Monarch Business School
University for Graduate Studies in Management

A System Analysis Approach to Analyze and Develop ERP Systems Framework Based on the Principles of Lean Manufacturing

PROGRAM:	Doctor of Professional Studies
SUBMISSION DATE:	15 February 2015
CANDIDATE:	Chalil du Plessis, B.Acc., M.Prof.
THESIS SUPERVISOR:	Dr. Barin Nag, Ph.D.
COMMITTEE CHAIR:	Dr. Jeffrey Shawn Henderson, D.Phil.
SECOND READER:	Dr. Norman Madarasz, Ph.D.
DEAN AND THIRD READER:	Dr. Donald York, D.Phil.

QUOTES

"'Exactly!' said Deep Thought. 'So once you do know what the question actually is, you'll know what the answer means.'" – *Douglas Adams, The Hitchhiker's Guide to the Galaxy*

"The Lean goal is waste elimination through the continuous improvement of all processes, and the methods of attaining this goal fall along a spectrum from the simplest to the most sophisticated initiatives." – *Steve Bell, Lean Enterprise System*

"In order to eliminate waste, you must develop eyes to see waste, and think of how you can eliminate the wastes that you see. And we must repeat this process. Forever, and ever, neither tiring nor ceasing." – *Taiichi Ohno*

DEDICATION

I give my thanks and praise to Allah, my Creator and the Creator of all Knowledge and Creation, for granting me the opportunity to write this thesis and for bestowing the knowledge upon me to complete this work.

Firstly, I dedicate this thesis to my dear parents for giving me the opportunities to study however difficult their circumstances might have been. Thank you for always enthusiastically supporting me in whatever I choose to endeavor in. You always give me your keen interest, love and encouragement and I will always love you for this.

Secondly, I am also dedicating this thesis to my dear and beloved wife, Sihaam and my loving daughter, Qamar for allowing me this opportunity to follow a dream. I give my thanks and love to them, for they are patiently giving me the time and support to complete this work.

Lastly, I would also like to thank my dear friend Terje and his family for inspiring me to take on this journey with him. Special thanks also to our dear friends Alan, Nahid and Yousef for their support and encouragement. Thank you to all my colleagues and in particular Mr. Abdullah Mustafa for always is enquiring on my progress. Your interest in my efforts is deeply appreciated and encouraged me to keep going to complete this thesis.

ACKNOWLEDGEMENTS

I would like to express my gratitude towards my academic supervisor, Dr. Barin Nag, Ph.D., for his guidance, mentorship, patience, support and commentary in overseeing the entire process. I feel privileged to be under the guidance of someone of your caliber and experience and appreciate the time you are dedicating to this task.

Secondly, I would like to take this opportunity to thank Dr. Jeffrey Shawn Henderson, D.Phil., Dean of Studies at UGSM-Monarch Business School, for the vision of Monarch University and for the inspiration, guidance and mentorship throughout the duration of this process.

I would also like to thank Dr. Donald York, D.Phil., Dean of Student Development, for his encouragement, his inspiration to complete the task at hand and for paving the way for us at UGSM-Monarch Business School.

PURPOSES AND ATTESTATION

This document is prepared as a Dissertation submission to UGSM-Monarch Business School Switzerland in fulfillment of the degree of:

Doctor of Professional Studies / Doctor of Management

The author hereby attests that the work herein provided in fulfillment of the above degree requirements is wholly of his own effort and hand. Further, the author attests that this document constitutes the entire submission of the dissertation component.

Dissertation Committee Members:

Thesis Supervisor	Dr. Barin Nag, Ph.D.
Committee Chair	Dr. Jeffrey Shawn Henderson, D.Phil.
Secondary Reader	Dr. Norman Madarasz, Ph.D.
Third Reader	Dr. Donald York, D.Phil.

____________________________________ ____________
Mr. Chalil du Plessis, B.Acc., M.Prof. Date

TABLE OF CONTENTS

Mr. Chalil du Plessis, B.Acc., M.Prof.
Final Submission To The Dissertation Committee
UGSM-Monarch Business School Switzerland
15 February 2015

TABLE OF FIGURES

LIST OF ABBREVIATIONS

AIF	Axapta Integration Framework
AIS	Accounting Information System
APS	Advanced Planning Systems
ASP	Application Service Provider
B2B	Business to Business
B2C	Business to Consumer
B2E	Business to Employee
BOM	Bill of Materials
BPR	Business Process Re-engineering
CIM	Computer Integrated Manufacturing
CMD	Cooperative Method Development
CRM	Customer Relationship Software
CW	Catch Weight
EAI	Enterprise Application Integration
EDI	Electronic Data Interchange
ERP	Enterprise Resource Planning
ES	Enterprise Systems
ESS	Enterprise System Software
GERP	Global ERP
HTML	Hypertext Markup Language
IAC	Items, Agents and Cash
IS	Information Systems
IT	Information Technology
JIT	Just in Time
KM	Knowledge Management
KPI	Key Performance Indicator
MIS	Management Information System
LEMF	Lean ERP Metrics Framework
MRP	Material Requirement Planning
PaaS	Platform as a Service
PDCA	Plan-Do-Check-Act
PDF	Portable Document Format
PLM	Product Lifecycle Management
RFID	Radio Frequency Identification Technology
SaaS	Software as a Service
SBE	Small Business Enterprise
SCM	Supply Chain Management
SLA	Service Level Agreement
SOA	Service Orientated Architecture
STK	Software Toolkit
TPS	Toyota Production System
TQM	Total Quality Management
UML	Universal Modeling Language
XML	Extensible Markup Language

CHAPTER ONE

INTRODUCTION

CHAPTER ONE - INTRODUCTION

1.0 BACKGROUND

Modern manufacturing applies Lean Manufacturing Systems, also known as the Toyota Production System (TPS), to reduce waste and increase efficiency. Organizations are often forced to implement their Lean manufacturing independently of their Enterprise Resource Planning (ERP) system due to their conflicting philosophies and therefore finding themselves administrating two independent systems (Bartholomew, 2012a; Steger-Jensen & Hvolby, 2008). Organizations make use of ERP systems for planning and to integrate back-office operations.

There are currently two points of view; those who believe that the Lean system must be independent of the ERP system and those who believe that an ERP system can contribute to a Lean system (Bartholomew, 1999). Those who believe that the two systems should be independent argue that the Lean principles promote a "pull" action through the system, constantly changing to get rid of all the waste or *muda* whereas a traditional ERP system promotes a "push" action (Bartholomew, 2012a). Taiichi Ohno, the founder of TPS, identifies the seven types of waste in a production system (Ohno, 1988) as:

- Transportation: The production processes and procedures require parts and products moved around unnecessarily.

- Inventory: Production processes and procedures cause accumulation of parts and products waiting to go into production.
- Motion: Unnecessary movement of production staff during the production process.
- Waiting: Waiting time spend by manufacturing staff for a previous process to complete.
- Over-Processing: Over design or weak design of processes and procedures add unnecessary steps to the production process.
- Over-Production: The production process results in the manufacturing of additional unnecessary units.
- Defects: Defective work results in reworking or scrapping of a product.
- With an eighth type of waste added by Womack and Jones (2003) namely goods and services that do not meet customer's needs.
- Other authors also added: Underutilization of people (Womack & Jones, 2003).

The following five principles of Lean thinking forms the antidote to waste in a Lean system (Womack & Jones, 2003):

- Customer specific Value: Only add value as needed by the customer.
- Identify the Value Stream: The value stream consists of all the steps in a production process.
- Flow: Make the steps in the value stream flow.
- Pull: Customers pull production from you; sell one, then make one.
- Pursue Perfection: Continuously improvement of processes by reducing time, space, cost and mistakes during the production process.

On the other hand, the main functionality of an ERP system is to record all historical transactions generated by the traditional push action for production. Therefore ERP systems are rather designed to record transactions instead of eliminating waste (Nauhria, Wadhwa, & Pandey, 2009). Gill (2007) argues the two apparent contradictory philosophies used in the same production system will cause the system to be out of sync and therefore ERP systems are not able to contribute to Lean systems.

The author believes that Lean and ERP might not be mutually exclusive in the field of ERP systems. Vendors of ERP systems such as SAP, Oracle and Microsoft have done some work in order to facilitate Lean principles by adding, modifying or enhancing their current system modules to address some of the requirements of Lean systems (Volkmann, 2011). Most of the modules thus far concentrate on the manufacturing industry and possibly only represent Lean tools or initiatives and might not necessarily apply the principles of Lean philosophy and Lean nature; however, there are several areas requiring study and development such as operations, accounting, information technology (IT), operations, and services. In 1988 the developer of the Toyota production system, Taiichi Ohno, wrote in the preface of his book *Toyota Production System: Beyond Large-Scale Production*:

> "The Toyota production system, however, is not just a production system. I am confident it will reveal its strength as a management system adapted to today's era of global markets and high-level computerized information systems." (Ohno, 1988, p. 15)

Ohno acknowledges two areas where he believes that Lean or TPS will show its strength, being: applied in the global markets and with the aid of computerized information systems. In the future it is expected that manufacturing industries and operations will be more globally oriented in the search for higher profits. Gartner Group supports this notion and predicts utilization of the global supply chain as a major strategic consideration for cost reduction of companies from 2011 to 2015 (Klappich, Aimi, Taylor, & Mcneill, 2011). Economic growth until 2015 will put pressure on supply chains to be able to deliver increased consumer demand (Klappich et al., 2011). The expectation is that organizations worldwide should be searching for cost reduction and profit maximization methods to implement. Lean and Six Sigma are popular methods to assist organizations to reduce costs and maximize profits. Furthermore, it should be noted that Six Sigma is a quality initiative that integrates well with Lean systems and TPS.

1.1 STATEMENT OF THE PROBLEM

ERP systems seek to collect and record data throughout the organization. IT considers manufacturing and other operations as part of the ERP system. With Lean philosophy becoming more popular in manufacturing organizations, ERP systems has to be designed to support both. Enterprise level ERP vendors such as SAP, Sage, Oracle and Microsoft have already attempted to address some of the Lean concepts such as Just-in-time (JIT) and Kanban in their manufacturing and operational modules by combining functionalities such as forecasting and production planning schedules. JIT is a system referring to timing whereby items needed for the production line are delivered in the correct quantities at the correct time when and where they are needed on the production line (Hirano, 1990). Kanban is a visual system with cards attached to items containing supplier information. When more items are needed for production the card is send back to the supplier to replenish the items (Liker & Burr, 1999). Kanban, as one of the lean tools, is used to achieve JIT. However, there is a lack of research and a proper understanding of how ERP systems can support Lean operations in the move to further globalization.

ERP systems typically focus on the organization itself and at most on inter-company functionalities but are weak in the inter-organizational functionalities required to support Lean operations in the global environment. Gartner coined the phrase ERP in 1990 and in 2000 they added ERP II referring to an ERP system than will not only serve the enterprise but will be “intra-enterprise”, currently known as B2B (Business to Business) and B2C (Business to Customer). This encompasses the use of CRM (Customer Relationship Management), SCM (Supply Chain Management) and ERP (Bakht, 2003).

The test hypothesis is that a Lean ERP framework could be designed with Lean principles and implemented in a global environment. In order for the hypothesis to have value, it must prove to benefit Lean and ERP by being able to contribute to the reduction of waste as per the Lean principle and to reduce costs in the traditional ERP operation. In a global environment the IT architecture and ERP framework design must be of use not only for large enterprises that can afford expensive global infrastructures but must also be accessible to the small and even single entrepreneur to participate as a Lean supplier in the global Lean supply chain.

1.2 THE PURPOSE STATEMENT

Management philosophies evolved in great strides at the same time as computerized systems or enterprise systems started evolving into integrated systems (Bartholomew, 1999). Designs of ERP systems tend to inherent the philosophy of particular management systems they support and that might be popular at the time. The ERP systems that evolved till now are criticized for not supporting the Lean philosophy and therefore not useful in a Lean manufacturing environment (Bartholomew, 2012a).

The relevance of this research is to examine and discover the differences between the Lean principles and ERP applied principles when designing, developing and implementing enterprise systems in organizations. Furthermore, the research will attempt to propose a conceptual framework that can reconcile these differences and bridge the gap between the two system philosophies. Such a framework would be significant for future development of ERP systems by vendors and researchers to ensure that enterprise systems designs contain the essential key elements of ERP and Lean philosophies.

The following section will discuss and explore the main research question through the application of the selected research methodology.

1.3 THE RESEARCH QUESTION

The purpose of this research is to study ways of narrowing the gap between Lean principles of operations and ERP applied principles. This can be achieved through analyses of already developed and implemented ERP modules of a software vendor that claims to support Lean principles and to develop a systems framework for ERP that can assist users of Lean operations in a global industry to bridge this “apparent” gap between the two systems. Thus, the thesis will attempt to address the following specific research question:

> Research Question:
>
> “What is the ERP systems framework that can be developed to incorporate Lean principles of operations, which will enable global Lean industry users to both reduce costs in their traditional ERP system while simultaneously reducing waste?”

The following section presents a description and overview of the research methodology followed for the purpose of the study.

1.4 THE RESEARCH METHODOLOGY

The thesis research methodology is based on a systems analysis approach following a multi-methodological research method as proposed by Nunamaker, Chen, and Purdin (1991). Their approach consists of four research strategies: theory building, experimentation, observation, and system development. These four strategies are applied within the system development research methodology proposed by Nunamaker et al. (1991) and adapted in an attempt to answer the research question. The researcher considers this approach most suitable to investigate the multiple facets of the underlying issue highlighted in the background. Furthermore, the research approach could support the author's believe that Lean and ERP might not be mutually exclusive and that vendors have done work already to enhance ERP systems to facilitate Lean principles and in specific the principles of Lean operations as proposed by Spear and Bowen (1999). The use of additional techniques common to the system analyst such as gap analysis, requirement analysis and use case study further extents the research methodology.

The research applies a mixed method approach to conduct experiments and observations to determine *a priori* knowledge and *a posteriori* knowledge of an existing ERP system. The quantitative analysis consisted of testing the elimination of waste by measuring the observed time of a process before and after treatment to eliminate waste. Furthermore, the qualitative analysis was conducted using the three phased Cooperative Method Development (CMD) (Dittrich, Rönkkö, Eriksson, Hansson, & Lindeberg, 2007) applied in two cycles. The first cycle of qualitative research conducted evaluated the functions as per the Lean functionalities identified through a focused literature review. The second cycle of qualitative research conducted evaluated the functions as per the Lean metrics proposed by Spear and Bowen (1999).

In case of evidence found in support of the null hypothesis, the remaining phases of the system development research as proposed by Nunamaker et al. (1991) was used where possible to contribute to complete the proposed framework in an attempt to answer the research question.

Details on the research methodology will be discussed and elaborated further in Chapter Three. The following section will discuss the significance of the study and the contribution within the Lean and ERP discipline's body of knowledge.

1.5 THE SIGNIFICANCE OF STUDY

The significance of this thesis is to contribute to the research and development evolving around the topics of Lean operational principles and Enterprise Resource Planning systems. Controversy exists surrounding the development of ERP systems and systems to support the concept of Lean manufacturing as described by its inventor

Taiichi Ohno. As mentioned earlier, ERP systems are generally developed based on the philosophy of mass production and the “push” system concept. Contrary to this concept, Lean systems are “pull” based systems where production is determined through customer demand and cost of production reduced through the elimination of waste. Even though authors such as Bartholomew (1999), Dixon (2004), Goddard (2003) and Hessman (2012) have been discussing this dilemma for more than a decade there seemingly has not been a significant number of research carried out to gain seminal knowledge and understanding of the problem at hand. More knowledge of how ERP and Lean can be reconciled into a holistic system could assist organizations implementing Lean concepts in the future. Software vendors does not seem to be aware of how can they can develop such systems. The development of a framework to understand the principles and philosophy that must be contained within an ERP systems to support Lean could assist ERP vendors to develop holistic systems that would be able to support Lean and ERP (Dixon, 2004).

Furthermore, this research project will study and contribute to a relatively new and understudied area of research in ERP. The author anticipates that the study will result in:

1. Identification and development of a Lean ERP framework for the design of modules to support Lean operations;
2. Propose a system architecture that can support Lean operations;
3. Use of the developed ERP system framework to assist users of Lean operations in a global industry.

The scope of this study as per the knowledge of the author have not been completed elsewhere. The void therefore provides an opportunity to contribute to new knowledge in the understanding of Lean principles of operations and ERP applied principles and how this knowledge assists in organizational systems to promote holistic solutions.

The bibliometric review presented in Table 5.1 was conducted using three well-known reference databases: Google Scholar, Jstor and ProQuest. Several combinations of ERP and Lean related terms were used to search the databases as indicated in Table 5.1. The results indicate support towards the notion that knowledge is lacking in the area of Lean ERP Principles of operation and the combination of Lean and ERP. The search results in comparison with that of Enterprise Resource Planning is significantly smaller particularly within Jstor and ProQuest. It is important to note that the research results were not verified per article and that some of the articles might not contain a direct relationship with the research. Furthermore, the results would contain references to all formats of books, articles and journals. However, the results do indicate a frequency of the occurrences of terms relevant to this research across all types of literature at large.

