✓	The panel of experts felt that the reason for a weaker correlation for SSM users as compared to that for the traditional method users was because of a lack of inclusion in terms of the general population and the decision-making process. They also felt that the results would have been better, in fact, more in favour of the SSM if the top management had aligned their objectives with the workforce to come to a working consensus.
[B] AMT Adoption Process and [C] Barriers and Resistance to AMT Adoption.	Rα= 0.75 0.01	Rβ= 0.88 0.01		✓	The panel of experts, while discussing the links between the AMT adoption process and the barriers and resistance to change in respect of AMT, felt that there was no knowledge of the role of SSMs in reducing barriers during the adoption stage. They felt that the available resources and knowledge were pointing to the fact that the SSM was being used for the planning and designing of projects and not being used during the

					implementation and execution of the project.
[C] Barriers and Resistance to AMT Adoption and [D] Benefits Realisation	Rα= 0.85 0.01	Rβ= 0.83 0.01	✓		The panel of experts agreed with the stronger correlation for SSM users with regard to the link between AMT Benefits Realisation and the Barriers and Resistance to AMT Adoption, mainly because, when done properly, the use of SSM could identify cogent barriers and resistance, while planning for the intended benefits during the planning stage.
[A] AMT Investment and Strategic Planning and [D] Benefits Realisation	Rα= 0.88 0.01	Rβ= 0.91 0.01		✓	The panel of experts presented their views on the association between MT Investment and Strategic Planning and benefits Realisation by disagreeing with the notion of a stronger correlation between these variables in respect of the users of traditional methods. They suggested that a holistic approach to SSM would enable the managers and decision makers to identify benefits that would be in line with the organisational goals and vision.
[E] SSM applicability and [A] AMT Investment and Strategic Planning	Rα= 0.60 0.01	Rβ= 0.53 0.01	✓		The panel of experts agreed with the claim that the SSM users have a stronger correlation between SSM Applicability and AMT Investment and Strategic Planning respectively because they believe SSM can provide a solution to the dichotomy in the labourforce which has been an issue affecting organisations when they bring both higher management and employees together for a joint session that aims to further grow the organisation.
[E] SSM Applicability and [B] AMT Adoption process	Rα= 0.47 0.01	Rβ= 0.59 0.01		✓	The panel of experts felt that the predominance of a stronger correlation by traditional users in respect of AMT adoption could be attributed to a lack of knowledge and of experience concerning the positive properties of the SSM. They

					expressed their views by claiming that the majority of employees do not get to experience SSM in action as has been the case with upper management using external consultants. In that way, the employees are aware of SSM, but rarely experience its applications and positive properties
[E] SSM Applicability and [C] Barriers and Resistance to AMT adoption	Rα= 0.54 0.01	Rβ= 0.55 0.01		✓	The opportunity to use systems tools such as PEST, SWOT, numerical evaluations, cause-and-effect analyses, etc. convinced the panel of experts that SSM users are better prepared to deal with possible issues that might arise during AMT adoption. The panel also shared their views in saying that the study population might be biased as the majority might not have experienced the positive aspects of SSM; otherwise, they were yet to see the results of SSM in AMT adoption being recorded in the literature.
[E] SSM applicability and [D] Benefits Realization.	Rα= 0.49 0.01	Rβ= 0.69 0.01		✓	In terms of the role of SSM in the Benefits Realisation of AMT adoption, the panel shared the view that while systemic planning is used for the identification of the said benefits, the SSM also presents an opportunity for the systemic implementation of tasks. The ability to combine both planning and implementation could help in the achievement of greater success in AMT adoption.

Table 4.3: Links between the investigative framework and the views of the panel of experts

Based on these results, SSM usage does not show a significant impact on the adoption of AMTs in the South African manufacturing industry. However, what emanated from the panel discussion suggests that SSM would provide significant advantages to the realisation of business success by manufacturing organisations even though there are limitations that surround the research, as further discussed in Chapter 5,

4.6.2 Hypothesis test

The hypotheses for this research were tested using independent sample t-tests at α=0.05 level of significance. The dataset was grouped on the basis of SSM usage and an analysis of the benefits was realised. The degrees of freedom (df) for the analysis were calculated as follows:

$Df = (n_1 - 1) + (n_2 - 1)$

N_1 = number of respondents using traditional methods for AMT adoption.

N_2 = Number of respondents using SSM for AMT adoption.

Using the formula, the degrees of freedom (df) = 107. The critical value (CV) for α= 0.05 on a two-tailed test with 107 degrees of freedom wascalculated at 1.98. Using these values, the results from the independent samples T-tests are discussed next.

HYPOTHESIS 1: ***Organisations that adopt [E] SSM will have a stronger correlation to success in [D] AMT Benefit Realisation than firms using traditional methods.***

NULL HYPOTHESIS 1: ***Organisations that do not adopt SSM [E] will not have a stronger correlation to success in [D] AMT Benefit Realisation than firms adopting SSM.***

This hypothesis was set out to assess whether organisations that use SSM in their adoption of AMTs achieve a higher level of success in AMT adoption than organisations that use traditional methods. This test was done by grouping the respondents into two categories: SSM users and traditional method users. Using this grouping, the hypothesis was tested using a two-tailed independent sample t-test at α=0.05 level of significance. The dataset was grouped in terms of SSM usage and an analysis of the benefits realised was used in testing the hypothesis.

Table 4.4 summarises the results of the independent sample t-test for the [D] Benefits Realisation construct. Notable differences in terms of [D] Benefits Realisation between both the SSM user group

and the traditional method user group were found. More specifically, stronger correlations were found in the three subscales. These subscales include (a) enhanced company image, (b) identification of new business opportunities, and lastly (c) overall satisfaction.

The t-values for the three subfactors were found to exceed 1.98 as they were recorded as 2.634, 2.05 and 4.36 respectively, while the P-values for the identification of new business opportunities and overall satisfaction were found to be equal to or less than 0.05. This indicates a significant statistical difference between SSM users and traditional method users.

[D] Benefits Realisation		Mean difference	t	Sig. (two-tailed)	95%confidence interval of the difference	95%confidence interval of the difference	Expert panel acceptance	
					lower	upper	Yes	No
Manufacturing success	Reduced lead time	0.20	1.38	0.17	-0.86	0.48		✓
	Increased productivity/volume throughput	0.01	0.06	0.95	-0.21	0.22		✓
	Increased product quality	-0.07	0.53	0.60	-0.34	0.20	✓	
	Increased in manufacturing flexibility	0.15	1.45	0.15	-0.06	0.35		✓
	Reduced labour costs	0.05	0.46	0.65	-0.16	0.25	✓	
Business success	Increased business growth	0.21	1.819	0.72	-0.019	0.44	✓	
	Positive ROI	-0.1	0.76	0.45	-0.36	0.16	✓	
	Better working conditions	-0.04	0.33	0.74	-0.29	0.21	✓	
	Identification of new business opportunities	-0.06	2.05	0.05	-0.12	-0.001	✓	
	Overall satisfaction	0.62	4.36	0.0001	0.34	0.91	✓	
	Organisational competitiveness	0.83	1.21	0.23	-0.05	0.22	✓	
	Enhanced company image	0.32	2.634	0.10	0.08	0.56	✓	
						Total=	**9**	**3**

Table 4.4: Results of the independent sample t-test for Hypothesis 1

Table 4.4: Results of the independent sample t-test for Hypothesis 1

Once these results, together with the mean differences (Table 4.4) and the outputs of the panel discussions, had been assessed, the panel was asked to either accept or reject the results of the t-test. This exercise resulted in the panel accepting that the use of SSM would benefit manufacturing organisations in terms of nine (9) of the 12 attributes used for measuring [D] Benefits Realisation. These results, together with the panel's acceptance of them, suggest that SSM can only improve the process of AMT adoption in ways that the traditional methods cannot. Furthermore, by realising the stronger correlations for SSM users in the benefit realisation construct, the panel of experts was able to build on the identification of new business opportunities for the growth of the company. As such, the panel members were able to recommend the acceptance of Hypothesis 1. The implications arising from this evidence are to the effect that organisations that use SSM in AMT adoption will exhibit greater success in adopting AMTs in the context of the South African manufacturing sector.

HYPOTHESIS 2: ***Organisations that associate [A] AMT Investment and Strategic Planning to [C] Barriers of Resistance to Change will have a stronger correlation with success in AMT adoption.***

NULL HYPOTHESIS 2: ***Organisations that do not associate [A] AMT Investment and Strategic Planning to [C] Barriers of Resistance to Change will not have a stronger correlation with success in AMT adoption.***

Hypothesis 2 tests whether the success of AMT adoption is dependent on the organisation's link of [A] AMT Investment and Strategic Planning to [C] Barriers and Resistance to Change. The results from the respondents with regards to this question indicated that all of the respondents agreed to their organisation linking AMT Investment and Strategic Planning to Barriers and Resistance to Change. An independent sample t-test could not be performed to test the hypothesis because the respondents all fell into the same group.

Although there is strong evidence that [A] AMT Investment and Strategic Planning and [C] Barriers and Resistance to AMT adoption are linked at Rα= 0.876 and Rβ= 0.776, these links are supported by inter-item correlations between both constructs. Table 4.5 displays the correlation matrix for [A] AMT Investment and Strategic Planning and [C] Barriers and Resistance to AMT Adoption constructs. Correlation coefficients above 0.6 indicate a strong correlation between the manufacturing organisations' linkage of AMT Strategic Planning towards the reduction of Barriers and Resistance to AMT adoption (A7) and three element of the barriers and resistance to AMT adoption construct, namely: the high cost of equipment (C1), the skills shortage (C3) and software costs and maintenance (C8). These correlations further support the hypothesis.

The panel of experts also agreed to accept Hypothesis 2, although, owing to the absence of comparative data, the researcher could neither accept nor reject the hypothesis because there was no statistical evidence to prove the null hypothesis, which states that organisations that do not link [A] AMT Investment and Strategic Planning to [C] Barriers and Resistance to AMT Adoption will not realise the intended benefits of AMT adoption in South Africa. This occurrence led to the realization of a limitation in the research sampling which is discussed in Chapter 5.

	C1	C2	C3	C4	C5	C6	C7	C8	C9
A1	-0.179	-0.125	-0.221*	0.040	0.028	-0.145	-0.071	-0.209*	0.136
A2	0.036	-0.074	-0.090	0.079	0.067	0.021	-0.145	0.003	0.080
A3	0.154	0.318**	0.184	0.302**	0.325**	0.000	0.263**	0.220*	0.101
A4	0.310**	0.318**	0.367**	0.590**	0.579**	0.031	0.272**	0.357**	0.064
A5	0.333**	0.534**	0.347**	0.885**	1.000**	0.024	0.480**	0.365**	0.144
A6	0.441**	0.972**	0.430**	0.436**	0.551**	0.098	0.962**	0.399**	0.350**
A7	0.829**	0.481**	0.923**	0.315**	0.402**	0.339**	0.423**	0.947**	0.240**
A8	0.355**	0.338**	0.414**	0.310**	0.312**	0.265**	0.264**	0.416**	0.182*

Table 4.5: Inter-item correlations for [A] AMT Investment and Strategic Planning and [C] Barriers and Resistance to Change. **= Significance at 0.05 level, *= Significance at 0.01 level

The results reported in this chapter are discussed in more detail in the next chapter. The limitations that this research faced are also dealt with.

CHAPTER 5: Discussion, limitations and recommendations

Following the aims and objectives of this research, the findings on the link between SSM and AMT adoption in selected South African manufacturing organisations are discussed in this section. They are based on the results from the statistical analyses recorded in Chapter Four and the views of the expert panel.