TABLE 1.5
BIBLIOMETRIC REVIEW OF ERP AND LEAN TERMS

		Google Scholar	Jstor	ProQuest
RANKING	**TERMS**	**SEARCH RESULTS**		
1	Enterprise Resource Planning Principles	817,000	4,329	50,657
2	Lean Principles	504,000	1,650	22,872
3	Lean principles of Operation	230,000	761	14,549
4	Lean Global Operation	174,000	496	46,583
5	Lean Architecture	149,000	308	6,853
6	Foundations of Lean	125,000	743	18,147
7	Foundations of Lean Operation	112,000	298	11,174
8	Lean and Enterprise Resource Planning	87,800	412	10,637
9	ERP Architecture	76,100	70	7,179
10	ERP Principles	75,900	194	5,722
11	ERP Global Operation	56,800	92	18,092
12	Lean Module	54,900	74	4,599
13	Foundations of ERP	43,500	129	6,210
14	Lean Operation module	34,200	41	3,387
15	Lean and ERP	17,700	47	2,504
16	Lean and ERP Operation	12,900	20	2,037
17	Global Lean ERP	10,600	26	2,504
18	Lean ERP Principles	8,600	16	974
19	Lean ERP Principles of Operation	7,780	9	887
20	Lean ERP Architecture	6,190	11	702
21	Lean ERP module	4,730	4	729
22	Lean ERP Principles of Operation and Module	2,860	0	288
23	Spear and Bowen and ERP	180	3	29

Source: Chalil du Plessis, 2013

It was important during the research to consider the possibility that the research could result in support of the notion that ERP vendors may have already developed Lean ERP system modules and may have already achieved the anticipated outcome of this research project to a degree. In such a case the results of the research project would have contributed to the body of knowledge as valuable literature in support of the point of view that ERP systems does support the Lean principles and would have still supported constructing the resulting framework.

Furthermore the researcher also took in consideration the possibility that the experimentation was not able to support the test theory that ERP modules could be designed to support Lean principles. In this case, the research results would indicate conditions under which ERP support Lean and conditions when ERP does not support Lean. It is pointed out that when there are two contrasting schools of thought, it is often the case that each school is right under certain conditions. The study also identify the areas most critical for further study in the near future with specific reference to Lean operations in a global industry.

1.6 THEORETICAL FRAMEWORK

The theoretical framework is structured around the literature that can be found related to the two philosophies of ERP and Lean. The theoretical literature review is further divided into interdisciplinary areas in order to develop a deeper understanding of the phenomenon of ERP systems and the Lean philosophy development of ERP systems. Furthermore, the theoretical literature review has been divided into the following categories to develop a better insight and understanding into existing theoretical literature:

- The Development of ERP Systems
- The Development of the Lean Philosophy
- ERP and Lean
- Lean Operations
- Architecture to Support Lean

The following is a synopsis of the literature that have been utilized during the study:

The Development of ERP Systems: This section discusses the elusive nature of defining Enterprise Resource Planning (ERP) since Gartner coined the term in the early 1990s. Definitions given by some prominent authors on ERP are discussed to find a valid working definition for the purpose of this study. An investigation of the available literature attempts to define the principles of the ERP philosophy. An apparent evolution of ERP and its philosophy from earlier MRP systems to recent concepts of ERPIII and Global ERP system are also investigated to understand the parallel development that occurred indicating an apparent transformation from closed introspective organizational based systems to extrospective, customer and vendor collaborative enterprise systems.

The Development of the Lean Philosophy: This section introduces the Toyota Productions System and the principles of Lean thinking. An overview of a number of

Lean tools and their application is given for a better understanding of the research covered later in Chapters Four and Five.

ERP and Lean: This section explores the combined concept of ERP and Lean. The introduction of Lean and information technology explores the concept of computerization of Lean. A few concepts proposed in the literature are explored how Lean and ERP can be combined.

Lean Operations: This section explores the definition of Operations within the theoretical literature and the functional areas related to Operational Management defined within information systems. The principles of Lean operations are introduced as proposed by Spear and Bowen (1999). This section also introduces the concept of using Spear and Bowen's (1999) principles as a metric to investigate the existence of Lean philosophy in an ERP system. Spear and Bowen's (1999) principles are proposed as suitable metrics used in the chosen research methodology discussed in Chapter Three. The theoretical literature also explores other proposed metrics of Lean operations applicable to ERP systems.

Architecture to Support Lean: This section explores IT architectures in the theoretical literature that are proposed that might be suitable in design for use with Lean ERP systems. However, the literature found on this subject seems to be sparse and generally speculative in nature.

1.7 NATURE OF RESEARCH

As mentioned, Lean manufacturing and ERP system are often found to be implemented in organizations as two independent system, however there are two points of view, those that believe that Lean systems should remain independent of an ERP system and those that believe ERP can co-exist with a Lean system (Bartholomew, 1999; Halgeri, McHaney, & Pei, 2010). The main argument for the use of ERP and Lean as independent systems is that ERP is based on a philosophy of “push” manufacturing traditionally used with mass production to push production toward the clients whereas Lean is based on a philosophy of “pull” manufacturing where production is pulled from the customer (Bartholomew, 2012a). There appears to be a lack of research in refuting this argument based on the design philosophy besides some efforts of prominent ERP vendors such as Oracle, SAP and Microsoft to develop and include Lean tools in their software. Furthermore, the available research also lacks empirical research to understand the design philosophy of these systems and how these systems might be reconciled within a single Lean ERP system.

The nature of the research consists of a multi methodological approach applying a mixed method research in order to answer the main research question. The research focuses on analyzing and testing the presence of elements of Lean philosophy that might be present in ERP systems. Furthermore, the aim of the research is to discover the components required to design a framework system developers and researchers could utilize to develop ERP systems in the milieu of Lean manufacturing.

1.8 DEFINITIONS

Definitions are provided here of some of the key terms used throughout the study in order to provide a general framework for clarification. Discussions of some of the definitions appear elsewhere in the thesis and in those cases only a working definition is given here:

Enterprise Resource Planning (ERP): ERP systems consist of core software supporting the different operational areas and its business processes by facilitating the business process and integration of the different tasks in the business process. These systems typically use a common database in order to generate management reports through the application of a common reporting tool (Monk & Wagner, 2009).

Enterprise System (ES): A configurable, modular system that allows a company to integrate data through a single database and streamline data flow throughout the entire organization providing management with access to real-time information. This definition is similar to that of ERP but without the underlying understanding of "resource planning" (Davenport, 1998; Davenport, 2000 p. 2).

Management Information System: A management information system is a combination of information systems from different functional areas in an organization (Senn, 1978).

1.9 LIMITATIONS AND DELIMITATIONS OF THE STUDY

No study or experiment can be assumed to be without any unambiguity and is expected to contain a number of limitations, assumptions and delimitations (Katz, 2009, p. 136). Limitations are variables that are not controllable by the researcher and might have an effect on the outcome of the study. On the other hand, delimitations are setting the borders, outline or scope of the study as to what is included or excluded and why (Mauch & Park, 2003, p. 115).

Limitations: The study is limited to the functionality found within Microsoft Axapta 2012 software and the Lean functionality that is on offer by the software vendor. The researcher conducted tests using demonstration software for Microsoft Axapta 2012 as a standard off-the-shelf product supplied by Microsoft as a Hyper-V virtual machine Image without any customization. The version of the software used during the study is limited to Microsoft Dynamics AX 2012 Application version 6.0.947.862 and does not include earlier or any future versions of the software. The study is further limited to a single vendor's software due to the time limit of the study that did not allow investigating a range of software.

Delimitation: Personal experience and bias from the researcher towards the software might have influenced the experiments due to the researcher's familiarity with Microsoft Axapta 2012. Quantitative testing was limited to tests identified from the gap and Requirement Analysis and considered feasible for this study. Qualitative testing is based on the opinion of the researcher and might contain some degree of bias in this regards based on personal experience. The researcher conducted qualitative and quantitative testing as laboratory and desk research to avoid the influence of participant's own understanding of the philosophies of ERP and Lean. Tests were limited to ten tests before and after improvements in order to limit the effect of a learning curve on how to operate the functions and improved skill of data entry through repetition.

1.10 ASSUMPTIONS

The researcher considered the following assumptions during the conduct of this research:

A. Most of the influential ERP software has similar functions:

The study is conducted with the assumption that most of the top software vendors have similar functionalities based on Gupta and Kohli's (2006) estimate that features of the top four vendors overlap at approximately by 60-70%. Therefore the results of this study can be assumed independent of a particular vendor's software.

B. ERP and Lean implementations are not limited to a specific industry or size:

The study is not limited to a specific industry or size of organization. The assumption is that the ERP software is suitably generic for the tested functionalities.

C. ERP and Lean implementations are not limited to organizational and management objectives:

Organizational and management objectives for the implementation of an ERP system and Lean philosophy is not being researched and it is assumed that there will be differences in this regard in practice.

D. The ERP software is independent of the IT infrastructure and hardware requirements:

The research was conducted with the assumption that the available IT infrastructure and hardware requirements required by the ERP software is independent from each other and is assumed not to have an influence on the results of the study.

E. Users and managers of ERP systems and Lean systems have the required skills and training to operate ERP systems:

The focus of the study is primarily on the functions within the ERP software and not the interaction between the user and machine. The assumption is that users and managers of ERP systems have the required skills and training to operate the system according to the offered functionality as intended by the vendors.

1.11 SUMMARY OF CHAPTER ONE

Understanding how to design ERP systems supporting the philosophy of Lean seems to be an understudied area in ERP and Lean systems research. Considering that ERP and Lean are essentially apposing philosophies with ERP supporting "push" action and Lean supporting "pull" action, the author believes that the underlying design of modern ERP systems might contain compatible elements of Lean operation principles and therefore does not render ERP and Lean mutually exclusive. An investigation and in-depth literature review is supporting the belief that such a study has not been conducted within the ERP and Lean arena.

Based on the stated research question, the researcher proposes a multi-methodological research method, extended to include system analysis tools, as a suitable research methodology to answer the research question. The expectation is that the outcome of the study will further give insight in identification and development of a Lean ERP framework for designing modules to support Lean operations. Furthermore, such a framework will assist in proposing a system architecture that can support Lean operations. The framework could also assist users of Lean operations in a global industry to improve their ERP systems to be Lean.

Furthermore, the result of the study could be in support of either of the two opposing points of view, providing a valuable contribution to the body of knowledge in the area of ERP and Lean system research. In the following chapter, the research investigates the related literature in order to illuminate and gain insight into the relevant literature domains.

Chapters Three and Four will focus on presenting the research design and the data collected during the research respectively. In Chapter Five the research results will be synthesized and integrated with the findings in respect to the research question. Chapter Five also introduces the new contribution to the ERP and Lean body of knowledge as a proposed framework. Chapter Six concludes with a summary of the study and the achievement as well as proposing a number of recommendations for future research.

CHAPTER TWO

LITERATURE REVIEW

CHAPTER TWO – LITERATURE REVIEW

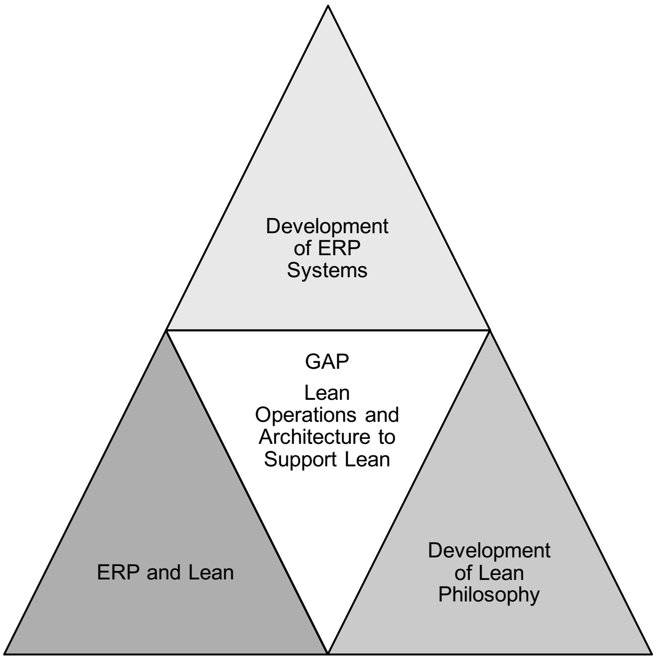
2.0 OVERVIEW

The thesis is grounded in the scholarly works of influential writers in the field of Lean manufacturing and Enterprise Resource Planning (ERP). The literature review is a general overview of the available literature in the relevant field of study with respect to the research question at hand. The literature falls within the following general topics:

- The Development of ERP Systems
- The Development of the Lean Philosophy
- ERP and Lean
- Lean Operations
- Architecture to Support Lean

The literature will attempt to identify the apparent gaps that exist in the available literature as presented in Figure 2.0:

FIGURE 2.0
IDENTIFY THE GAP



Source: Chalil du Plessis, 2013

Prominent authors within the field of study include authors such as: D. Bartholomew, T. Davenport, R.W. Goddard, J.P. Womack, D. Roos, D.T. Jones, J. Liker and Taiichi Ohno.

2.1 THE DEVELOPMENT OF ERP SYSTEMS

The development of ERP systems began with the development of Material Requirement Planning (MRP) in the early 1950s when software was designed to improve the calculation of material requirements in the manufacturing process and to streamline the ordering process of raw materials. During the 1970s MRP developed into Manufacturing Resource Planning (MRPII) by adding more functionality to MRP software such as: sales planning, capacity management and scheduling of production. Computer Integrated Manufacturing (CIM) emerged as the next step in the 1980s by embedding technical functions of product development and the production process in the MRPII system, as well as the development of additional functions such as computer aided engineering and computer aided design, integrated with business, administrative and technical functions. (Klaus, Rosemann, & Gable, 2000) During the 1990s MRPII expanded into a concept of a totally integrated enterprise solution into what is known today as enterprise resource planning or ERP, a term coined by the Gartner Group of Stamford, Connecticut, USA (Chen, 2001).

2.1.1 Definition for ERP

An agreed upon definition for ERP by academia seems to be elusive even after more than two decades since Gartner coined the term in the early 1990s. Several authors have proposed definitions for ERP and exploring the literature for a number of these definitions indicates how academia perceives ERP systems today. These definitions also give an indication of the development that occurred in the ERP arena. The following literature review highlights the difference of opinion amongst academia on the nature and definition of ERP.

Gartner coined the term ERP envisioning that the MRP systems at the time should be developing beyond the extent of the previously defined MRP II. Gartner defined the primary criteria of ERP as software that will integrate across and between functions. Software vendors embraced and invested in Gartner's ERP concept and by 1999 J.D. Edwards, Oracle, Peoplesoft, Baan and SAP controlled the ERP market (Jacobs & Weston, 2007). A decade later, Klaus et al. (2000) conducted an analysis in the form of an expert opinion survey amongst twelve notable researchers in the ERP, asking them to provide their own definition of ERP. From the respondents, nine different points of view were received. They do; however, come to the conclusion that it seems that IS adopted the name of ERP and is a commonly used term for "integrated business application packages." Klaus et al. (2000) defines packaged business application software as software solutions with the aim of integrating all automated functions and processes of a business utilizing a single architecture to provide a holistic point of view. The definition by Klaus et al. (2000) is similar to the criteria set out originally by Gartner but interestingly defined as "packaged" software. Three different perspectives also developed out of ERP according to Klaus et al. (2000):

1. The perspective of computer software as a product or a commodity retailed and commercially sold by a vendor as a predefined package. Carr (2003) also refers to the commoditization of software and computers.
2. The perspective of developing software to map processes and data of an organization into a comprehensive integrated framework.
3. ERP systems form a key component of a business infrastructure.

Klaus et al. (2000) further define the following as characteristics of an ERP system:

- ERP is a package of generic software that is configurable to the requirements of a wide range of industries, contains preconfigured templates for a particular industry or for the user as software to configure to their personal requirements.
- ERP is a standard software package and have a rich potential of customization. Customization is the process of tailoring the software to specific requirement of a business during deployment.
- ERP is application software differentiated from other software such as database management, middleware and operating systems.
- The basis of ERP software is an underlying integrated database that stores the transactional data and master data.
- The main feature of ERP is that the solutions support the core business processes of the business and administrative functionalities.
- Frequency and repetition of its use supports recurring business processes.
- A technical feature of ERP is the use of a consistent graphical user interface (GUI) across all the application areas.
- Most ERP systems consist of three-tier client-server architecture with a database, application or business logic and presentation layer.
- The complexity of ERP requires adequate administration modules such as user administration, database configuration, systems monitoring and performance management due to the large volume of transactions.

Davenport (1998) describes an enterprise system (ES) as a configurable, modular system that allows a company to integrate data through a single database and streamline data flow throughout the entire organization providing management with access to real-time information. However, Davenport does not use the term ERP, only in passing does he refers to ERP as “also commonly referred to as enterprise resource planning, or ERP systems” (Davenport, 1998). He prefers using the term ES even though the term ERP has been in use for almost a decade. According to Davenport (2000, p. 2) ERP is a clumsy reference to the origins of MRP and that enterprise systems have grown beyond the original concept of “resource planning” and does not only consist of “resource planning” software as the acronym ERP refers to.