5.1 Discussion of findings

The study investigated the relationship between SSM and AMT adoption in the South African manufacturing industry. The findings showed links between [A] AMT Investment and Strategic Planning, [B] the AMT Adoption Process, [C] Barriers and Resistance to Change, and [D] Benefits Realisation in terms of the application of SSM to AMT adoption. As seen in Figure 4.9, all links were supported for both SSM usage and traditional method usage.

The results of the descriptive analysis showed that 31% of the sampled population are not aware of SSM or other systems tools which means that only 69% of the respondents are familiar with SSM. However, only 32% of the population actively uses SSM in the adoption of AMTs. This result indicates a lack of general awareness in the manufacturing industries in South Africa of the applications of SSM in AMT adoption.

The findings suggest that the use of SSM does not show a strong statistical significance for the majority of the links presented in the investigative frame work. However, the correlations for the links in the case of the traditional method users proved to be stronger in six out of eight cases. Furthermore, these links showed a strong significant correlation within the constructs of the investigative framework, which is the basis of this research.

The research objective was to investigate the applicability of SSM in the adoption of AMTs by organisations, and even though there were stronger correlations for most of the links between the constructs in the case of the traditional method users, correlational values such as $R\alpha=0.61$ between [A] AMT Investment and Strategic Planning and [B] AMT Adoption Process; $R\alpha=0.75$ between [B] AMT

Adoption Process and [C] Barriers and Resistance to Change; Rα=0.88 between [A] AMT Investment and Strategic Planning and [D] Benefits Realization were found. These correlations indicate that there are significant links between SSM and AMT adoption.

The correlational findings between [A] AMT Investment and Strategic Planning and [B] AMT Adoption Process showed a strong correlation for both SSM users(Rα=0.61) and traditional method users (Rβ= 0.82), suggesting that the level of acceptance in the organisations of the traditional method is high and that these methods are comprehensible to the participants. The lack of knowledge of the benefits of SSM could be a factor in affecting the findings pertaining to the traditional method users which is a function of the limitations discussed in section 5.2.

The application level of SSM, as presented by Hanafizadeh et.al (2017), which suggests the possibility of using SSM as a hybrid method of enquiry, could be applicable in this scenario. This suggests that SSM be used alongside the traditional methods to further gain the acceptance of the traditional method users and concomitantly provide a systemic and holistic approach to AMT adoption without withdrawing the techniques that are trusted by the traditional method users. The suggestion of the panel of experts to slowly integrate SSM into the manufacturing organisation in question in order to obviate the generation of barriers in those participants who strongly believe in the use of traditional methods is also in line with Hanafizadeh et.al (2017)'s observations.

The link between [B] AMT Adoption Process and [C] Barriers and Resistance to Adoption showed a lower correlation for SSM users (Rα=0.75) as compared to the corresponding link for the traditional method users (Rβ= 0.88). This is indicative of the fact that the respondents are more inclined towards using traditional methods in practice as opposed to SSM. This is in line with the structural nature of the implementation of tasks allocated during the strategic planning stage. It is assumed that respondents would generally believe that the AMT adoption process is all about following instructions and executing orders. The significant correlation for SSM usage (Rα=0.75) in this link, although weaker than that for the traditional method, is supported by Doloi (2011), Sankaran et.al (2009) and Crawford

et al. (2003). As discussed in section 2.5, these researchers observed improvements in the project management stages when SSM is applied to the three stages of AMT adoption.

The stronger correlation for SSM users that exists between [C] Barriers and Resistance to AMT Adoption and [D] Benefits Realisation is in line with the observations made by Maqsood etal. (2001), which pointed out the advantages of using SSM in the identification of threats that undermine the strengths and opportunities in an organisation. The findings show a stronger correlation for SSM users ($R\alpha=0.85$) in the link between [C] Barriers and Resistance to Change and [D] Benefits Realisation, as opposed to the corresponding link for these constructs for the traditional method users ($R\beta= 0.83$).

The panel agreed with this view and suggested that SSM has the potential to identify possible barriers that may not be accounted for in the traditional methods. These barriers could be a key to the realisation by the manufacturing organisations of major business benefits. The panel also suggested that the participatory attribute of SSM in involving the stakeholders could assist in the mitigation of workforce barriers that might arise on account of exclusion. This finding is consistent with the findings of Van Rooyen et al. (2016), where SSM was observed as a tool for identifying underlying issues in the South African transportation industry, and with those of Maje (2014) which found that SSM is useful in the management of risk in supply chain management in South Africa.

On account of the weaker correlation shown in the case of respondents that used SSM for AMT adoption, the correlation analysis could not support a strong statistical argument that SSM is a more efficient application better suited to AMT adoption. Although SSM has been observed to present significant advantages across organisational processes, such as AMT adoption (Maje, 2014; Van Rooyen et al., 2016; Proches & Bodhanya, 2015; Doloi, 2011; Behera et al., 2015), the findings made on the basis of the data from the sampled population in this research were unable to justify the role of SSM in manufacturing organisations.

Although the views of the panel of experts suggest that SSM would benefit manufacturing organisations during their process of adopting AMTs, the correlational analyses and t-test did not fully provide statistical proof that SSM is applicable in all aspects of AMT adoption. The outcome of the decision to accept Hypothesis 1 and the assumption that organisations that use SSM would have a stronger correlation to AMT adoption and, therefore, greater success, than firms using traditional methods was based on the combination of the panel of expert views and the evidences in business success advantages. The results pertaining to the Hypothesis 1 test are discussed next.

Hypothesis 1: Independent sample t-tests were used to test the assumptions made in Hypothesis 1 (presented in section 1.5.1). The respondents were divided into two sample groups based on their usage of SSM in AMT adoption. The benefits realisation constructs was tested against this grouping to test whether the use of SSM affects the success of AMT adoption. Success in this case was judged using the [D] Benefits Realisation construct.