Wallace and Kremzar (2001) in their book *ERP Making it Happen,* also argue against the use of the terminology Enterprise Resource Planning (ERP) to describe what they refer to as “enterprise wide transaction processing software”. According to Wallace and Kremzar (2001), ERP should be used in the context of all systems and processes throughout an enterprise that contributes to the activity of “resource planning”. Wallace and Kremzar (2001) remark that using the acronym ERP referring to enterprise software as “sloppy terminology” and they prefer not to use the acronym ERP in reference to enterprise systems. Wallace and Kremzar (2001) propose to use the acronym ES for Enterprise Software arguing the software supports the activity of resource planning and does not truly execute resource planning (p. 3). This is a similar criticism used by Davenport (2000). Based on this distinction between ERP and ES (Wallace & Kremzar, 2001) classify typical business processes of an organization as follows presented in Table 2.1.1:

TABLE 2.1.1 WALLACE AND KREMZAR'S ERP PROCESSES		
ERP PROCESSES NOT PART OF A TYPICAL ES:	ERP PROCESSES FOUND IN A TYPICAL ES:	NON-ERP PROCESSES FOUND IN A TYPICAL ES:
Sales Forecasting	Master Production Scheduling	Accounts Receivable
Sales and Operations Planning	Rough-Cut Capacity Planning	Accounts Payable
Advanced Planning Systems	Material Requirements Planning	General Ledger
Supplier Rating Systems	Capacity Requirements Planning	Cash Management
Performance Metrics	Distribution Requirements Planning	Customer Relations Management
	Customer Order Entry and Promising	Human Resources
		Data Warehousing
Source Adapted: (Wallace & Kremzar, 2001,p 4)		

Wallace and Kremzar (2001) make a distinction between ES and ERP and they regard ERP as those processes specifically to production contained within the ES. A number of the processes such as Sales Forecasting, planning systems, Supplier Rating and Performance Metrics are considered as part of an ERP system however are not included in the ES. Wallace and Kremzar (2001) propose a more comprehensive definition for ERP as "management tools" and not explicitly as software, however they are referring to an ERP as the foundation to e-commerce. They attempt to clarify ERP from a production and supply chain point of view regardless of them being software systems or not (p. 5).

Rashid, Hossain and Patrick (2002) define ERP systems as “software for business management” and encompass software modules used within all of the functional areas in an organization. This definition of ERP by Rashid et al. (2002) ignores the distinction between ERP and ES followed by Wallace and Kremzar (2001). Rashid et al. (2002) characterize an ERP system as follows:

1. The design is modular in nature with modules typically defined such as financial, manufacturing, accounting and distribution.
2. A common centralized database management system (DBMS) is present to manage the shared data.
3. The integration between modules is seamless providing transparency through standard interfaces.
4. The systems are generally complex and costly.
5. They have adaptable business processes and include best business practices.
6. Integration to the company’s business functions requires time-consuming tailoring and system configuration.
7. The modules allow for real time data processing in batch and online processing modes.

8. The systems are Internet enabled or in the process of development.

Shanks, Seddon and Willcocks (2003) in a collection of articles, *Second-wave Enterprise Resource Planning Systems Implementation and Effectiveness*, view ERP as a class in a collective group of enterprise software called Enterprise System Software (ESS). The following classes of system software such as enterprise resource planning (ERP), customer relationship management (CRM), supply chain management (SCM), product life cycle management (PLM), enterprise application integration (EAI), data warehousing and decision support, intelligent presentation layer, and e-Procurement, e-Marketplace and electronic exchange software are contained within ESS. (p. 2)

Shang and Seddon (in Shanks et al., 2003), define ERP as application software modules packaged as semi-finished, configurable products imbedded with pre-defined best practices and the ability to define new operational and managerial processes forming the primary engine for integration of information technology, data and processes, in real-time, across external and internal value chains (Shanks et al., 2003, p. 75).

In defining ERP, Shang and Seddon has moved away from the original meaning of the acronym namely “Enterprise Resource Planning” and focus on integration of data, processes and information technology across the internal and external value chains of an organization. This definition seems to be suitably generic to be able to include any development of software modules in the future without being restrictive to “resource planning” per se as the definitions from previously mentioned authors.

Shehab, Sharp, Supramaniam and Spedding (2004) define an ERP system as an integrated collection of software used as a business management system to manage and integrate the business functions of an organization. In this definition the emphasis is not on enterprise, resource or planning but on the collaborative functionality of sets of software very similar to the definition of ERP proposed by Shanks et al. (2003).

A more recent definition of ERP by Monk and Wagner (2009) emphasize ERP as facilitating the input and output of business processes in an organization. Their definition defines ERP as “core” software to coordinate information across an organization through managing the business processes. The ERP system support business processes by integrating the business task across related business areas through utilizing a common database and extracting output through common management reporting tools (Monk & Wagner, 2009, p. 1).

To use the phrase ERP for the purpose of the research would be acceptable to understand the concept of integration between business application packages. Whether the application of ERP is in a single company or as a global concept would be irrelevant as a literal interpretation but rather how we would apply the concept. It might be valid to still use the phrase ERP even though it has more functionality or changed functionality (Klaus et al., 2000).

The following subsection will review the evolutionary nature of ERP system and its development in relation to its functionality.

2.1.2 Overview of the evolution of ERP

Legacy programming languages such as COBOL, ALGOL and FORTRAN were used during the 1960s by organizations to develop and implement primarily the automation of inventory control systems and in the following decade the attention moved to production and material requirement planning (MRP) based on the master production schedule (Rashid et al., 2002). MRP systems were later improved to include ordering of materials and components for the manufacturing process by applying the logic of the universal manufacturing equation in the MRP system (Wallace & Kremzar, 2001, p. 6). Even though hardware and software developed during the 1960s and 1970s changed the way computers were applied in business, they were not developed sufficiently to provide integrated, real time systems for decision making. The rapid development of the computer hardware and software during the 1970s as described by Moore’s Law, doubling the capabilities of the computer chip every eighteen months, allowed for more sophisticated software to be developed such as relational databases to store, retrieve and analyze large sets of data (Monk & Wagner, 2009, p. 19). Furthermore, the concept of the spreadsheet developed allowing complex business analysis to be performed by managers without having to do programming (Monk & Wagner, 2009, p. 20). In 1972 the founders of SAP, today a leading ERP vendor, set their goal to develop a standard configurable software to fit the needs of every company as well as a software where systems will be available to users via computer screens accessing data in real-time (Monk & Wagner, 2009, p. 24).

Development during the 1980s placed the emphasis on synchronization of material and production requirement thereby optimizing the production processes. MRP expanded during the 1980s from being a material planning and control system to encompass planning of almost all resources of an organization. Wight (as cited in Chen, 2001) named this phenomena MRPII in order to distinguish it from the earlier MRP. The development during the MRPII-era widened the scope of development to include areas such as shop floor and distribution management, project management, finance, human resource management and engineering (Rashid et al., 2002). MRPII evolved out of the close-loop MRP adding the following functionality:

- Sales and Operational Planning: provides management greater control over the operational aspect of the business by addition of processes to balance the supply and demand.
- Financial: translation of the operational plan expressed in units into financial terms by incorporating monetary values of inventory.

- Simulation: generation of a “what-if” scenario in units and currency on an aggregate or “rough-cut” basis (Wallace & Kremzar, 2001, p. 9 & 10).

Enterprise resource planning (ERP) made its appearance during the late 1980s beginning of the 1990s introducing enterprise wide integrated business processes including manufacturing, distribution, accounting, financial, human resource management, project management, inventory management, service and maintenance, and transportation providing more accessibility, visibility and consistency to the business processes of an organization (Rashid et al., 2002). One of the key differences between MRP II and ERP is that ERP was designed for plan and control of business functions across an enterprise not only in the manufacturing sector but also for companies in all sectors (Aslan, Stevenson, & Hendry, 2012).

Companies are generally organized in areas of functionality: Marketing and Sales, Accounting and Finance, Human Resource Management and Supply Chain Management (Monk & Wagner, 2009, p. 2). The inefficiency of the functional business model developed by General Motors’ Alfred P. Sloan during the 1930s, where information flow between operating group is via the top management, causes silos of information that restrict the flow of information between operating levels (Monk & Wagner, 2009, p. 22). During the 1990s business starts to abandon this model in favor of process-orientated models that promotes flow of information across functions. With the economic pressures of the late 1980s, managers were considering ERP systems as a way to solve their business problems (Monk &

Wagner, 2009, p. 23). Vendors were addressing these business requirements by extending the functionality of the core modules during the 1990s adding Advanced Planning and Scheduling (APS), Customer Relationship Management (CRM) and Supply Chain Management (SCM). These modules became known as "extended ERP" (Rashid et al., 2002). Today ERP systems such as SAP and other vendor software ensure high levels of data quality in a company by providing a single data entry process to the same database for all systems in the company minimizing human interaction to eliminate frequent mistakes (Monk & Wagner, 2009, p. 26). Due to their historical background, vendors built up their expertise over the years in different business areas such as SAP in logistics, Baan in manufacturing, Peoplesoft in human resource management and Oracle in financial management (Rashid et al., 2002).

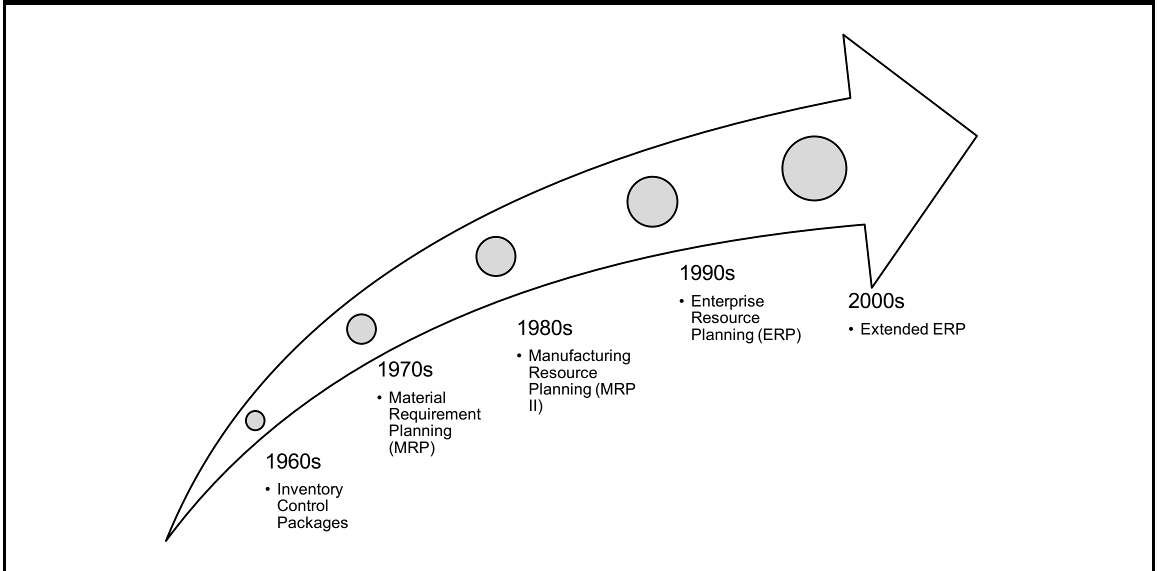
A number of factors influenced the development of ERP:

- According to Moore's Law speed and power of hardware and software increased and at the same time cost and size decreased.
- Multiple users could access common data through the earlier development of the client-server architecture.
- Software became increasingly more sophisticated throughout the integration of financial information and the manufacturing resource planning.
- Business managers demanded more efficient information systems to manage larger, more complex and competitive businesses.

- Software companies such as SAP develop the concept of a modular ERP whereby real-time data sharing takes place through a common database integrating all operations of a business. Typical software modules are Sales and Distribution, Materials Management, Productions Planning, Quality Management and Financial Management (Monk & Wagner, 2009, p. 43).

Rashid et al. (2002) summarize the historical events related to ERP in the following Figure 2.1.2:

FIGURE 2.1.2
ERP EVOLUTION



Source: Rashid et al. (2002)

The following phase of development after ERP was again coined by Garner as ERP II (Bond et al., 2000). Ross, Vitale and Willcocks in their article: *The Continuing ERP Revolution: Sustainable Lessons, New Modes of Delivery,* define a "second wave" or

ERP II as a strategy of developing and deploying applications to expand the current deployed ERP system's functionalities through the integration of internal and external collaborative, operational and financial processes (in Shanks et al., 2003, p. 115). The following section will discuss ERP II in more details from the perspective of the philosophy of ERP.

2.1.3 Evolution of ERP Philosophy

The previous sections discussed defining ERP and the apparent evolution of ERP over the past five decades driven by the rapid changing technology and demand from business to expand the functionalities of the systems. The following subsections will explore the philosophy and principles that seems to have developed through this apparent development of ERP. This section will also indicate the current and future developments how the underlying philosophy and principles are evolving and adapting to global demand.

2.1.3.1 Pre-ERP and ERP

Before ERP as a term was established, literature generally referred to systems used in an organization as Management Information Systems (MIS). After Gartner established the term ERP in 1990 most of the literature tend to use the term ERP as a generic reference to systems used in an organization or enterprise as discussed in the earlier sections. Senn (1978) describes MIS as a system, and this does not necessarily assume to be a computerized system, that condenses and filters data in an organized fashion to the point that information becomes useful, reliable, accurate and timely in the decision making process at several levels of the organization at reasonable cost. Earlier literature establishes the following MIS principles:

- A management information system is a combination of information systems from the different functional areas in an organization.
- The database forms the foundation of an MIS and facilitates the integration of the information systems between the different functional areas. However, as a management tool the MIS requires control to ensure the reliability, integrity and adaptability.
- The primary focus when developing a management information system should be on the systems that are supporting the primary revenue streams of the organization.
- The structure of a management information system significantly impacts managerial decision effectiveness (Senn, 1978).

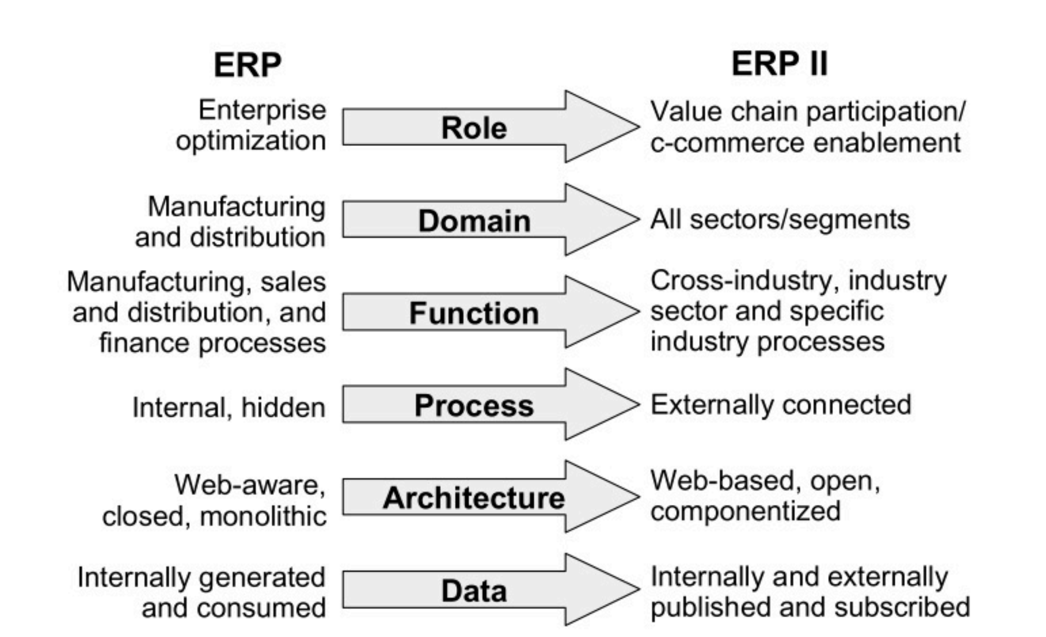
Integrated ERP software today is a complex combination and integration of software and hardware managing all the different functional areas of an organization. It only became feasible during the 1990s when software and hardware evolved sufficiently to support such complex systems. The vision of integrated information systems and the re-engineering of company structures from a functional to a business process focus also contributed to the development of ERP concepts (Monk & Wagner, 2009,

p. 19). Until recently the ERP philosophy is still described as software attempting to integrate departments and application modules to be a single system with a central database from where all departments stores and retrieves information (Halgeri et al., 2010). On the other hand Krause (2007) explains the philosophy of ERP from a different point of view. According to Krause (2007), ERP grew out of accounting logic of controlling all functions of an organization and to provide audit trails and cost accounting to management of an organization. Subsequently, the development of software is based on this logic and eventually became the dominant philosophy of entire ERP systems.