It appears that the application of SSM in the adoption of AMTs in manufacturing organisations is a positive innovation since it showed significant impacts in this research in the realisation of benefits. Judging from the results, and considering that, the manufacturing organisations are generally satisfied with the performance of the adopted AMTs in terms of the benefits that they experience, this can in fact be explained using the Estathiades et al. (2001) findings which claimed that over 92.3% of manufacturing organisations that adopted AMTs realised Technical success.

The three factors which allowed for this hypothesis to be accepted ($t > 1.98$, $P < 0.05$) include the following: (a) enhanced company image, (b) identification of new business opportunities and (c) overall satisfaction. . As such, SSM usage would be expected to lead to an enhanced company image, the identification of new opportunities and the overall satisfaction of the stakeholders. This is important to note because research evidence has reported that most manufacturing organisations adopting AMTs have a higher chance of realising technical success but not so much of realising manufacturing success and business success (Efstathiades et al. (2001); Banakar et.al (2010)). This

presents the possibility that SSM can help overcome this challenge. The holistic approach associated with SSM allows for the attainment of benefits that traditional methods have not been able to effectively achieve.

Hypothesis 2: The link between [C] Barriers and Resistance to Change and [A] AMT Strategic Planning which was tested in Hypothesis 2 (presented in section 1.5.3) and the null hypothesis were not rejected on account of the paucity of enough statistical evidence. The respondents all agreed to link [A] AMT Investment and Strategic Planning to [C] Barriers and Resistance to Change. As such, there was no control group to test the null hypothesis. However, the panel accepted Hypotheses 2, as well as the results from the inter-item correlation matrix between the two constructs (Table 4.4), which shows a significant correlation, greater than 0.6 at significance level of 0.05, for some of the elements of the constructs.

The panel's views on Hypothesis 2 are in line with the findings of Efstathiades et al. (2001), who developed a model that incorporates a series of strategic planning procedures and implementation parameters towards a successful adoption of AMT. Findings from Cook (1994) emphasise the importance of strategic planning in manufacturing as a cognisant requirement for success in AMT adoption.

Even though SSM has been around since its introduction by Checkland in the 70s, it has not been featured in the literature for AMT adoption in manufacturing organisations. However, there have been similar applications in other fields of research which have shown that the application of SSM in industrial processes, for instance, can produce benefits that would otherwise not have been realised. Research evidence such as that released by Proches and Bodhanya (2015), explored the application of SSM in the operations of the sugar industry of South Africa. The objective of these researchers was to develop improvement action plans using SSM tools and they were actually able to account for complexities that would not have been observed through the traditional hard approach. SSM has also been used by researchers such as Doloi (2011); Behera et al. (2015) and Walker and Steinfort (2013)

in project and performance management, and it has been recorded that SSM has been effective in these fields.

The findings from the analyses of results and the views of the panel of experts have shown that SSM presents a considerable advantage in certain aspects of AMT adoption in relation to the barriers of resistance to change, and to investment and strategic planning in achieving business success. Despite the limitations that have riddled this research, it has been found to provide adequate proof that SSM provides considerable benefits and opportunities for further research into AMT adoption.

5.2 Research limitations

The limitations faced by this research are discussed in this section. However, It is worthy of note that these limitations are not limited to the points made in this section.

Because of these limitations, the generalisations made in terms of the findings of this research have been compromised. The study was limited to the location of the manufacturing organisations (South Africa). Therefore, the findings could be a limiting factor for making generalisations concerning AMTs in manufacturing organisations in other countries. Furthermore, the study does not address specific groups of people in terms of, amongst others, race, and economic and educational background, which could significantly affect the findings of the research.

The research method was found to be appropriate for the scope of this research, however, as the sampled population of the study reflected that some of the respondents are not familiar with SSM and this might have affected their perception of SSM and its application since they have no experience or knowledge of the benefits or advantages of the application of SSM.

The results showed that only 31% of the sampled population are aware of SSM; 33% are aware of other systems tools; while 36% are not aware of systems tools such as SSM. This may have affected the findings from the research as their lack of knowledge could have caused the participants' responses to be biased. This, in turn, could have led to the stronger correlation recorded for the users

of traditional methods for the adoption of AMTs, on account of their familiarity with the known scientific characteristics of Traditional methods used in AMT adoption.

5.3 Recommendations for future research

In order to gain deeper insights into the role that SSM plays in AMT adoption in the South African manufacturing industries, further research should be done in the field of the application of systems thinking techniques, such as in incorporating SSM in the South African manufacturing industry, as well as globally.

Future research should acknowledge the limitations described in Section 5.2 as regards the sampling strategy of the research. The sample for the research presented bias in the respondents as a few of the respondents were not aware of SSM and other systems-thinking techniques. By focusing on a sample population that had knowledge of the application of both SSM and traditional methods in their organisations for the adoption of AMTs, the elimination of possible bias that might have been present, owing to the fact that some of the respondents had no knowledge of SSM and other systems-thinking techniques, might have presented more accurate and valid responses.

Furthermore, owing to the gap in literature as regards the application of SSM in AMT adoption by the manufacturing industy, it is worthy to note that there is an opportunity for further research into the application of systems science, such as in SSM, in the adoption of AMTs in manufacturing industries, as this would improve the body of knowledge and present managers with insights into the potential and possibilities of SSM usage. Such opportunities led the researcher to recommend the application of SSM in further research into AMT adoption.

With due consideration to the exploratory nature of this research, it is the opinion of this researcher that the body of knowledge in system science would benefit from a more in-depth research into the application of SSM by manufacturing organisations in the adoption of AMTs by manufacturing organisations. With respect to this point, the researcher recommends that further studies should build

on the findings of this research and utilize a case study research method into studying the role of SSM in AMT adoption in manufacturing organisations being that this research has found considerable prospects for SSM usage in manufacturing organisations adoption of AMTs. Case study research is recommended because it is of the researchers opinion that a more in-depth and accurate data that would represent the systemic nature of the problem.