2.1.3.2 ERP II

Almost a decade after the original definition of ERP was defined, Gartner declared the beginning of a new chapter in the life of ERP systems as “ERP II” (Bond et al., 2000). According to Bond et al. (2000) there was a need to redefine ERP’s role towards a culture of collaboration with other enterprises and not only the application of e-commerce for trading between companies. Enterprises were starting to position themselves away from vertically integrated organization towards agile, core competency based enterprises within the supply chain and value network. Bond et al. (2000) also defines c-commerce, or collaborative commerce, as the electronic, business orientated interaction between organizations, personnel and that of its trading partners and customers within the trading community. Gartner also proposes an “ERP II” framework whereby they are envisioning that by 2005 ERP will move from an introspective organization focusing on integrating and optimizing its own processes and systems to an "extrospective" organization, collaborating on the levels of role, domain, function, process, architecture and data with other organizations (Bond et al., 2000). Figure 2.1.3.2 A depicts the framework as proposed by Gartner:

FIGURE 2.1.3.2 A
ERP II DEFINITION FRAMEWORK ERP



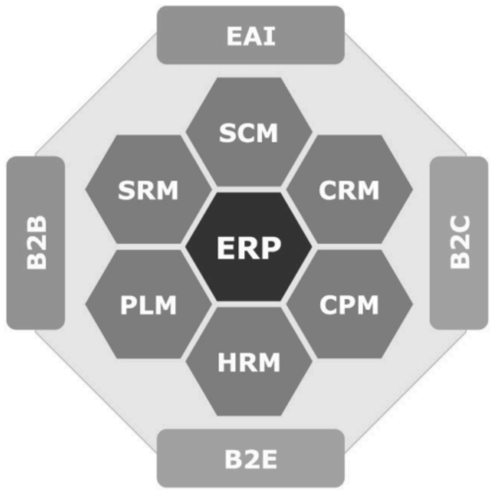
Source: Gartner in Bond et al. (2000)

Leading vendors adopted this new philosophy in the design of their ERP packages through redesigning their architecture and modularization of the ERP into e-business and collaboration modules in the supply chain. However, new technologies were not necessary the inventions of the ERP vendors themselves but often that of other vendors that have been incorporated into their ERP software such as .NET and J2EE, Oracle and MS-SQL databases and business intelligence tools based on

OLAP technology. XML standards were also incorporated into the ERP infrastructures (Møller, 2005). Contrary to this view Pollock and Williams in their book *Software and Organization*, explain the development to ERP II not as a radical shift as Gartner proposed but rather as an incremental development through adding on of functions by vendors to their existing ERP systems (Pollock & Williams, 2008, p. 58).

Møller (2005) illustrates the modular design of ERP II using the standard ERP as the base and collaboration modules or components with the following conceptual framework presented in Figure 2.1.3.2 B:

FIGURE 2.1.3.2 B
CONCEPTUAL FRAMEWORK FOR ERP II



Source: Møller (2005)

They further explain the framework as four layers in Table 2.1.3.2:

TABLE 2.1.3.2
THE FOUR LAYERS IN ERP II

Layer	Components	
Foundation	Core	Integrated database (DB) Application framework (AF)
Process	Central	Enterprise resource planning (ERP) Business process management (BPM)
Analytical	Corporate	Supply chain management (SCM) Customer relationship management (CRM) Supplier relationship management (SRM) Product lifecycle management (PLM) Employee lifecycle management (ELM) Corporate performance management (CPM)
Portal	Collaborative	Business-to-consumer (B2C) Business-to-business (B2B) Business-to-employee (B2E) Enterprise application integration (EAI)

Source: Møller (2005)

It is evident from the above table and the indicated components that ERP remains a part of the Process layer as a Central component. The portal layer consists of the collaborative layer decomposed to modules such as Business-to-Consumer (B2C), Business-to-Business (B2B), Business-to-Employee (B2E) and Enterprise application integration (EAI). These modules facilitate the communication and integration between the external actors such as customers, employees as well as external organizations and the ERP II (Bakry & Bakry, 2005; Møller, 2005; Shtub & Karni, 2009). These collaborative modules are therefore the outward facing modules of the enterprise or c-commerce as per the original Gartner definition (Aslan et al., 2012; Bond et al., 2000; Subramoniam, Nizar, Krishnankutty, & Gopalakrishnan, 2009).

The following sub-section will discuss a new evolving concept of ERP III indicating a morphing of the ERP philosophy towards a concept of virtual organizations.

2.1.3.3 ERP III

Organizations are continuously seeking to automate and extend the functionality of their ERP systems and vendors are trying to expand their products (Lõrincz, 2005). The evolution of ERP from the initial MRP systems to MRP II through to the current ERP II systems have changed the view of information systems from inward looking systems to outward collaborative systems as discussed in the previous section on ERP II. Concepts such as SOA (Service Orientated Architecture), also sometimes referred to as SaaS (Software as a Service), where reusable application services are developed that can be “plugged in” to other application to dynamically assemble new application show promise to extend the functionality of ERP II (Wood, 2007).

The concept of ERP III is not widely covered in the literature and in practice the term of ERP III is not frequently used. Knowledge is identified by Xu, Wang, Luo and Shi (2006) as an invisible asset of an enterprise and therefore knowledge has to be managed as an asset in the same way other assets of the organization are managed. Implementation of integrated knowledge management (KM) systems with ERP systems will give organization a strategic and competitive advantage in the market. This concept of KM and the ERP integration was proposed as ERP III (Li Da Xu, 2011). Wood (2007) also proposed a similar link between ERP II and KM as ERP III.

Wood argues that the “knowledge” or “know-how” of employees is an asset of the organization that can be captured and converted to ERP systems coupled with the ability to collaborate with the customer community comprises the next generation of business transformation as ERP III. Using this captured knowledge and SOA then allows an organization to develop a “learning organization” by developing re-usable application services based on the captured knowledge and apply them to various ERP applications.

Wood (2010) describes ERP III as the collaboration of internal and external data streams allowing the integration of fans and critics to become part of the extended ERP and ERP II of an organization. This integration beyond the normal customer and supplier often in dialogue form and exchange of information contribute to innovate, produce and sell better products or services. In context of this definition Wood (2010) describes ERP III as the formation of a “borderless enterprise” through the combination of a host of technical collaborative tools such as social media internet technology and SOA and analytical search engines. A simple example of the application of ERP III would be the use of social media software such as Facebook and the “Like” option to analyze customers and critics feedback on a product. Using this information the organization can innovate, produce and sell more customer centric products and services (Wood, 2010).

Wan and Clegg (2011) also offers a definition for ERP III being a future virtual enterprise structure with a flexible, yet powerful information system incorporating web-based SOA and cloud computing version, enabling virtual enterprises to have flexibility, agility and dynamic “amorphousness”. This structure would be able to integrate organizations across legal entities to include customers and the market place in general eventually forming a dialog between the customers, the organization’s ERP system and the vendors through application of technologies such as SOA, PaaS, SaaS and tools for Service Level Agreements (SLA) to engage the vendors in the sales cycle. This concept is similar to that of (Wood, 2010) describing the “borderless enterprise”, however the definition by Wan and Clegg (2011) is more comparable to what can be defined as a cloud based ERP (Saeed, Juell-Skielse, & Uppström, 2012).

From the two definitions offered by Wood (2010) and Wan & Clegg (2011) it is clear that the academia is still in the process of determining the nature of ERP III or what would be perceived as ERP III. Currently there is the KM and ERP philosophy of Wood and contra to this concept that of Wan and Clegg with a cloud and ERP concept. What is important that in both of these definitions are pointing to a direction of a virtual or borderless enterprise that encompasses primarily the collaboration of customers and vendors using service orientated technology integrated with an organization’s ERP system.

2.1.3.4 Global ERP Systems

The number of companies operating in the global environment is increasing constantly and with that the need for these companies to have a global view of their processes through the use of their ERP systems (Seidel & Back, 2009, 2011). As companies are decentralizing these organization are required to have multisite management and planning functionality (Shah & Mehta, 2011). Even though ERP systems have become an essential part of any organization's infrastructure, the use of ERP systems in a global environment brings several issues such as culture and local requirements as well as an impact on the balance achieved between the level of standardization and local requirements (Hawking, 2007). Country specific features that are required for an ERP include custom and excise taxes, revenue handling, commercial codes, financial and cost accounting, banking and bank account rules, legal environment and jurisdiction which might require levels of customization to the ERP system (Molnár, Szabó, & Benczúr, 2013; Veague, 2011). The influence on ERP systems in a global environment could be on several levels. ERP systems require adaptation and change on each of these levels according to the environment. (Molnár, 2011) mentions several of these levels as factors and their effect on the ERP system as shown in Table 2.1.3.4:

TABLE 2.1.3.4
GLOBALIZATION FACTORS AND THE EFFECT ON ERP SYSTEMS

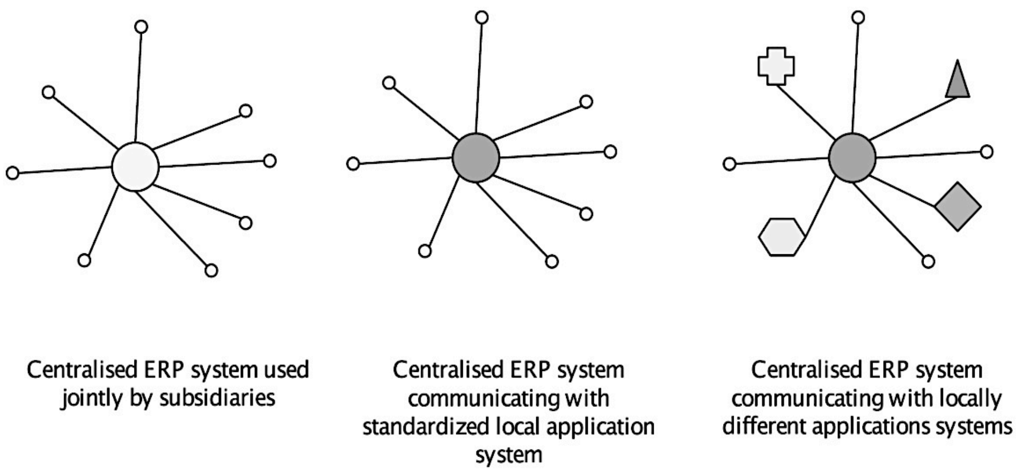
Factor	Description	Effect on ERP
Integration of Markets	Economic change demands integration and globalization and therefore changes in financial and operation business processes.	Change of business process causes change in ERP architecture
Integration between Operational and Administrative sites	Downsizing and re-allocation of operation to geographical different sites away from administrative functions	Re-organization of the ERP processes
Integration between suppliers, service providers and manufacturers	Development and integration of supply chains globally between manufacturer and commercial companies and enforces close cooperation	Coupling of ERP systems between manufacturer and commercial companies
Integration of multi-hardware and software components	Acquisitions, buyout and takeovers result in more homogeneous IT infrastructure	Re-engineering of business processes to adapt to changed software architectures

Source Adapted: Molnár (2011)

Based on the socio-technological architecture models proposed by Gronau in his article *Unternehmens mit ERP-Systemen*, (cited in Molnár, 2011), Molnár (2011) investigates and describe the global ERP tendencies for ERP architectures and found the main trends are developing as follows:

1. Systems are being standardized for the country specific application and integrated into to a central standardized ERP.
2. Certain business processes, business services and by implication the application services are standardized within a region.
3. Existing legacy systems are centralized within countries.
4. Standardization and centralization occurs generally where functions and services are strongly influenced by the country's market and volatility.

FIGURE 2.1.3.4 A
GRONAU'S BASIC MODELS OF COMMUNICATION FOR ENTERPRISE ARCHITECTURE OF ERP SYSTEMS

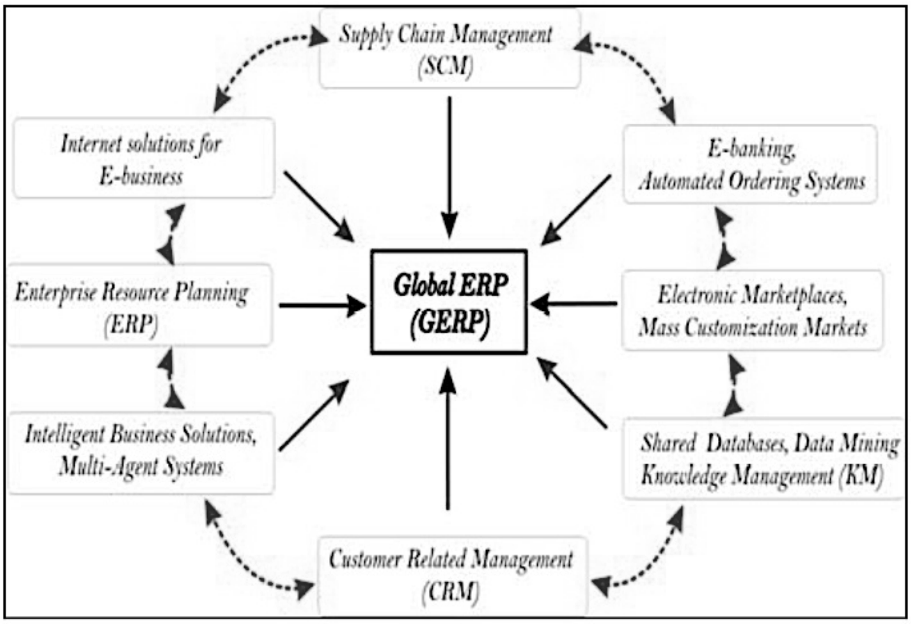


Source: Molnár (2011)

Gronau's basic model of a centralized ERP system would be the ideal if we apply the model to the earlier definitions of ERP as mentioned in section 2.1.1. Davenport's (1998) description of an enterprise system to be configurable, modular and with integrated data utilizing a single database matches the centralized model. However, (Molnár, 2011) comes to the conclusion that not only does Gronau's models of ERP architecture in Figure 2.1.3.4 A seems to apply in practice but also that there are a number of variant models emerging influenced by the local and global environment. Vendors intend to design a single instance ERP package with as much functionality to address global requirements however influences of an organization's business processes in a global context enforces hybrid architectures between that of country based applications and integrated standardized global ERP systems (Molnár, 2011). Molnár's (2011) research therefore strongly supports the evolving nature of ERP and its philosophy.

New concepts proposed are based on this evolving nature of ERP. One such concept is that of multi agent based ERP for use in a global ERP (GERP). In a global environment one of the areas that have to rely on such a concept will be SCM. Increased requirements with accelerated rates of demand from customers are leading to faster information demands on all the participants in a supply chain, and requires better ERP systems and tools to integrate the different parties. Telecommunications and the Internet technologies are most likely to provide the communication "back bone" for such a GERP in conjunction with standardization of processes to provide flexibility between organizations. Multi agents can provide the computing paradigms required to decentralize and share information but have to be developed on a global or worldwide basis (Akkermans, Bogerd, Yücesan, & Van Wassenhove, 2003; Plikynas, 2008). Figure 2.1.3.4 B indicates GERP and the related platforms:

FIGURE 2.1.3.4 B
GLOBAL ENTERPRISE RESOURCE PLANNING (GERP) AND RELATED PLATFORMS



Source: Plikynas (2008)

This approach is a further indication that the ERP philosophy is evolving from an enterprise centric view where the systems are all integrated to serve a particular organization to that of flowing of information and process orientated through multiple organizations and systems (Plikynas, 2010). Plikynas (2010) gives the example of a configurator where a combination of predefined options supports mass customization of products for customers. The configurator is software that translates the customer demand into an assemble-to-order process and then translated into the proper appropriate production order.

From the literature it is evident that the philosophy of ERP is evolving however in practice there still seem to be vendors that have not adopted these concepts. These vendors define a global ERP system as a system of standardized business systems across multiple countries with a single database in the system for reporting and consolidation purposes. The argument is that this will ensures that every stakeholder have a consistent view of the same data (Tan, 2010). Further reasons used for a single database and single instance of an application in a global ERP are the consolidation of IT assets in order to keep overhead cost down. Running a single instance of an application can ensure the consistent processes and data quality across a global organization. The use of a single application instance also provides management with a single data model across all global entities within the organization. An example would be the use of single part numbers across the global organization or where the customer number is universal regardless in which country the customers would be conducting business with the global organization (Veague, 2011). However Veague (2011) does agree that different models might apply influenced by the organization's business philosophy and that hybrid models do apply with some division running the same application but with different implementation model or even different applications suitable to their requirements. Gartner refers to this model as a federated approach whereby each entity is supporting their own instance of ERP and the use of data synchronization between these instances to form a consolidated ERP (Hestermann, Pang, & Montgomery, 2012). Veague (2011) cautions against such extreme models as they are inherently a one-way street for extracting and analyzing data, pulling data from the diverse application databases to a single database such as a data warehouse. To keep the consistency between the transactional data and the data warehouse can be difficult task and the auditability of data between the source and data warehouse could be affected.

The following section will introduce the development of the ERP database concepts in relationship to the philosophy of ERP.

2.1.4 Development of ERP Database Concepts

ERP systems are generally supported by relational database technology allowing the ERP software vendors to develop the required flexibility in the business logic and database structure, supporting implementation of multiple modules in parallel (Shehab et al., 2004).

Most of the definitions for ERP refer to the requirement of a single database to enable the tight integration of company-wide business processes. By the mid-1980s the technology know as database management system (DBMS) existed to allow a single database to hold a large amount of data in an organized fashion and to retrieve the data easily from such a large database (Monk & Wagner, 2009).

Earlier database structures for computerized accounting systems followed the traditional model of double-entry accounting described by Pacioli during the renaissance period (Ferran & Salim, 2011). These principles are still followed by many of the accounting systems of the most well-know ERP systems such as Oracle Financial and SAP (Ferran & Salim, 2011).