5.4 Significance of the research

There is considerable evidence in the research into AMT adoption by manufacturing organisations that organisations are generally not able to fully realise the benefits emanating from AMT adoption (Kotha et al. (2000).; Noori H (1997) Banakar et al. (2010)). According to Efstathiades et al. (2001) and Beatty (1993), research suggests that in their struggle to achieve manufacturing and business success, 41% and 43.5% of the manufacturing organisations are aware of the benefits that AMTs can bring to these two sectors of their enterprises respectively.

This research study explored the prospects of the holistic view approach presented by SSM to investigate whether there is a stronger correlation amongst manufacturing organisations towards better AMT adoption as opposed to their use of traditional methods. As presented in Figure 4.9, this research study found that there is a significant correlation between SSM and AMT adoption links, however, there are stronger correlations for traditional method usage for most of the links presented by the investigative framework (Figure 1.2). When the significant benefits associated with SSM usage, alongside the statistical evidence that SSM would lead to improved business success, are considered in conjunction with its limitations, discussed in Section 5.2, and the scarcity of research in the field of systems thinking for AMT adoption, the conclusion reached is that there is a strong correlation between SSM usage and AMT adoption. These correlations suggest that there is an opportunity for further in-depth research into the usage of system science techniques such as SSM into enabling a better AMT adoption by manufacturing organisations most importantly in the attainment of business success.

Thus, in conclusion, further research into the adoption of AMTs in the South African manufacturing industry could build on the findings of this research. Furthermore, SSM could be applied to good effect in the adoption of AMTs to study the benefits realised as opposed to those ensuing from the application of traditional methods and also, the provision of more academic research in the field of system science in the manufacturing environment.

5.5 Summary of findings

From this research, the most significant findings seem to be that SSM usage has significant correlations with all the links in the investigative framework presented in Figure 1.2. However, it is worthy of note that the use of the traditional method displays an even stronger correlation with the relevant links (a total of six out of the eight links points to the stronger correlation.) The use of SSM, on the other hand, only shows a higher level of correlation between [C] Barriers and Resistance to AMT Adoption and [D] Benefits Realisation; as well as for the link between [E] SSM Applicability and [A] AMT Investment and Strategic Planning.

In testing both hypotheses put forward by the research, SSM usage presented enough statistical proof for the researcher and the panel of experts to accept Hypothesis 1, where SSM users reflected a stronger correlation to indicators of business success. This was found to be really worthy to note since it has been discussed in the literature that manufacturing organisations adopting AMTs seldom realise business success (Efstathiades et al. (2001) and Beatty (1993).

The test for Hypothesis 2 was unable to present enough statistical evidence to lead to an acceptance or rejection of the hypothesis as the respondents all fell into the same category, making a comparison impossible. However, an inter-item correlation indicated that linking [C] Barriers and Resistance to Change to [A] AMT Investment and Strategic Planning presents a high level of correlation towards barriers such as the high cost of the equipment (C1), the skills shortage (C3) and the costs and maintenance of the software (C8), with $P>0.8$ for the three barriers.

With the available findings presented to the panel, their views were in support of the benefits of SSM in AMT adoption, even in the case of links where traditional methods displayed a higher level of correlation. Highlights from the panel's views were the ability of SSM to mitigate the dichotomy in the labor force by bringing top management and employees together for a joint session towards the adoption of AMT, and the opportunity to use systems tools such as PEST, SWOT, numerical evaluation, and others amongst a list of benefits of using SSM over traditional methods.

Taking into consideration the limitations faced by this research, and the absence of available research in the use of SSM in AMT adoption, the researcher is convinced that SSM provides a vast advantage in the adoption of AMTs in the manufacturing organisations in South Africa, and this topic should be further explored in research. However, the high correlation levels s displayed by traditional methods suggest that SSM should perhaps be used as a hybrid approach until enough significant statistical and analytical data have been accessed to prove that SSM alone can manage AMT adoption in manufacturing organisations.

Chapter 6: Conclusion

This study contributes to the body of knowledge of AMT adoption in manufacturing industries by indicating significant correlations between SSM and AMT adoption. This is a new development in literature because there has not been any research on any AMT adoption process that uses SSM. The presence of these significant correlations introduces a new way to approach AMT adoption using SSM.

The research explored the possibility of a paradigm shift from traditional methods for AMT adoption towards the use of a holistic SSM approach, and in terms of the research objectives, the following requirements were satisfied:

a) The collection of quantitative data sourced from 182 sampled organisations across nine industry sectors;
b) The use of Pearson's and Spearman's RHO correlation analyses to identify links in the investigative framework (Figure 1.2) and to show how each construct relates to the other/s;
c) The validation of findings by an expert panel;
d) The identification of opportunities for further research

The major findings showed that even though SSM presents significant correlations between the links in the investigative framework, the traditional method users presented with higher values for the correlational levels between most of the links. However, SSM users displayed a higher level of correlation for elements of business success, which has been found to be an area of benefits that manufacturing organisations seldom realise.

One of the major shortcomings of the research in terms of its limitations was the demography of the sampled population with regards to the knowledge and usage of SSM. Findings showed that 30% of the respondents are not aware of SSM and other system techniques. This was pointed out in the views of the expert panel as a possible source of bias, and it could also have an effect on the findings of the correlational analyses.

From the research conducted, and considering the findings, expert panel validation, limitations and recommendations for future research, it may be concluded that SSM presents a holistic approach that shows the potential to benefit manufacturing organisations when linking [C] Barriers and Resistance to [D] Benefits Realisation. SSM is one way of getting a holistic view of organisational systems environment and actors. From the research conducted, further empirical research may still be required in this area as there is little evidence to significantly indicate that SSM presents the best option for AMT adoption in manufacturing organisations. SSM usage in this research has only successfully shown significant correlations with the various constructs of AMT adoption and it could be the foundation for further research in AMT adoption.

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Appendix A:

Research Instrument:

Confidential

MSC_AMT ADOPTION

UNIVERSITY OF WITWATERSRAND SCHOOL OF MECHANICAL, INDUSTRIAL AND AERONAUTICAL ENGINEERING.