Ferran and Salim (2011) argue that the traditional model of accounting and therefore the database structure have lost its validity in term of data duplication throughout the databases of an accounting system. Traditionally accounting data is a summary of data contained in subsystems and therefore becomes redundant in a computerized system where computers can easily recalculate totals every time. Vendors generally describe these subsystems today by ERP vendors as modules of an ERP system such as financial, operational, supply chain and manufacturing. This concept is in line with the principle of Lean to reduce waste and in this case the reduction of waste in inventory if we draw a parallel of database entries as “information Inventory”. This concept will also be applicable as continuous improvement of a system to add to customer value. Reducing transactions in the database, less IT resources are requires such as storage space and therefore reducing costs. A further argument by Ferran and Salim (2011) is that the traditional accounting database design requires cross referencing between transactional tables and updating of summary tables every time a transaction occurs. This makes the transaction process longer and has the possibility of inconsistencies between primary information of account details and summary data. Ferran and Salim (2011) further explain that the concept of double entry as per se is not a redundancy however the physical storage of the separate double entry is a redundancy. The redundancy can be easily explained through two examples: (1) Invoice header information and customer statement and (2) Accounts Payable (AP) or Accounts Receivables (AR) and Cash or Bank Ledger (BL). Invoice header information such as customer ID and address would be a redundancy in the invoice header table and the customer table. A similar redundancy would exist between AP, AR and BL as customer or Vendor ID, date and document number of the cash transaction. Ferran and Salim (2011) describe their Items, Agents and Cash (IAC) model as a reclassification of the traditional accounting entities of Assets, Liabilities, Capital, Revenue and Expenses into Items, Agents and Cash. Their argument is that this reclassification reduces the number of tables to two physical databases (Agent and Items) and one logical table (Cash). Furthermore, their IAC model reduces the redundancies in the database with added benefits such as faster response time, reduction in storage space and cutting out the redundancy between the ledger and the sub-ledgers. A further advantage according to Ferran and Salim (2011) of the IAC model is for the application programmer since the number of tables as well as the number of development tasks are reduced. The authors claim that the IAC model has been in use at more than fifty companies for the past three years. At the time of the literature review there was not any further evidence or literature available with more in-depth research of the IAC method. However, what it does indicate is that ERP systems and systems database design is inherited from a traditional method where transactions were recorded by hand in physical ledger and sub-ledgers. Instead of redesigning the model to fit new technology of databases and software programs, the model was kept and technology was adapted to fit the model. This inherently contains a large amount of potential waste than can be eliminated from ERP systems.

The following section will review some of the recent forms of architecture used to support ERP systems.

2.1.5 Architectures to Support ERP

Web services or service-oriented architecture (SOA) is software that allows software to transfer data between systems without developing complex software links. The concept of SOA relies on the use of open standards between software developers making it possible to develop reusable code and simplifies integration of software therefore reducing cost and time of development and implementations. This method is growing in popularity amongst vendors and customers of ERP. IT analyst group Ovum, reported twenty percent of U.S. Companies using SOA during their implementations experienced “unexpected complicity” (Monk & Wagner, 2009, p.42, p. 224).

B2B e-commerce and exchanging business data electronically between companies is not a recent concept. Transfer of standard business documents from computer to computer electronically through telephone lines has been in existence since the 1960s through systems known as electronic data inter-change (EDI). This method of data interchange was expensive since only a limited number of service providers were able to provide the service to companies. However, internet based procurement and on-line buying and selling through websites are becoming popular since they are less expensive and suppliers often offers competitive pricing if purchases are made through their websites. An effective use of this method would be to feed the orders from the website electronically into the ERP system. Extensible Markup Language (XML), a programming language used to design web-sites on the internet, makes it possible to program tagged data that can be transferred directly to a database such as the ERP database without conversion through a middleware or re-entering the data. (Monk & Wagner, 2009, pp. 212-213, p. 215, pp. 228-229).

Application service providers (ASP) are generally fee based service companies providing applications through a network such as the Internet. This allows companies to outsource applications such as e-mail, accounting and other software. A familiar example offer for free for personal use would be e-mail through the internet such as Yahoo and Google Mail (Monk & Wagner, 2009, p. 217)

Enterprise Portal allows a company to give users access to their systems through a central access point with a secure link through a web browser. These enterprise portals allow the user to "personalize" his portal access through shortcuts to most frequently used software applications such as the ERP system and other useful electronic information such as calendars, financial metrics and stock market (Monk & Wagner, 2009, p. 224).

Radio frequency identification technology (RFID) is used within the ERP architecture to effectively track physical items moving through a supply chain. An RFID tag is a small physical device containing a microprocessor and antenna. An RFID reader can transmit and receive radio signals to and from the tag. Information from the tag can then be transferred to other systems such as the ERP system for example item codes, description and position in a supply chain or in a ware-house (Monk & Wagner, 2009, p. 230).

The following section will discuss potential problems during the implementation of ERP systems as well as concepts used to measure the success of an ERP system in an organization.

2.1.6 Success of an Integrated ERP Implementation

Davenport (1998) argues that fragmented systems in a company are directly responsible for high costs caused by the cost of data storage, rekeying and reformatting of data, updating of obsolete code and automated transfer of data between systems. Integrated system such as enterprise systems (ES), or ERP, solves the problem of fragmented systems. Davenport (1998) describes an integrated system as having one central database. Davenport (1998) further argues that an ES is largely dependent on configuration options build into the system. This allows the system configuration to be as close as possible for the best fit for the company's business requirements. The question is what if this is not the case? Two situations are possible with neither as the ideal situation. One is to rewrite some of the ES code or two, using the existing systems and rather design interfaces to the ES. Both these options are expensive and time consuming. This can affect the integration integrity of the ES.

Davenport (1998) claims that the higher the degree of customization, the lesser the degree of seamless communication with suppliers and customers. This could be the case even where the suppliers and customers use the same ES systems and seamless integration is possible to a high degree but seamless integration is weakened by customization of the supplier or customer ES. However, with standards such as XML, HTML and SOA this might not entirely be the case today. These standards facilitate the integration between disparate systems.

A centralized database design could possibly lock an organization to particular vendor software. The business logic design of system modules often requires the use of a centralized database design therefore forcing an organization to only make use of a particular vendor's software. As Shehab et al. (2004) point out, this does not necessary mean that all the system modules are of the best quality (best-of-breed) or reflects best practice. Therefore, a centralized database is not necessary part of the definition for ES or ERP. Davenport's (1998) definition of an ERP seems to be strongly influenced by the particular software design used by SAP R/3 in the case studies referenced in his article. SAP uses a single database for integrating all their modules. This is not necessary the case for all ERP systems such as Microsoft Dynamics, Sage and Oracle to name a few. The core modules might be using a single database but add-on modules often designed by third party software designer will be controlling their own databases. Integration is not done on database level but rather on an application level through an STK (Software Tool Kit) or web parts from the original vendor. Web parts allow any software to communicate to another by simply providing data in a predefined format to the vendor software. In practice it is often a rule of thumb that when designing integration between different systems, not to write to a foreign database but go through the business logic using integration software supplied by the designers of a software. This could be a simple import function.

Shehab et al. (2004) categorize the implementation of an ERP system according to different primary objectives however a number of the categories requires the implementation of integrated systems for example business process re-engineering (BPR), attempts to eliminate organizational and technical bottlenecks, quality improvement of data, integration of business processes and the reduction in stand-alone systems and interfaces. The evidence is growing pointing to increase in cost and overrun of ERP implementation projects where generic off-the-shelf business software are adapted to company and national cultures (Shehab et al., 2004).

Measuring the return on investment (ROI), a popular measuring term for ERP investments, can be measured and interpreted in a number of ways:

- An ERP system if implemented can increase productivity through faster production and reduction in operating expenses through eliminating redundant and duplicated data. An important question is how to measure the monetary value for the “competitive edge” of a company with ERP against that of the company without an ERP.
- An ERP system can save employees, customers and suppliers much frustration and time. This is an obvious benefits but rather difficult to convert to a monetary value.
- Cost savings and increase in revenue are effect of an ERP investment that can occur over a number of years and is hard to measure the exact monetary value accrued.
- To isolate the exact effect of an ERP implementation that often takes a number of years is very difficult to quantify and to determine how it is affecting the cost and profitability of a company.
- Availability of real time data for communication with customers provided by an ERP system improves customer relationships and increase sales (Monk & Wagner, 2009, p. 36)

Researchers do not agree on which indicators to use in measuring a complex system such as ERP. A common approach to measure success is using financial key performance indicators (KPI’s) as proposed by Matolcsy (as cited in Wieder, Booth, Matolcsy, & Ossimitz, 2006; Snyder & Hamdan, 2010). Snyder and Hamdan (2010) comes to the conclusion that longer time frames and more accurate measurement tools need to be devised to accurately measure the implementation success of ERP.

Wieder et al. (2006) set out in their research the objective to challenge the existing claim by ERP vendors as to the benefits of their products. Through their literature review they found that recent examples of accounting research investigating the impact of ERP on the performance of organizations provided valuable insight however, they were similar in their research approach through:

- The use of publicly available financial data such as published financial reports.
- The studies do not distinguish between measuring the business performance and measuring business process performance.
- Depended variables used are only the adoption of the ERP and the time of adoption.

Wieder et al. (2006) argues that this approach is not sufficient to measure the success and calls for a more complete approach. They based their study on a model framework proposed by Dehning and Richardson (as cited in Wieder et al., 2006) to develop a performance measurement model. The model essentially focuses in three areas of measurement namely: IT-measures, business process performance and firm or company performance measure. Using a survey with a final sample size of one hundred and two companies in the Australian market and testing six predefined predictions, the results were rather surprising on business process level or overall company level in that no significant performance improvement were found between companies adopting ERP and those that did not adopt an ERP. The study contradicts the claim from vendors that ERP implementation will improve a company's performance. However, their findings indicates that those companies that implemented ERP and SCM have increased business process performance in comparison to those companies not adopting both ERP and SCM.

Goeke and Faley (2009) approached their research by measuring the success factor of ERP implementation using the gross margin of the companies. This approach seems to be unique since they could not find any other comparable research available based on the gross margin to measure the business value of ERP investment. Selecting the "SAP successes" from the SAP case studies and using the company's published financial data for a period of three years pre-installation and three years of post-implementation to compare, they found in support of their hypothesis, the gross margin improved however there was no improvement in the operating margin.

Saira, Zariyawati and Annuar (2010) research investigated the effect of information system adoption on Malaysian SBE's measuring performance as an indicator. The objective of their study was to show that the adoption of an information system by SME's, provides businesses with the right capabilities and resources to face competitive pressure therefore improving business efficiency. The result from the study supports that the use if accounting systems did increase the performance of SME's (Saira et al., 2010).

The following section will discuss the development of the Lean philosophy and the concept of computerization.

2.2 THE DEVELOPMENT OF LEAN PHILOSOPHY

2.2.1 History of Toyota Production System

One of the most influential and widely cited books in operations management is *The Machine that Changed the World* by Womack and Jones (Holweg, 2007). Their book was the result of five years of research at the MIT International Motor Vehicle Program (IMVP), investigating and describing the Toyota Production System or TPS. Taiichi Ohno and Eiji Toyoda pioneered TPS after World War II during the Japanese economic recession. Womack and Jones compared TPS with the mass production systems developed by Henry Ford and Alfred Sloan after World War I (Womack, Jones, & Roos, 1990). The research led to the inception of the phrase “Lean production” that was coined by one of the IMVP researchers, John Krafcik, for this unique system designed by Ohno and Toyoda since it uses less of everything compared with a mass production system (Holweg, 2007; Womack et al., 1990). The basic idea of the Toyota production system or Lean production is “absolute elimination of waste” and that there are two pillars supporting this idea or philosophy (Ohno, 1988):

- Just-in-time
- Autonomation

If Just-in-Time could be achieved a company would approach zero level “inventory” (Ohno, 1988). Just-in-time was one of the first concepts to be computerized as part of ERP systems however implementing a computerized Lean concept does not mean that Lean as a philosophy has been implemented on the shop floor (Hirano, 1990).

Autonomation or *Jidoka* in TPS does not mean “automation” such as in a computerized system, but rather “a machine connected to an automatic stopping device” (Ohno, 1988). Such a device would stop the production immediately on detection of a defect or when there is a problem anywhere on the production line. Stopping the complete production line and correcting the problem avoids further problems down the line and eliminates waste. Autonomation also eliminates other forms of waste such as time and cost of a person simply watching a machine when there is no problem at all. Autonomation in a computerized environment could typically be a system monitoring processes of an ERP system and could even execute corrective actions without human interaction. Such an ERP module could typically monitor for defects in database records such as missing information or inaccurate information. Defects are recognized by Lean principles as a form of waste that requires re-work and does not add value to the customer (George, 2003).

Ohno (1988) discusses the use of computers and IS in TPS cautioning against the use of IS in the oversupply of information where it will cause confusion and disruption of the flow of the production system and therefore cause waste. He also sees the oversupply of information as a form of waste and not in line with the just-in-time principle. The cost of computers and peripherals is also a form of waste when a simple manually updated form attached to an item in production or a human action can suffice. Just-in time and autonomation will be important criteria against which to measure the successful outcome of the proposed research.

Liker (2004) expands the Lean philosophy into fourteen management principles that can be applied to any kind of industry and the eighth Principle, “use only reliable, thoroughly tested technology that serves your people and processes”. Liker (2004) would be of particular interest to the research.

The previous sections on ERP indicate one of the core functions of ERP is to automate and support business processes within an organization. The following section will discuss the development of Lean thinking and its principles and how these could apply to the processes that ERP could support within an organization.

2.2.2 Lean Thinking

James Womack and Daniel Jones establish the concept of Lean thinking according to five principles as:

1. Specifying the precise value by product

2. Defining a value stream for each product
3. Continuous flow of value
4. Allow customers to pull value from the manufacturer and
5. Finally to seek perfection (Womack & Jones, 2003, p. 17).

They further describe Lean thinking as the antidote to waste or *muda*, the Japanese word for waste. Lean thinking provide the way to do more with less, striving to come closer to providing customers with the value they want (Womack & Jones, 2003, p. 25). To implement Lean thinking, one of the technique known as value stream mapping is used to identify value stream for each product from raw material throughout to the final product to the customer (Womack & Jones, 2003, p. 19).

Using the Lean thinking paradigm Poppendieck (2002) applies the philosophy of Lean thinking to software development. Guided by the principles of Lean thinking, Poppendieck (2002) propose four basic principles of Lean development. Firstly, add nothing but value through elimination of waste. Secondly, focus the development around people working on the processes that add value to the customer. Thirdly, make the development process flow through the demand from a customer using a “pull” action when needed and finally, optimization of the development process across the organization by placing all the necessary skills in the same development teams. To identify waste in software development, (Poppendieck & Poppendieck, 2003) translate the seven wastes of manufacturing to software development presented in Table 2.2.2:

TABLE 2.2.2 THE SEVEN WASTES	
Waste of Manufacturing	**Waste of Software Development**
Overproduction	Development of extra features
Inventory	Work only partially completed
Extra Processing	Extra Processes in documentation
Transportation	Switching of developers between tasks
Waiting	Waiting caused by unnecessary delays
Motion	Movement of artifacts and information between team members
Defects	Product of defect impact and time the defect stays undetected
Source: Poppendieck and Poppendieck (2003)	

Following the success of Womack and Jones's *Lean Thinking: Banish Waste and Create Wealth in Your Corporation,* Liker (2004) published *The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer* explaining the business philosophy and management principles underlying the Toyota Production System and The Toyota Way. Liker (2004) identified fourteen principles and classified them into four categories also known as the four P's:

- Long Term Philosophy: What drives the Lean philosophy to succeed in an organization is focusing on a long term approach of adding value to customers and society and it is driven from the top management of the organization.
- The Right Process will Produce the Right results: The key to Lean is flow through all process starting from a one-piece flow process and through experience learning the process that will give the correct results.
- Add Value to the Organization by Developing Your People and Partners: Sets of tools to support the people in the Lean systems to continuously develop and improve.
- Continuously Solving the Root Problems to Drive Organizational Learning: Identification of root causes through analysis, reflection and communication. Solutions found through root cause analysis are then turned into standardized practices forming a continuous process of learning in the organization (Liker, 2004, p. 16).

Liker's book became the first to explain the Lean philosophy in order for managers to be able to apply Lean thinking outside of Japan where it originated at Toyota (Liker, 2004, p. 32). Toyota, true to the nature of learning and continues improvement, also learned from American quality pioneers such as W. Edwards Demming. Teaching at quality and productivity seminars in Japan, Demming expanded the concept of "customer" in the Lean philosophy to include external and internal customers. Each person or step in the production line or business process is to become a customer to the previous person or step and became an integral part of the pull system. The Demming Cycle or Plan-Do-Check-Act (PDCA) Cycle was also adopted in the kaizen activity of Lean which is the process of incremental improvements to eliminating waste (Liker, 2004, p. 45).

To define value for both external and internal customers is a question of what does the customer want from the process. The Lean philosophy teaches to see the processes through the customer's eyes and to separate the value-added steps from the non-value-added steps therefore, eliminate waste by removing the non-value-added steps from processes of manufacturing, information or services (Liker, 2004, p. 49). Liker (2004) cautions as to the importance of specific tools and its application do not manifest the Lean philosophy. It requires a believe in the principles of Lean and the appropriate use of Lean tools applicable in the organization's situation for Lean to be successful (Escobar & Revilla, 2005; J. K. Liker, 2004, p. 153; Paul, 2005). Bhasin and Burcher (2006) argues that the implementation of tools and techniques are often not a problem in an organization however the success of applying Lean in an organization is depending on a mixture of tools and philosophy and requires at least the following elements to be present:

- Application of five or more of the Lean tools
- Applying the philosophy of Lean as a long term objective
- Applying the philosophy of continues improvement and

- Change the organizational culture to empower workers to apply Lean principles (Bhasin & Burcher, 2006).

Rich, Bateman, Esain, Massey and Samual (2006) note as a criticism against Lean thinking, the approach of improvement by eliminate waste ignores the existence of variation unlike other improvement philosophies such as Total Quality Management (TQM), Six Sigma and theory of constraints. They argue that the use of tools can only take a snapshot of a process at any one time and cannot be representative of the populations of all data points. Lean thinking attempts to achieve perfection through the elimination of common cause variation whereas the other philosophies are based on the control and reduction of variability (Rich et al., 2006, p. 127). A more recent criticism against Lean is that it is simply a repackaging or an updated version of the JIT method and shares the same approach to change in focusing on elimination of waste and adding value (Naslund, 2008). According to Naslund (2008) based on a study of publication frequency of the past thirty years to investigate the nature of transition from JIT to Lean and TQM to Six Sigma, Lean and Six Sigma essentially shares the same fundamental approaches originating from goals, approach, tools, history and common success factors (CSF). Naslund (2008) argues that JIT and Lean ideas are not that different from TQM and Six Sigma. Furthermore, that a gap in time between JIT and Lean was filled by the contributions from business process re-engineering (BPR) and predicts that there will be a new method promoted soon, already manifested through the promotion of the concept of Lean six sigma. This apparent “fad” as described by Naslund (2008) could be explained by

Stone's (2012) categorization of four decades of scholarly literature into five themes starting with the Discovery phase (1970-1990), Dissemination phase (1991-1996), Implementation phase (1997-2000), Enterprise phase (2001-2005), and the most recent phase of Performance (2006-2009). According to Stone, TPS was first described in an English article by Sugimori and Kusunoki (1977): *Toyota production system and Kanban system materialization of just-in-time and respect-for-human system,* describing Kanban, the system of JIT in production control. Stone's conclusion of the literature language during the Dissemination phase transforming from ideology to jargon as articles are referring to Lean as the MIT model, TQM, JIT and agile manufacturing system could refute Naslund's (2008) criticism.

The following section will define the Lean tools that are referred to throughout this thesis.

2.2.3 Tools Used in Lean

In the previous section discussing the concepts and thinking behind Lean as a philosophy, a number of Lean tools and techniques are mentioned. It is argued that the success of Lean depends on the understanding of the Lean philosophy but also the appropriate use of Lean tools applicable in an organizations situation (Escobar & Revilla, 2005; J. K. Liker, 2004, p. 153; Paul, 2005). Published first in Japan in 1998 and translated and published in the English language the following year, Hiroyuki Hirano's *JIT Implementation Manual: The Complete Guide to Just-in-Time*, (1990) discuss in detail a number of the modern tools or techniques used by Lean. Some of these tools are also shared by the six sigma philosophy originating from the same fundamental approaches as remarked by (Naslund, 2008). It is important to give a brief discussion in order to understand how some of the techniques or tools through their application in an organization address the principles of Lean.

5S: Originally developed by Hiroyuki Hirano, the five S's refer to the Romanized Japanese terms used to order the work place and in the process expose waste and errors (Hirano, 1990). The five terms are:

- Seiri (organization)
- Seiton (tidiness)
- Seiso (purity)
- Seiketso (cleanliness) and
- Shitsuke (discipline) (Sye & Jones, 2011)

Liker (2004) summarize the actions as follows:

- Sort (organization) - the actions of sorting items and keep what is needed and getting rid of unnecessary items within the workplace.
- Straighten (orderliness) - "A place for everything and everything in its place"
- Shine (cleanliness) - The action of cleaning and acts as a form of inspection to expose any possible failures later on.

- Standardize (create rules) - Implement systems and procedures to maintain and monitor sort, straighten and shine.
- Sustain (self-discipline) - maintain the workplace once stabilized and practice ongoing actions of improvement.

5 Whys: Hirano (1990) describe the five Whys as part of the procedure of standardizing work. Through the practice of asking the question “why?” at least five times why a failure occurred the real root cause of the problem will most likely be revealed (Sye & Jones, 2011).

Andon lights and cords: A system consisting of switches or pull cords in close proximity of the operators to trigger a visual or audio signal to the supervisor when a problem is experienced in the production line. The supervisor needs to respond accordingly to resolve the problem (Houy, 2005). Andon can also signal deviations in e.g. take time (Rich et al., 2006). At Toyota, the andon is called a “fixed-position line stop system” using lights similar to that of a traffic light. When an operator experience a problem and press the andon, a yellow light will light up on the line. The line will continue and the supervisor has until the line reaches a predetermined point. If the problem was not solved and the andon cancelled by the supervisor the light will turn red and the line will stop in order to resolve the problem (Liker, 2004).

Autonomation or Jidoka: Sakichi Toyoda developed the Jidoka concept that would become one of the key pillars of the Toyota Production System (Liker, 2004). The concept of autonomation or Jidoka in Japanese refers to a semi-automatic process for the machine to detect a problem and automatically shuts down (Sye & Jones, 2011). Hirano (1990) describes it as automation with a “human touch” meaning that it is different from automation in that build into the machine is the ability to evaluate a problem and stopping itself as if it has human intelligence (Liker, 2004). This allows the separation of operator and machine in order for the operator to perform other tasks and avoid watching a machine that constitutes waste (Sye & Jones, 2011). This is similar than andon except that the machine is stopping itself and not a human being when it encounters a problem for example quality of an part that could cause a defect further down the line, a machine part broken or need maintenance or backing up of production flow (Liker, 2004).

Just-in-time (JIT): A set of principles, tools and techniques applied to eliminate waste through the correct timing of the production flow, which supply parts or goods to the production line just in time to be used in the correct quantity and to the production processes that requires them (Hirano, 1990). JIT is driven by a downstream operation pulling the required parts from another downstream operation (Sye & Jones, 2011). JIT applies to the complete supply chain to deliver small quantities with short lead times according to customer needs (Liker, 2004).

Kaizen: The technique of Kaizen requires analyzing processes and applying improvements in small increments in order to eliminate waste (Liker, 2004, p. 45). Kaizen can be applied to production as well as administrative activities (Rich et al., 2006, p. 13). An intense effort of Kaizen known as a Kaizen Blitz, is a rapid and overpowering effort of Kaizen performed by a team or individuals on a process, product, system or services to dissect a process and reassemble in a better way eliminating waste (Sye & Jones, 2011, p. 16).

Kanban: Constituting an integral part of the JIT production system, Kanban is a stocking technique consisting of containers, cards or electronic signals to trigger flow of actual materials used containing replenishment information and is used to control the pull system at a manageable pace (Bell & Orzen, 2011, p. 125; Hirano, 1990, p. 24; Sye & Jones, 2011, p. 17). Hirano (1990) describes the Kanban system as an invisible conveyor that connects the different processes with each other. Many forms of Kanban can exist of which there are three typical types according to their function: move or conveyance Kanban to move stock from a downstream to an upstream operation, production Kanban to instruct to production of a part or item to a downstream operation and a supplier Kanban to instruct a supplier to replenish parts or raw materials to an operation. The Kanban card is an authorization to supply to the upstream process (Powell, 2012; Ramnath, 2010).

Poka-Yoke: The use of simple, low cost devices or approaches to ensure quality or that a mistake does not pass down the line. Poka-Yoke is also known error-proofing approach to production. Examples of such devices could be contact devices, vibration, pressure or temperature switches. A Poka-Yoke can also be as simple as using color codes for parts that fit each other or components that can only go together in one configuration (Rich et al., 2006, p. 125; Sye & Jones, 2011, p. 19; Syspro, 2007).

Takt Time: Takt is the German term used for measure or beat. To determine the takt time in manufacturing one would simply divide (a) the daily available working time by (b) the rate at which the customers place orders daily (Liker, 2004, p. 134; Sye & Jones, 2011, p. 23).

Value Stream: The value stream consists of all the external and internal integrated and connected activities and processes required from the inception of a product or service to the final delivery to the customer (Duque & Cadavid, 2007; Sye & Jones, 2011). The activities in the value stream are categorized as:

- Activities or processes adding value to the customer
- Activities or processes that do not add value to the customer but are necessary or cannot be avoided
- Activities or processes that do not add value to the customer and should be removed (Duque & Cadavid, 2007).

Value stream mapping is used to identifying the activities or processes in a value stream.

Value Stream Mapping: Originated from the “material and information flow diagram” used by Toyota to teach manufacturing suppliers TPS, a value stream map describes in a linear process flow the process whereby the flow of materials and information using simple icons and graphics (Liker, 2004, p. 355; Sye & Jones, 2011, p. 24). Starting from the upper right hand of a page with a customer order the value stream flow moves counterclockwise throughout the different sections of an organization until it finally ends with the delivery at the customer (Bell, 2006, p. 71).

The following section will discuss points of view from the literature around the topic of the use of information technology (IS) and the Lean philosophy.

2.3 ERP AND LEAN

2.3.1 Lean and Information Technology (IT)

The earliest mention of a computerized system and Kanban is in an article by Sugimori and Kusunoki (1977) listing a number of reasons why Toyota at the time no longer relied on the use of what then was called an “electronic computer” but rather on the Kanban System. The reasons at the time was:

- They could reduce the cost of processing information which was costly in terms of implementing systems to calculate production schedule and maintaining the information to be real time and
- Using Kanban, workshop managers were able to perceive the continuous changes to adjust production capacities, operating rate and manpower more rapid and accurately than a computer.

Almost two decades later Davenport and Short (1990) argues that telecommunications and information technology are transforming organizations in the same way that Taylorism did earlier. Referring to industrial engineering, Davenport and Short (1990) predicts that the capabilities offered then by telecommunications and information technology have the potential to change the way that industrial engineering will be practiced and the skills required to practice the discipline of industrial engineering. However, business process have not been designed with any form of IT in mind and more than often have been designed long before the existence of any of the technologies that we have today. Therefore, when we apply technology today to any business process it most likely is only to speed up and/or to automate a process or part of a process (Davenport & Short, 1990). The advise given by Davenport and Short (1990) is to consider the role for IT in a process through redesign and IT should be considered already in the early stages of redesign of a business process. Hammer (as cited in Schonberger, 2007) considers automation of a system that was not redesigned for automation as “automation of waste”. Liker (2004) gives similar advise in the context of Lean that it is often better to use manual processes even when automation is available. People are more flexible than machines and when a system or process has not been fully designed to be efficient it is better to use a manual process until it is clear where automation through the use of information systems can improve the process (Liker, 2004).

Hirano (1990) divides systems of an organization into two areas namely the information-based factors as management systems and the equipment-based factors as the physical systems. Management systems are systems consisting of an organizational framework, clerical procedures and information related systems that by their nature are susceptible to improvement through computerization. Physical systems on the other hand deal with the plant equipment, production methods and equipment related aspects (Hirano, 1990, p. 23). Using the example of a waste filled production system with a deep bill of materials, Hirano (1990) explains that the computerization of such a system will result in a waste filled production management system. Subsequently the factory ends up with an additional task of maintaining and revising the computerized bill of materials whenever there are any changes. Additionally this would cause a lengthy calculation of required material orders for such a deep bill of materials and the further need for training additional staff as operators and programmers to operate such a complex system. The initial waste in the systems creates more subsequent waste after computerization (Hirano, 1990, p. 100).

To further illustrate the considerations of computerization Hirano (1990) explains the introduction of computerization to shorten lead-times and what effects it would have on the paper lead-time and the physical lead-times. Computerization can be helpful in facilitating and speeding up the paper lead-times to calculate an efficient production schedule however the physical lead-times are not necessarily affected. Physical lead-times of the production require a different treatment in the form of a factory-based improvement to shorten the physical lead-times (Hirano, 1990, p. 22). Simply computerizing systems or tasks does not equate to improvement and requires a proper evaluation of the situation as to the application and effect of computerization. Hirano (1990) noted that factory managers often assume the implementation of computer-based system will have a magical effect and miraculously streamline factory operations without their management involvement. (p. 22)

The following section will discuss the concept of Lean used specifically with ERP systems and if the principles of ERP can support the principles of Lean.

2.3.2. Lean ERP Concept

ERP systems are based on concepts originating from the traditional mass production environment initiated by Henry Ford after World War I. The initial MRP systems were designed to deal with complex bill of material, insufficient workflows and unnecessary data collection (Bartholomew, 1999; Bradford, Mayfield, & Toney, 2001). Within these ERP systems, MRP II is still used as the planning system with production levels based on sales forecasts. Lean production uses a “pull” system where customer demand determines the production levels (Bartholomew, 1999). Such differences between the two concepts have companies facing a dilemma with ERP systems wanting to implement Lean. Dixon (2004) attempts to argue a case for “other” IT applications that can support Lean but then concludes that software vendors will have to find creative ways to redesign the logic of ERP in the future to combine Lean and ERP in order to be competitive in the market.

The dual implementation of ERP and Lean within the same organization seems to be very likely (Goddard, 2003). Corporate companies implementing Lean would have already invested in ERP systems and simply turning off the ERP system might not be feasible. In most cases the extended sub-systems of the ERP system are still needed, such as: Accounting, Human Resource Planning and Corporate Planning (Bartholomew, 1999). Lean ERP system modules satisfying both systems can prevent companies that are implementing Lean from abandoning their ERP system for the sake of the Lean implementation.

When one consider the ERP system as a value stream in the Lean environment, it might be possible to optimize ERP under the principles of Lean. As part of the research methodology, this research will attempt to evaluate the already existing features in some of the standard commercially available ERP systems for such optimized Lean features.

Syspro, a leading software development company summarized in their white paper, “*The When, Why and How of ERP support for LEAN”,* the potential integration points between the nine components of ERP and fourteen Lean initiatives or tools (Syspro, 2007). In the Lean-ERP integration matrix represented in Table 2.3.2 the greyed boxes indicates the areas where ERP components and Lean initiatives can potentially integrate while the blank spaces indicate where they do not integrate.

TABLE 2.3.2
LEAN-ERP INTEGRATION MATRIX

Lean: ERP	FIN	HR	S & D	Mfg.	MM	Logistics	Report	Bus Rules	Work Flow
Value Stream Mapping	■		■	■	■	■	■	■	■
Quality At The Source	■	■		■			■		■
Workplace Organization: 5 S	■			■	■				
TPM	■			■			■	■	■
Visual Management							■		■
Set-up Reduction	■			■	■		■	■	■
Batch Size Reduction	■			■	■		■	■	■
Cellular Manufacturing				■	■		■		■
Standardized Work								■	
Work Balancing				■				■	■
Production Leveling				■	■		■	■	■
Point-of-use Systems				■	■		■	■	■
Kaizen							■		■
Kanban					■		■	■	■

Source: Syspro (2007)

The above matrix is an important guideline to indicate the potential areas to successfully develop Lean ERP modules. The following indicates the potential mutual exclusivity of ERP and Lean and therefore the non-integration:

- Relevant Lean tools and ERP components are not implemented for example Material Management (MM) or Inventory Control exists in the ERP but the Lean Kanban tool is not implemented or not properly applied (Syspro, 2007).
- A weak implementation of an ERP module where information to be used by the Lean tool does not exist or contains inaccurate information (Syspro, 2007).
- ERP systems by nature are configured once and then to repeat processes continuously whereas Lean requires continuous modification in a process to move closer to the Lean objectives. The inflexibility in the configuration and customization possibilities within an ERP system can force the mutual exclusivity of the two systems (Syspro, 2007).
- The implementation of an inflexible ERP system first and then Lean afterwards (Lean Advisors, 2011).

However, other non-IT related factors could also cause the non-integration of the two systems, such as:

- Production orders are based on sales forecasts and not on a “pull” action from customer orders as per the Lean principles (Zylstra, 1999).

- Factors such as legal and bureaucratic systems of countries can force long lead times to replenish stock forcing manufacturers to build-up stocks therefore working against the Lean principle of JIT.

Hessman (2012) explores customization of ERP systems within a Lean production environment using IFS ERP software at Miller St. Nazianz Inc., a large tractor sprayer manufacturer based in Nazianz, Wis. Their requirement as a Lean manufacturer is unique and not available in off-the-shelf ERP systems. IFS ERP systems consist of SOA components that can be used to customize their ERP system. Hessman (2012) continues that the focus is moving from vendors to configure ERP systems to that of the user to configure ERP systems provided that these ERP systems have the capabilities. Andy Vabulas, the CEO of an IFS service is of the opinion that SOA components allow the flexibility to ERP systems required to configure the system to optimize the company's business model (Hessman, 2012).

Wells (2010) lists flexibility as an important requirement of organizations when evaluating ERP systems and vendors for implementation. ERP system should be able to expose transactions to vendors and customers without having to install software at the vendor or customer or having to conduct training to use the system. This requirement of flexibility points to one of the Lean principles of pulling the transaction from the customer and seems to becoming a standard requirement for ERP systems regardless of Lean principles being followed in a company or not.

Wells (2010) further includes the support of Lean principles as criteria of evaluation of ERP software vendor selection but does not elaborate sufficiently on the criteria of evaluation for Lean principles. However, this would indicate that there is a need for ERP systems to be able to support Lean principles.

The following section and its subsections will introduce the concept of Lean operations, its principles and relevance to the research.

2.4 LEAN OPERATIONS

In earlier decades, the term “operations” would primarily refer to the manufacturing operations of an enterprise but over time the term also came to include other service systems thus including all functional areas of an organization, such as: marketing, accounting, purchasing, information management, engineering and resource management (Bayraktar, Jothishankar, Tatoglu, & Wu, 2007). In the earlier sections of this thesis the discussion focuses primarily on the topic of manufacturing, however, other service systems as named above also contribute important elements to the proposed study.

These functional areas are also not without conflict when it comes to following a traditional or Lean philosophy. That is to say, managers would not be able to use the traditional “manage by results” methodology in a Lean environment nor judge the performance of the business correctly (Johnson, 2007). Thus, a major requirement of the study is to focus on all systems of operation to thoroughly complete the Lean "thread".