I am a master's student in industrial engineering at the University of Witwatersrand, with student number: 1031813.

I am conducting a research on identifying improvement areas using Soft Systems Methodology in the adoption of Advanced Manufacturing Technologies (AMT) in South African manufacturing industry.

AMTs are a variety of modern technologies designed to accomplish or support manufacturing tasks. AMTs can include Software such as CAD/CAM/CAE/MRP/SCADA/HMI, hardware such as LAN/Sensors/process instruments, plant and equipment such as Robots/FMS/CNC/3D PRINTING and Soft technologies such as LEAN/SIX-SIGMA/VA/VM/VE.

Soft systems methodology (SSM) is a holistic process of looking into complex, unstructured problems using systems thinking. It is particularly effective in analysing the Human activity system (HAS) in a pluralist context where the values, beliefs or expectations of stakeholders differs but yet genuine compromise is possible.

It would be appreciated if you could take the time to complete this questionnaire to contribute to this research. It is ultimately seeking to benefit the manufacturing sector in South Africa. The questionnaire is mostly a tick box exercise and should take no longer than 10-15 minutes to complete. Participation is voluntary and you can withdraw at any time without consequences. All data gained from the survey will be kept confidential. By completing this questionnaire it is taken that you voluntarily agreed to take part in this research.

Should you have any further questions/concerns/feedback please contact the researcher or supervisor as below

Researcher name: Oluwatosin Awosusi;

Researcher E-mail: 1031813@students.wits.ac.za;

Researcher phone number: +27643263966.

Supervisors name: Raj Siriram, Prof. (raj@alpha-concepts.com)

Thank You.

Screener questions.

This section is aimed at gaining some general demographic data required to test the hypotheses put forward in the research. Please select the answer that is most applicable to you.

1)	Organisation name:	_____
2)	Designation in the organization:	_____
3)	Please indicate your role in your organisations AMT adoption:	◯ Involved in AMT investment and decision making. ◯ Involved in the AMT adoption process. ◯ Involved in the usage of AMT's. ◯ None of the above.
4)	Categorize your firm into one of the following categories.	◯ Multinational company ◯ National local company ◯ Joint venture, mergers or strategic alliance ◯ Others
5)	Would you be consenting to participating in this survey?	◯ Yes ◯ No
6)	Would you prefer your organisation not be mentioned as one of the organisations participating in this research.	◯ Prefer to be mentioned. ◯ Prefer NOT to be mentioned.
7)	Into which of the following industry categories would you classify your organisation.	◯ Chemical industry ◯ Textile industry ◯ Pulp and paper ◯ Automotive ◯ Metal and Steel ◯ FMCG and beverages ◯ Others
8)	What type of manufacturing system does your organisation employ?	◯ Jobbing production ◯ Batch production ◯ Continous/flow-line/mass production
9)	Indicate your estimated organizational size in terms of number of employees.	◯ 1-100 ◯ 101-200 ◯ 201-300 ◯ >300
10)	What is the estimated number of years in experience With AMT adoption.	◯ 0-5 Years ◯ 6-10 Years ◯ 11-15 Years ◯ > 15 Years
11)	Is your organisation exposed to Soft systems Methodology concepts.	◯ Yes ◯ No

12) If your answer to the question above is NO, has your organisation been exposed to other innovative decision making and management techniques E.g: Systems thinking, Systems dynamics modelling, Value Management/Engineering/Analysis, etc.?

- ◯ Yes.
- ◯ No.

13) How will you rate your organisation's Usage of Soft systems Methodology concepts in decision making.

- ◯ Never
- ◯ Almost Never
- ◯ Occasionally Sometimes
- ◯ Almost Every Time
- ◯ Every Time

[A] AMT INVESTMENT AND STRATEGIC PLANNING.

This section aims to rate the the importance of various AMT planning and investments criteria in contribution to the success of AMT adoption.

14) Was there a set planning stage prior to AMT investment?
- ○ Yes.
- ○ No.

15) Following the decision to implement an AMT, were formal assessment techniques used to select the most appropriate AMT in which to invest? (E.g. the development of a specification that the technology must meet).
- ○ Yes.
- ○ No.

Use the Likert Scale to indicate your perception about the following statements during the AMT planning and investment stage.

		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	X
16)	The decision to adopt AMT was properly justified in alignment to the organization's strategic plan.	○	○	○	○	○	○
17)	Compatibility of proposed AMT was properly evaluated to align with existing organizational infrastructure(i.e existing technology).	○	○	○	○	○	○
18)	The level of investment by management was justified by the organizations manufacturing strategy.	○	○	○	○	○	○
19)	People were involved from a variety of functions in the technology proposal formulations and decisions.	○	○	○	○	○	○
20)	There were strategic plans to account for possible barriers and resistance that may occur during the AMT adoption process.	○	○	○	○	○	○
21)	AMT investment was complemented by investment in operator training.	○	○	○	○	○	○

[B] AMT ADOPTION PROCESS.

Use the Likert Scale to indicate your perception about the following statements during the AMT adoption process.

		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	X
22)	The adoption of AMT was supervised by AMT champions and employees with previous relevant experience with AMT adoption.	○	○	○	○	○	○
23)	Tasks were strategically planned and allocated towards the success of AMT adoption.	○	○	○	○	○	○
24)	Interdepartmental work teams were on-board the AMT adoption process.	○	○	○	○	○	○
25)	Best practices were developed to best manage the AMT's.	○	○	○	○	○	○
26)	There were proper Communication channels during the AMT adoption process. (Inter-departmental / Management-Shop floor).	○	○	○	○	○	○

[C] BARRIERS AND RESISTANCE TO AMT ADOPTION.