2.4.1. Definition of Operations

Operations consists of a processes whereby the input consists of raw materials, labor, equipment, capital resources and information and with the output as goods and services (Bayraktar et al., 2007). Where there is a process with feedback from customers about cost, quality and variety of the product and services the Operations Management process serves as a form of continues improvement, enhancing quality and customer satisfaction (Bayraktar et al., 2007).

The development of computer and computer information contributed to the Operations Management since the early seventies with the development of tools such as Material Requirement Planning (MRP), Material Resource Planning (MRPII), Total Quality Management (TQM) and Kanban. Today, tools such as Customer Relationship Management (CRM), Supplier Relationship Management and Knowledge Management (KM) have been developed as management models and software have been developed for computers applying these models (Bayraktar et al., 2007). Bayraktar et al. (2007) claims that globalization and high quality of communication media contributes to the virtualization of the business environment allowing information to flow easily between business partners. The operational software developed during the early years were standalone systems and without a shared database or integration of information. Regardless of these shortcomings, the software developed contributed tremendously to Operations management through improved scheduling, forecast, planning and management (Bayraktar et al., 2007).

2.4.2 Principles of Lean Operations

Through a literature search it was found that there is not any known articles that are referencing Spear and Bowen's principles of Lean operations related to design or development of ERP and/or Lean modules using their principles as the core philosophy. Most of literature found referencing Lean and ERP discusses application of the Lean principles in the development process (Poppendieck, 2002), in the software service industry (Staats, Brunner, & Upton, 2011) or Lean tools included as part of the functionality of an ERP system in the form of modules (Bhasin & Burcher, 2006). If one considers the ERP system as a value stream and consider the processes within the ERP system as a production process of information then we can argue that the principles of Lean should apply to the "production process" as we would apply them to any operation. A considerable amount of literature exists discussing the development of ERP. Several articles argue for and against the use of ERP systems with Lean for example O'Brien (as cited in Herrmann, 2005) argues against the use of ERP in a Lean environment and claims that ERP is based on the philosophy of mass production and functions since inception of Taylorism. Miller (2004) argues that Lean and ERP are not mutually exclusive but claims that a "Lean

ERP" as a design should differ from the traditional design. One way of refuting such an argument would be to investigate the principles of Lean and investigate if they are applied in an ERP system or if it requires a different design philosophy other than what has been applied to ERP until now. There seems to be a gap in the literature around the subject of the design of ERP systems based on the principles of Lean, not as a process of design but as a philosophy, in the same way as literature claims that ERP is based on the philosophy of mass production.

Almost a decade after Womack and Jones have published a number of books and articles on the principles of Lean many companies tried to adopt Lean. The Lean concept did not only remain restricted to automotive manufacturing but is now also used in diverse industries such as aerospace, consumer products, metal processing and industrial products. However, Spear and Bowen (1999) reported that companies such as GM, Ford and Chrysler failed at achieving the same success that Toyota had through the implementation of TPS. A critical question asked by Spear and Bowen (1999) was why companies were unsuccessful even though Toyota was open in sharing their practices. After four year of extensive research conducted in fourty manufacturing plants in the United States, Europe and Japan, Spear and Bowen (1999) suggests that replicating the tools and practices were being confused with the system itself and identified four underlying principles practiced by Toyota. They propose three rules or principles of design and a fourth rule of improvement. It seems that ERP systems have reached a similar confusion where the design and embedding of Lean tools into ERP systems and where the vendors consider this a Lean system.

However, the literature is not conclusive on the success or design of Lean ERP systems and remains silent on principles that should be used. It seems logical that the principles identified by Spear and Bowen (1999) can be applied to ERP systems consisting of design principles as well as a principle of improvement. Furthermore, these four important rules or principles for Lean operations could be considered as a set of metrics to measure the Lean nature of ERP system modules. The rules as identified by Spear and Bowen (1999) are presented in the Table 2.4.2. Using these rules, Lean ERP system metrics are proposed and expanded upon below in the section “Research Methodology”.

TABLE 2.4.2 PRINCIPLES OF LEAN OPERATIONS	
Rule 1	All work must be highly specified as to content, sequence, timing and outcome.
Rule 2	Every customer-supplier connection must be direct with a yes-or-no way to send requests and receive responses.
Rule 3	The pathway for every product and service must be simple and direct.
Rule 4	Any improvement must be made in accordance with the scientific method, under guidance of a teacher, at the lowest possible level in the organization.
Source: Spear and Bowen (1999)	

These rules are being translated in order to use as a metric and discussed further in detail in chapter Three.

2.4.3 Metrics to Measure Lean Operations

Very few studies on quantitative analysis of Lean measures have been done thus far (Khadem, Ali, & Seifodinni, 2008). Having a properly designed and comprehensive Lean metrics in the competitive global market would give companies the necessary competitive edge in the global market to optimize productivity.

Khadem et al. (2008) demonstrates through the use of a series of simulation models developed using Arena simulation software the effectiveness of Lean metrics in a manufacturing environment and that by using Lean metrics, problems can be identified as well as identifying that certain improvements can increase productivity. They based their models on what they classified as primary metrics that includes Dock-to-Dock Time, First Time Throughput Capability, Overall Equipment Efficiency and Build-to-Schedule Ratio. Secondary metrics would include days on hand inventory, value adding ratio, manufacturing cycle time, 5s diagnostic rating and square footage required. Based on the success of the research they propose that these Lean metrics are build-in functions to simulation software for manufacturing systems.

Duque and Cadavid (2007) also propose a system of metrics through identifying five areas that should be measured for improvement after implementation of Lean principles such as elimination of waste, continues improvement of processes, continuous flow and pull systems in the organization, establishing multifunctional teams and improvement in information systems. Of interest to us is the area of information systems and the *a priori* metrics proposed by Duque and Cadavid (2007) to measure the improvements made by a Lean implementation. They argue that the *a priori* metric such as frequency of information to employees, percentage of documented procedures and the frequency by which line or cell progress information boards are refreshed are being assisted by Lean activities such as work standardization, visual controls, information displays, empowerment of the employee and leading by example through management involvement. Table 2.4.3 was extracted from the main table of metrics proposed by Duque and Cadavid (2007) to indicate the metrics for information systems.

TABLE 2.4.3
EXPECTED IMPACT OF LEAN ACTIVITIES ON PERFORMANCE METRICS

⇑: Help the Metric ⇓: Hurts the Metric	Work Standardization	Visual Controls	Information displays	Empowerment	Leading by example
Frequency of information			⇑	⇑	⇑
% Of procedures documented	⇑	⇑	⇑		
Frequency of updating boards			⇑	⇑	

Source Adapted: Duque and Cadavid (2007)

Duque and Cadavid (2007) also recognizes the importance of the ERP system and the value of the information contained within the system across the areas of operations such as manufacturing, marketing and logistics as a source of inputs for a

Lean system. ERP systems can provide the Information to Lean system tools for example to calculate takt time, Heijunka box information, cycles and schedules of the water spider and Kanbans required in a manufacturing process. Duque and Cadavid (2007) further suggest that their proposed metrics should be expanded to the Lean supply chain network across collaborating companies. A further logical extension then would be to extend at least the same metrics to the global Lean supply chain where participating companies can be sharing this information on a daily basis. Such information would be critical in achieving to deliver the best possible value to the customer through elimination of waste and continuous improvement. Further metrics proposed to measure the Lean value of an ERP system are also proposed by Krause (2007) such as measuring minimized mouse clicks, navigation time and net throughput amount of functions as a combination of clicks, navigation time and processing time.

Although all of the above are valid metrics to measure the effect of Lean or how effective a Lean tool has been established, none of the authors are proposing metrics based on the Lean principles of operations as established by Spear and Bowen (1999). One of the objectives of this thesis is to investigate how these principles are applicable to ERP systems and their modules.

The following section will discuss some of the available architectures that might be suitable to support the Lean ERP concept as discussed.

2.5 ARCHITECTURE TO SUPPORT LEAN

One of the study objectives is to design or propose IT architecture to support Lean operations. Such architecture will have to adhere to the principles of Lean as mentioned earlier for the study to be successful. Today's ERP software design developing mode allows software reuse only at class level. This kind of development mode results in inefficient, low quality and poor variability of the ERP system (Yue-xiao, Song, & Hui-you, 2008). A further limitation is that current ERP architecture is designed for integrating systems of a single organization and is unable to address complex and unpredictable changes in the global market (Plikynas, 2010). IT architecture designs, such as: service orientated architecture (SOA) (Biennier & Legait, 2008; Mahmood, 2007), component based ERP with layered architecture (Yue-xiao et al., 2008) and multi-agent systems (Plikynas, 2008) have been proposed in the last few years to address software flexibility and global use of ERP systems. The research will investigate the suitability of some of these architectures through the perspective of Lean global operations.

2.6 SUMMARY OF CHAPTER TWO

For almost seven decades software engineers has been developing software to manage resources and systems in organizations yet concepts and philosophies are still evolving and changing constantly as technology improves every day around us. New concept and philosophies might strengthen older concepts and often they stand in direct contrast to each other. Supporters of Enterprise Resource Planning systems (ERP) and the Lean philosophy that grew out of the Toyota Production system found themselves in a position of contrast with the introduction of Lean by Womack and Jones in the early 1990s. Not only is there a controversy between ERP and Lean but also in defining the term ERP seems to be elusive. Authors such as Wallace & Kremzar (2001) and Davenport (2000) criticize the term ERP and suggest that the acronym does not match the functionality of the software anymore. Klaus et al. (2002) claims that the use of the acronyms MRP, MRP II, CIM and ERP at different times indicates an apparent development and misleading in the literal meanings.

The literature review indicates very few scholarly works explore and discuss the philosophy and principles of ERP even though many authors would refer to the “principles of ERP”. Senn (1978) explains the principles of earlier MIS to have been developed from managerial systems and was later manifested in the developments that lead to the ERP concepts in the 1990s (Monk & Wagner, 2009). Krause (2007) claims that ERP developed out of the accounting and auditing functions of the organization forming the dominant logic of ERP. Despite the difference of opinion on the origins of the philosophy or principles, ERP seems to continue developing with new terms introduced such as ERP II, ERP III and Global ERP. The literature review reveals that the philosophy has evolved from organizational centric designs to collaborative, outward looking “borderless enterprise” systems (Wood, 2010) and flexible, agile and “amorphous” virtual enterprise structures (Wan & Clegg, 2011).

Globalization of organizations also have an influence on ERP systems on several levels of integration namely integration of markets, integration of operational and administrative sites, integration of suppliers, manufacturers and service providers and hardware and software components (Molnár, 2011). Molnár (2011) also demonstrates support for the evolving nature of ERP through Gronau’s models of communication for enterprise ERP. Further concepts such as Multi agent systems proposed by Akkermans et al. (2003) and Global ERP by Plikynas (2008) further demonstrates the ERP philosophy evolving to flowing information and processes through multiple organizations. However these concepts have not been adopted by software vendors and organizations as observed by Tan (2010) and claims that the traditional concept of a single instance and database to ensure a consistent view of the same data to be the reason for the lack of adopting these global concepts such as multi agents. Veague (2011) on the other hand support the idea of hybrid implementation models of ERP in the global environment.

The use of relational database technology supports the ERP business logic (Shehab et al., 2004) however Ferran and Salim (2011) argues that the traditional model of accounting and the database structure modeled on the accounting structure has lost it validity. They propose a system, IAC, to reduce the transactions in the database and simplifying the traditional method of recording transactions to the database.

However, not much evidence exists of research done in the area of ERP systems using this particular method. On the other hand, the method does demonstrate the reduction of transactions in the database with the same results as a traditional ERP.

At the same time as ERP continued on its evolutionary process, the west started to learn about TPS from the research done by Womack, Jones and Roos (1990). The first decade of Lean focused on the production processes and tools promoted by Lean to primarily eliminate waste. Ohno (1988) and Hirano (1990) mention their reservations about the use of computers as a possible source of waste in the oversupply of information and computerizing Lean concepts such as JIT on the shop floor and points out that implementing Lean tools do not mean that a Lean philosophy has been implemented. Sugimori and Kusunoki (1977) even give strong reasons why Toyota chose a manual Kanban system over the use of an “electronic computer”.

Even though the Lean philosophy and the application of the philosophy is widely covered through the work of authors such as Liker (2004) and Hirano (2009), their discussion of Lean and ERP are not substantial and tend to be more cautionary against the use of ERP systems in a Lean environment. Dixon (2004) on the other hand attempt to support the use of ERP systems in a Lean environment using other non-ERP systems but finally remarks that ERP systems need to be redesigned to support the Lean environment. Goddard (2003) argues for the dual implementation of ERP and Lean within the same organization rather than one or the other. Syspro

(2007) maps the potential integration points of ERP with Lean tools but does not substantiate these integrations with any research.

Exploring the literature on the principles of Lean operations no know articles were found to contain any research applying the principles of Lean operations, as established by Spear and Bowen (1999), to ERP systems. The principle argument used for not using ERP in a Lean environment is that ERP systems reflect the philosophy of mass production. Surprisingly, no research exists to investigate if ERP systems contain the principles of Lean using Spear and Bowen's principles of design and improvement in an attempt to refute such an argument. This thesis will attempt to contribute to the literature to fill the gap in this regard. Khadem et al. (2008) and Duque et al. (2008) propose systems of metrics to measure for the effectiveness of Lean operations in their reference to information systems however none of these metrics are directly based on the Lean principles of operation as established by Spear and Bowen (1999).

The literature review concludes by exploring the available literature on the architecture that could support an IT structure for Lean ERP systems based on the principles of Lean operations. The literature seems to be weak in available research investigating the architecture suitable for Lean ERP systems. Yue-xiao et al. (2008) criticize the current ERP software design as not being suitable for a Lean architectural design and propose a component based ERP with a layered architecture. Some authors are in support of SOA and multi-agent systems as suitable architectures.

CHAPTER THREE

RESEARCH METHODOLOGY

CHAPTER THREE – RESEARCH METHODOLOGY

3.0 OVERVIEW

The thesis research methodology will be based on a systems analysis approach following a multi-methodological research method as proposed by Nunamaker, Chen, and Purdin (1991). Their approach consists of four research strategies: theory building, experimentation, observation, and system development. These have been adapted for the purpose of developing a Lean ERP framework based on the below described processes and as illustrated in Figure 3.0:

1. Theory Building:

Grounded in the Lean theory the principle hypothesis is that a Lean ERP framework could be designed with Lean principles and implemented in a global environment. The research required developing sub-hypotheses during the system analysis phase for each identified module.

2. Experimentation:

Experimentation was used to facilitate the observation phase as well as testing of the ERP modules for the metrics indicated in Table 3.0 based on the principles of Lean operations:

TABLE 3.0 LEAN PRINCIPLE OF OPERATIONS - METRICS FOR A LEAN MODULE	
RULE 1	**All work must be highly specified as to content, sequence, timing and outcome:** • Sequence of data entry steps are clear • Information to be entered are clear and specific • Procedures to perform a task are specified • The time to perform a task in the software can be measured and optimized
RULE 2	**Every customer-supplier connection must be direct with a yes-or-no way to send requests and receive responses:** • Information is evaluated as correct before committed to the database • Connecting processes or modules are direct and standarized • Time between each connecting process can be measured and optimized
RULE 3	**The pathway for every product and service must be simple and direct:** • Workflow through the system is simple and specific • The workflow can only change when redesigned • Workflow is specific to identify the next procedure, module and person
RULE 4	**Any improvement must be made in accordance with the scientific method, under guidance of a teacher, at the lowest possible level in the organization:** • Improvements are made scientifically and according to Rules 1- 3 for example changing the software configuration settings of the software.
Source Adapted: Spear and Bowen (1999)	

Experiments will be conducted primarily on Microsoft Dynamics AX (Microsoft White Paper, 2012) due to the author's familiarity with the software as a consultant and system analyst. Microsoft Dynamics AX demonstration software and data were used to test results for input and output.

3. Observation:

Most of the work to collect the requirements and functionalities was done through physical observation and analysis of existing ERP Lean modules of Microsoft Dynamics AX. These observations were done using demonstration packages that are available and can process data and produce results. Use case data was used to evaluate the results and behavior to understand the "current state" of modules already developed by vendors. These use cases were also used during the experimentation of modules for comparison and validation.

4. System Development:

System development as a research methodology consists of the following five stages as shown in the diagram in Figure 3.0, and is described as a "Super-methodology" containing a hierarchy of "Sub-methodologies".

A. Construct a Conceptual Framework

In order to understand the system requirements and functionalities a gap analysis was used. Secondary data analysis (Zikmund, 2000) of literature was used to identify requirements and functionalities of a Lean system, analyzing them against the existing functionality within the existing vendor Lean modules. From the literature, the gap analysis was prepared to indicate the desired requirements and functionalities that would be required for a Lean ERP system. The functionalities of the existing vendors' modules have been analyzed using physical testing of vendor demonstration software and analysis of the vendor literature.

B. Determine System Architecture

From the gap analysis the requirements was determined in terms of software architecture that should be included within a Lean ERP framework. Gregor and Jones (2007) describe the architecture as the “blueprint” of an IS artifact. Words and diagrams were used as illustrative techniques to elucidate the architectural design.