Use the Likert Scale to indicate your perception about the following factors as barriers and resistance to to the success of AMT adoption in your organisation.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	X
27) The lack of financial justification due to the high cost of equipment.	○	○	○	○	○	○
28) The high cost of integration of the new technology.	○	○	○	○	○	○
29) The shortage of available skills in the organization.	○	○	○	○	○	○
30) The presence of workers resistance.	○	○	○	○	○	○
31) lack of proper technological/technical support or service (from vendors or consultants).	○	○	○	○	○	○
32) The resistance to the introduction of new technology by management.	○	○	○	○	○	○
33) Inability to evaluate new technology by the management.	○	○	○	○	○	○
34) The cost to develop and maintain software for the new technology.	○	○	○	○	○	○
35) The cost of ensuring cyber security.	○	○	○	○	○	○

[D] AMT BENEFITS REALIZATION

Use the Likert Scale to indicate your perception about the benefits released by your organisation from the adoption of AMTs.

		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	X
36)	Organisational competitiveness.	○	○	○	○	○	○
37)	Increased business growth.	○	○	○	○	○	○
38)	Enhanced company image.	○	○	○	○	○	○
39)	Reduced lead time.	○	○	○	○	○	○
40)	Increased productivity/volume throughput.	○	○	○	○	○	○
41)	Positive return on investment.	○	○	○	○	○	○
42)	Increased product quality.	○	○	○	○	○	○
43)	Better working conditions.	○	○	○	○	○	○
44)	Increased manufacturing flexibility.	○	○	○	○	○	○
45)	Reduced labour cost.	○	○	○	○	○	○

46) Were new business opportunities identified following AMT adoption?
- ○ Yes
- ○ No

47) Please rate your overall satisfaction with the results of the AMT adoption in which you have been involved in.
- ○ Very dissatisfied
- ○ Not satisfied
- ○ Neither satisfied nor dissatisfied
- ○ Satisfied
- ○ Very satisfied

[E] SSM APPLICABILITY

This section aims to rate the role of SSM in organisational AMT adoption according to your agreement or disagreement using the Likert scale to respond to the following statements.

		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	X
48)	The involvement of SSM and other systems techniques will improve AMT adoption process.	○	○	○	○	○	○
49)	Our organization uses traditional methods instead of SSM and other systems techniques when adopting AMT's.	○	○	○	○	○	○
50)	The better understanding of the organizational environment and actors gained from the use of Systems techniques will better help in AMT investment justification and strategic planning.	○	○	○	○	○	○
51)	Our organization grows faster as a result of successful AMT adoption compared to our competitors.	○	○	○	○	○	○
52)	SSM and other innovative system tools has help improve the organizations AMT investments and strategic planning processes.	○	○	○	○	○	○
53)	Exposure of SSM and other innovative system techniques will enable the organization to realize the full potential benefits from AMT adoption.	○	○	○	○	○	○
54)	Systems thinking will enable our organization to respond better and faster to customer preferences and requirements.	○	○	○	○	○	○
55)	The industry in which our organization operates demands constant improvements in AMT's to remain competitive.	○	○	○	○	○	○
56)							

SSM and other innovative system techniques can help reduce the barriers and resistance faced by the organization when adopting AMT's.	○	○	○	○	○	○

Appendix B: List of sampled manufacturing companies:

1. HULAMIN LIMITED	2. LANSERIA BRICKS
3. COROBRIK (PTY) LTD	4. STRAPPING AND PROFILE MANUFACTURERS CC
5. MELCO CONVEYOR EQUIPMENT (PTY) LTD	6. PROJECT CONCERN MFG PTY LTD
7. SAM ENGINEERING PTY LTD	8. LANDIS & GYR (PTY) LTD
9. TUBECON AFRICA (PTY) LTD	10. BOWLER METCALF PTY LTD
11. SONDOR INDUSTRIES PTY LTD	12. AMKA PRODUCTS PTY LTD
13. CLOSEAL MANUFACTURING PTY	14. JOHNSON AND JOHNSON PTY LTD
15. DESIGN SOUTH AFRICA	16. COLGATE-PALMOLIVE PTY LTD
17. VITAFOAM SOUTH AFRICA	18. EVAPCO SA (PTY) LTD
19. VIBRAMECH	20. BATA SHOES
21. VEYANCE TECHNOLOGIES AND CONTINENTAL	22. KANSAI PLASCON AFRICA PTY LTD
23. SUSTECH MANUFACTURING	24. MAHLE BEHR SOUTH AFRICA PTY LTD
25. SABMILLER	26. TORRE PARTS AND COMPONENTS PTY LTD
27. UNILEVER	28. EVONIK ACRYLICS AFRICA PTY LTD
29. COCACOLA(SABMILLER,CCSB)	30. FONTANA MANUFACTURERES PTY LTD
31. CLOVER INDUSTRIES	32. GALISON MANUFACTURING
33. TRANSPACO LIMITED	34. PRECOOL MANUFACTURING CO PTY LTD
35. BRITISH AMERICAN TOBACCO	36. PRECISION VALVE SA (PTY) LTD
37. TWIN SAVER GROUP	38. GELVENOR TEXTILES
39. MCCAIN FOODS (SA)(PTY) LTD	40. DEFY APPLIANCES (PTY) LTD
41. PIONEER FOODS MANUFACTURING	42. UNIVERSAL TISSUE (PTY) LTD
43. PROCTER AND GAMBLE	44. PROMASIDOR S A (PTY) LTD
45. TIGER BRANDS	46. PROFECTION MANUFACTURERS CC
47. RCL FOODS	48. STRAPPING & PROFILE MANUFACTURERS CC
49. TELLUMAT (PTY) LTD	50. TANK MANUFACTURERS PTY LIMITED
51. DISTELL GROUP	52. TRANSVAAL ELECTRIC MOTOR PTY LTD
53. ALBANY FACTORIES	54. GAUTENG RUBBER AND SEAL COMPANY PTY LTD
55. EVEREADY (PTY) LTD	56. GILO ENGINEERING & MANUFACTURING CO
57. APOLLO BRICK (PTY) LTD	58. LESCO MANUFACTURING PTY
59. NESTLE SA	60. VOMAK INDUSTRIES PTY
61. LOVELL INDUSTRIES	62. KAYDAV GROUP LIMITED
63. TONGAAT HULETT SUGAR	64. PRATLEY (PTY) LTD
65. GLEDHOW SUGAR COMPANY	66. LIBCOR INDUSTRIAL MACHINERY PTY LTD
67. SAFINTRA PTY LTD	68. KELLOGG COMPANY OF SOUTH
69. ILLOVO SUGAR,	70. MASTER PLASTICS LIMITED
71. GEAR PUMP MANUFACTURING PTY LTD	72. EVOWOOD PTY LIMITED
73. MME MANUFACTURING (PTY) LTD	74. SUMITOMO RUBBER SA PTY LTD (SRSA)
75. BRITS AUTOMOTIVE SYSTEMS PTY LTD	76. RC&C MANUFACTURING COMPANY PTY LTD

77. DUYS COMPONENT MANUFACTURERS (PTY) LTD	78. TEGA INDUSTRIES SOUTH AFRICA (PTY) LTD
79. VOLKSWAGEN SA	80. SOUTH OCEAN ELECTRIC WIRE COMPANY
81. FLEXTECH CC	82. SMITHS MANUFACTURING PTY LTD
83. HISENSE (PTY) LTD	84. KEYPAK PTY LTD
85. TOYOTA SA MOTORS	86. ROTHCO (PTY) LTD
87. IVECO SA (PTY)	88. PIONEER PLASTICS (PTY) LTD
89. AEROSUD ENGINEERING (PTY)	90. RECKITT BENCKISER (PTY) LTD
91. BMW PLANT ROSSLYN	92. SELAGO INDUSTRIES (PTY) LTD
93. PASDEC AUTOMOTIVE TECHNOLOGIES	94. GEUSTYN & HORAK MFG (PTY)LTD
95. FELTEX AUTOMOTIVE(A DIVISION OF KAP PTY)	96. GOODYEAR SA (PTY) LTD
97. AFROX	98. LESIRA MANUFACTURING PTY LTD
99. TERRACOR (PTY) LTD	100. PENCAR MANUFACTURERS PTY LTD
101. POWDER LAK	102. GOLD CIRCLE (PTY) LTD
103. FAMOUS BRANDS LIMITED	104. SENIOR FLEXONICS SA(PTY) LTD
105. CAPE COMPOSITE PTY	106. SAFELINE MARKETING
107. CONSOL	108. BANDAG CALEDON
109. DIVPHARM MANUFACTURING AND PACKAGING	110. ATVAL-AVENG DFC
111. HERSOL MANUFACTURING LABORATORIES (PTY) LTD	112. DEMAN MANUFACTURING PTY LTD
113. SAFRIPOL	114. PREMIER VALVES (PTY) LTD
115. BLENDCOR (PTY) LTD	116. SILVERTON INDUSTRIES (PTY) LTD
117. AFRICAN PIPE INDUSTRIES	118. SAMES (PTY) LTD
119. INTEGRAL MANUFACTURING	120. C.R.I. PUMPS S.A (PTY) LIMITED
121. METNOR MANUFACTURING CC	122. ABERDARE CABLES (PTY) LTD
123. COPALCOR GROUP	124. SIMBA (PTY) LTD
125. SIM MANUFACTURING CO (PTY) LTD	126. KAYDAV GROUP (PTY) LTD
127. ARCELORMITTAL SOUTH AFRICA LTD	128. RESTONIC (PTY) LTD
129. CAN IT	130. MAZOR GROUP LTD
131. ALUMINIUM FOIL CONVERTERS PTY LTD	132. CERAMIC INDUSTRIES LIMITED
133. VORARC	134. BELL EQUIPMENT COMPANY SA (PTY) LTD
135. UNIVERSAL PAPER MANUFACTURERS (PTY) LTD	136. DELTA EMD LTD
137. SAPPI LIMITED	138. DISTRIBUTION AND WAREHOUSING NET LTD
139. PG BISON LIMITED	140. REX TRUEFORM CLOTHING COMPANY LTD
141. MUST PAPER INDUSTRIES	142. SPANJAARD LTD
143. CONQUEST PAPER	144. UNI-SPAN MANUFACTURING
145. VEKTRONIX	146. BIC SOUTH AFRICA (PTY) LTD
147. ULRICH SEATS (PTY) LTD	148. CFW INDUSTRIES PTY LTD
149. GEORGE SWITCHBOARD MANUFACTURING CC	150. CHESPAK (PTY) LTD
151. ZENITH INSTRUMENTS	152. CHIORINO SOUTH AFRICA PTY LTD
153. CZ ELECTRONICS PTY	154. COBA PLASTICS PTY LTD
155. VTRONIX	156. COLCAB (PTY) LTD
157. SABERTEK	158. DENSO S A PTY LTD

159.JASCO	160.EASYCOM INDUSTRIAL MFG (PTY) LTD
161.TRIWAK TECHNOLOGIES CC,	162.ECAM (PTY) LTD
163.ASTRAPAK	164.NAMPAK LIMITED
165.ITB MANUFACTURING (PTY) LTD	166.DEKRO PAINTS (PTY) LTD
167.FERRO PLASTICS	168.HEINZ FISCHER ENGINEERING (PTY) LTD
169.PIONEER PLASTICS	170.MECHCAL (PTY) LTD
171.MPACT LIMITED	172.SEATING PTY
173.DELTA RUBBER COMPANY	174.GEORGIAN MANUFACTURING (PTY) LTD
175.ITALPAC PTY	176.KARO MANUFACTURING PTY LTD,
177.CARNILINX (PTY) LTD	178.CHATTON MANUFACTURING
179.ARMINEL INDUSTRIES (PTY) LTD	180.ENTRAWOOD CC
181.ACTOM INDUSTRY	182.RWL FURNITURE