C. Analyze and Design the Framework

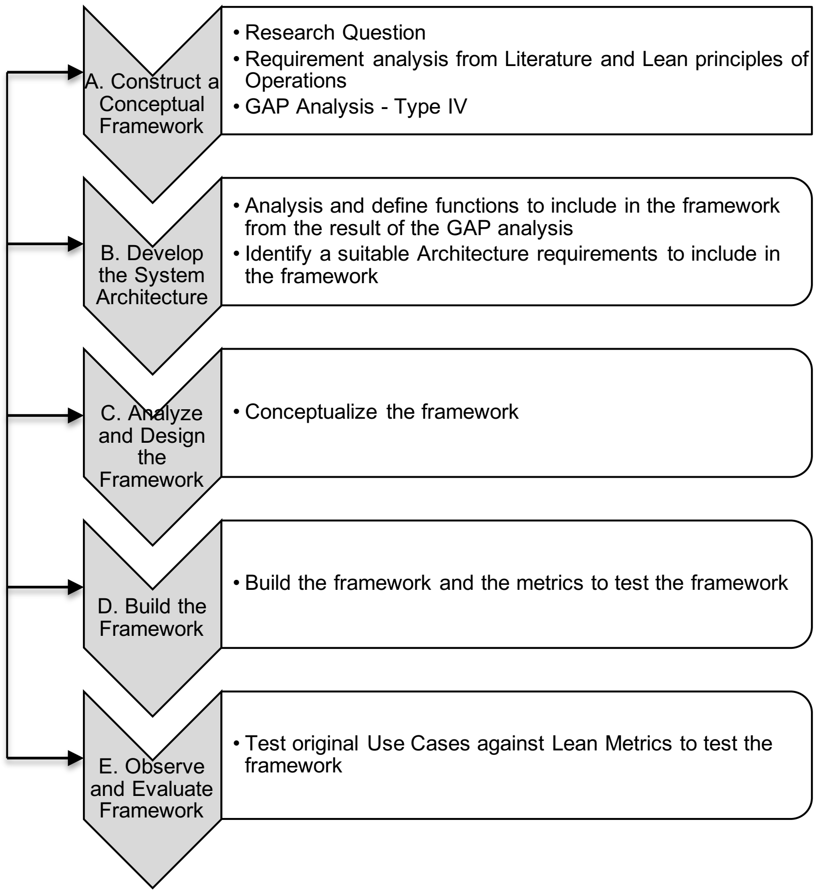
The required database, knowledgebase and required processes were determined during this phase. This is a continuation of the design flow from the previous phase. Alternative solutions were also proposed during this phase for inclusion in the framework.

D. Build the Framework

In order to test the original hypothesis and the underlying theories of the proposed framework it was necessary to design a number of metrics that could be tested. During this phase the researcher will also learn if the framework can be tested through testing and observation of a number of metrics designed to test the Lean principles of operations.

FIGURE 3.0
A PROCESS FOR FRAMEWORK DEVELOPMENT RESEARCH

Framework Development Research | Research Issue



Source Adapted: Nunamaker et al. (1991)

E. Observe and Evaluate the System

Observation and evaluation of the framework will form the basis of the final synthesis of the thesis. Prepared case studies were tested using the framework constructed in the previous step to gather observational data that will be measured against the Lean metrics as established under the experimental strategy.

3.1 APPROPRIATENESS

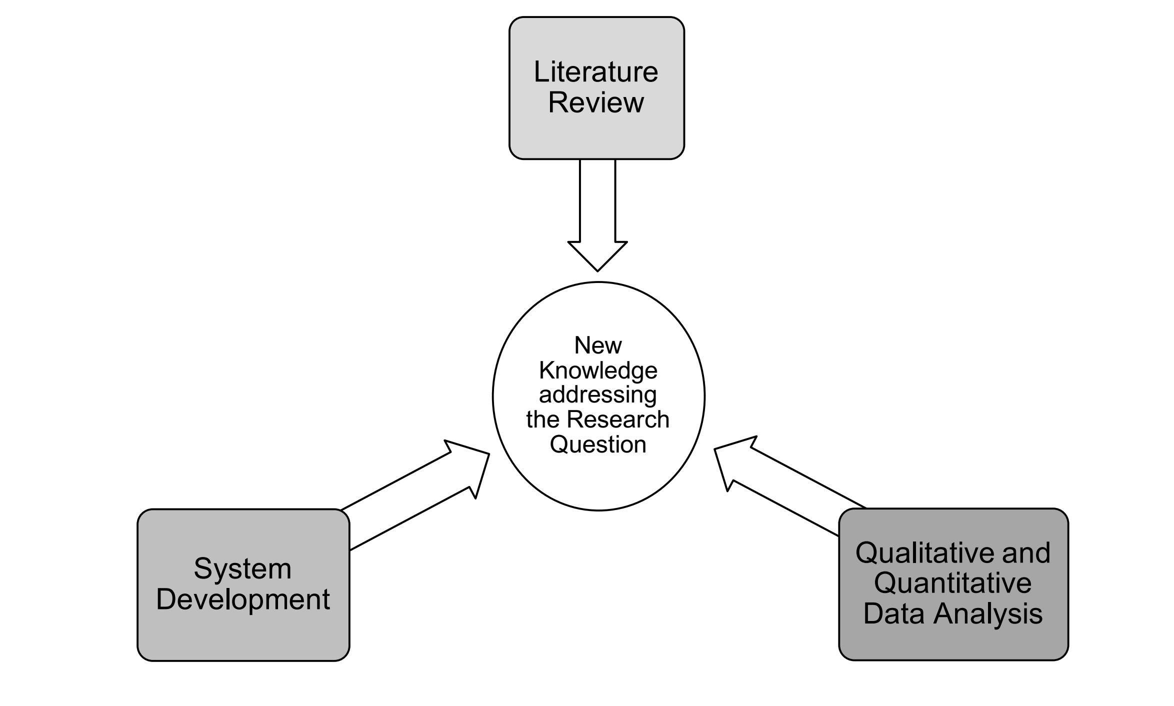
Mixed Method research can be described as the third paradigm in research with quantitative and qualitative methods being the first and second paradigms respectively and where these methods can be used independently (concurrently) or one approach support the other (sequentially) in order to understand a phenomena through merging or comparing the results (Venkatesh & Brown, 2013). During this research, the sequential approach was followed for most of the qualitative and quantitative experiments. Venkatesh and Brown (2013) also notes that combining multiple methods can have a harmonious coexistence and feasibility for research thus recommending the use of mixed method approach to finding theoretically plausible answers. Warfield (2010) calls for a shift in paradigm towards mixed method research and claims that mixed method research illustrated that the combination of computer science and human behavior necessitates the use of both research methodologies for the advancement of IT/IS knowledge. However, Venkatesh and Brown's (2013) research shows that less than five percent of studies published in six major IS journals applied mixed methods in their research. When conducting mixed method research the basic component for quantitative and qualitative research methodologies should not be combined or eliminated into a single methodology (Warfield, 2010).

From the results of the gap analysis as described in Section 3.4 - Sampling Method, it is evident that it will be more appropriate to follow a mixed method of research applying quantitative and qualitative techniques to collect data. Data for this research was collected through the use of experimentation and testing as described in Section 3.2 - Research Design.

3.2 RESEARCH DESIGN

The aim of the present research is to address the research question as set out below applying a multi-methodological approach as described earlier. As illustrated in Figure 3.2 the research will attempt to achieve this aim through the triangulation of the literature review with the data collected through a mixed quantitative and qualitative methodology:

FIGURE 3.2
RESEARCH METHOD TRIANGULATION



Source: Chalil du Plessis, 2013

Research Question:

"What is the ERP systems framework that can be developed to incorporate Lean principles of operations, which will enable global Lean industry users to both reduce costs in their traditional ERP system while simultaneously reducing waste?"

A test hypothesis of the research was formulated as follows:

H0: ERP systems have not been designed to support the principles of Lean operations.

H1: Vendors have already designed ERP modules to support the principles of Lean operations and therefore ERP modules can be developed based on Lean principles.

The following areas of practical research has been identified within the research methodology as proposed by Nunamaker et al. (1991) as described in the Overview at the beginning of chapter Three:

- Gap Analysis
- Requirement Analysis
- Use Cases
- Experimentation
- Observation

A. <u>Gap Analysis</u>

Performing a gap analysis related to ERP system is a technique often used in ERP system analysis as a method to determine the variances or difference between the required business processes and the functionalities of an already existing ERP system. It is a formalized comparison between the current state of an ERP system in an organization and the desired state of the ERP system (Eckartz, Daneva, Wieringa, & van Hillegersberg, 2009; Shtub & Karni, 2009). The goal of the gap analysis is to understand these differences or gaps and to find a way that these gaps can be reduced or removed and bring the current state and future state of the ERP system closer together. In ERP systems this could be done by developing additional functionality in the ERP system, reconfigure the ERP system or change the business processes. Shtub and Karni (2009) identifies three types of approaches to use a gap analysis with ERP systems:

Type I: Comparison between a general reference model and specific business requirements. This approach is typical where a customized ERP system would be the result. The general reference model could be extracted from literature, Internet and other system descriptions found in the same industry as the organization that is specifying the business requirement.

Type II: Comparison between a specific organization's business requirement and that of a particular vendor's software. This approach is typically used in evaluation of "out-of-the-box" or "off-the-shelf" software available in the market.

Type III: Comparison of the business requirements of an organization and its current existing ERP system. This is approach is useful where the organization wants to make improvements to the current system or that its business requirements have changed since the implementation of the ERP system.

The researcher proposes a fourth approach or Type IV for the purpose of the research. This approach requires the comparison of a general reference model with that of particular vendor software. The researcher will be comparing the general reference model determined through a requirement analysis extracted from a focused literature review and the functionality of Microsoft Dynamics AX 2012.

The information that was recorded in the gap analysis are: Use Case Reference Number, Brief Description of the gap, the article reference from where the requirement was collected and the classification as Qualitative or Quantitative testing required (Appendix B).

B. Requirement Analysis

A basic description of a Requirement Analysis (RA) would be list of “wishes” or requirements given by stakeholders in order to develop a software application. The general objective of a RA is to list and analyze these requirements to establish which of the requirements are feasible. Furthermore, the RA helps the system analyst to get a better understanding of the required functionality and as a tool to establish the scope or boundaries of software development that might be undertaken (Quiescenti, Bruccoleri, La Commare, Noto La Diega, & Perrone, 2006). The use of a requirement analysis ensures that the final application would meet the expectations of the stakeholders. A popular method of gathering information for an RA would be through interviews with the relevant stakeholders. Furthermore the RA is a means to provide support for the requirement for a system and whether pre-packaged or off-the-shelf packages have such functionality or not (Yousefi, 2011).

The objective of the RA for the research would be to use the RA to determine the general reference model for the gap analysis according the proposed type IV approach. As mentioned earlier, the source for the RA will be a focused literature review. The literature should cover topics where the authors are referring to what they will consider as functionality required to be in a Lean ERP system.

C. Use Case

The Universal Modeling Language (UML) was developed through the efforts of Grady Booch, Ivar Jacobson, and James Rumbaugh as its original designers with the objective of consolidating the numerous object-orientated methods that developed during the late 80s and early 90s. These methods were attempts as alternatives to analysis and design to address the emergence of more complex object-orientated programming languages during the late 80s. Some of these methods were more prominent such as Booch, Jacobson's OOSE (Object-Oriented Software Engineering), and Rumbaugh's OMT (Object Modeling Technique). Other important methods also included Fusion, Shlaer-Mellor, and Coad-Yourdon (Booch, Rumbaugh, & Jacobson, 1999). Each of these had its strengths and weaknesses and in particular Jacobson’s OOSE provided excellent support for use cases as a way to drive requirements capture, analysis, and high-level design. Use cases was included as one of the seven elements namely classes, interfaces, collaborations, use cases, active classes, components, and nodes in the Universal Modeling Language (UML) model with its first released UML 1.3 during the fall of 1998 (Booch et al., 1999). Alistair Cockburn, a notable author and authority on use cases, broadly defines use case as a method to describe the possible ways users (the actors) and a system will interact with each other to achieve a particular goal (Cockburn, 2001)

The objective of the observation phase as described in the research methodology is to observe and understand the "current state" of the system under observation and in particular to understand if the system under observation contains elements of Lean principles. Many Lean tools have been developed in order to improve the manufacturing process but none thus far that can be used to observe the interaction of a user with an ERP system however, the use case as defined in the UML context can be useful as a Lean technique (Sloan, 2005). The use case will be used to record the observation of the "actor" with the system rather than describing a possible sequence of interaction for the purpose of developing a framework. This observation can be described as the "as-is" state. The use cases were used to test the support for the null hypothesis H0. Each of the requirements recorded in the gap analysis and selected for inclusion in the observation were used as a use case for the observation based on the requirement and the relevant functional area.

Based on the suggestions by Sloan (2005) and combining it with a generic template freely available for use case recording, a template was compiled to facilitate observations. Sections are included to measure the Lean principles of operations (Spear & Bowen, 1999) as described in the research methodology overview. The Use-Case template is set out in Appendix A.

The following is a brief description for each of the sections in the Use Case template and the information that it can contain:

<u>Use Case ID:</u> A simple identification of the use case. A reference consisting of the relevant module and use case number for the module was used throughout the research. Where more than one use case was identified for each module, the notation PRUC#1 was used where PR refers to the module, UC for use case and a sequential number of the use case.

<u>Module Description:</u> A brief description of the module that is under evaluation in the use case.

<u>Use Case Name:</u> A brief description of the use case to identify the use case within the module.

<u>Goal:</u> Describes the intention of the user or “primary actor” in the use case.

<u>Location:</u> Describe generally the physical location for the use case however for the purpose of the research the location was described as the already designed software, Microsoft Dynamics AX 2012.

Primary Actor: This will be the user of the ERP system. For the purpose of the research the researcher did the physical interaction with the system during testing and experimentation.

Actor: These are also described as the secondary actors. Coleman (1998) describes secondary actors as actors that are required by the system to complete its task.

Analysis Description: Describe the primary actor's interaction with the system. The step-by-step interaction is described under the section basic flow.

Information System Description: Describes the software that is being researched. An ERP system might be described as a secondary actor under different use case analysis.

Equipment or Peripherals used: Describes hardware that might be needed for the use case to be completed. This is a class of secondary actors.

Time measured: The measured time for executing the use case from beginning till the goal is achieved. Tests were repeated ten times for selected use cases identified to be quantitative tests. Execution times were recorded using IOgraph software that can electronically record the time. The times recorded were tabulated and the mean time calculated. The data for the transactions used in the use cases will be generated using a random transaction generator prepared by the researcher as described in Section 3.4 - Sampling Method later in this chapter. The same data was used to do a second test on the use cases after identifying potential waste and making adjustments to eliminate the waste. Times were recorded in the same ways as the first test, tabulated and the mean time calculated. The first and second test results were compared to identify if there was an improvement. It may be required to repeat the test if there is no significant improvement after using a different method to eliminate any identified waste.

Value Stream Mapping: Value stream mapping was added as a Lean tool to assist in measuring the time and to identify waste. This was useful to identify the areas of improvement through eliminating waste of time in the use case.

Lean Metrics: Spear and Bowen (1999) proposed four rules to identify whether operations can be consider Lean. Each of the rules has been adapted to ERP related criteria to form a Lean metric with which we can measure the operational leanness of the system. Having build-in tools is not an indication that the system was designed with Lean principles in mind. If evidence of the rules could be found then we can consider that the ERP system might be able to support Lean operations and therefore contribute to Lean. Measuring these Lean metrics in the ERP system through the use cases allows us to measure through the “black box” instead of around the system. The following metrics were therefore used to measure the “leanness” of the ERP system by evaluating the selected use cases for the following:

Rule 1: All work must be highly specified as to content, sequence, timing and outcome:

- Sequence of data entry steps are clear: data entry steps show follow a logical sequence when entering data and follow some pattern from top to bottom and left to right.
- Information to be entered is clear and specific: data entry fields should be marked clearly what type of information is to be entered in the field.
- Procedures to perform a task are specified: considering that procedures are collections of steps then the procedures should be descriptive enough to understand what the user will achieve by following the particular procedure e.g. “Customer invoice entry” and not simply “invoice”. “Invoice” can refer to several types of invoices.
- The time to perform a task in the software can be measured and optimized: a task could be a procedure or a single step performed in the system. This metric was measured as time mentioned earlier and the value stream mapping of the process.

Rule 2: Every customer-supplier connection must be direct with a yes-or-no method to send requests and receive responses:

- Information is evaluated as correct before committed to the database: information that needs to be entered can be selected from a drop down list from a predefined table.

- Connecting processes or modules are direct and standardized: processes must be organized to follow each other and can be described as a flowing process.
- Time between each connecting process can be measured and optimized: processes can be connected together to minimize or organized as groups to be executed together to minimize time between processes.

Rule 3: The pathway for every product and service must be simple and direct:

- Workflow through the system is simple and specific: the workflow must be clear for the user as to what is the next step in the process.
- The workflow can only change when redesigned: workflow should be free of multiple options that can cause confusion or cause the work to be done differently every time.
- Workflow is specific to identify the next procedure, module and person: the workflow should indicate to the user and prompt the user for the next procedure or module. The workflow should be connected to persons rather than positions.

Rule 4: Any improvement must be made in accordance with the scientific method, under guidance of a teacher, at the lowest possible level in the organization:

- Improvements are made scientifically and according to Rules 1- 3 for example changing the software configuration settings of the software:

when improvements are identified, a hypothesis should be tested with experimentation to test if changes will improve the system.

Notes and Improvement Opportunities: The researcher can note any observations such as data input/output, movement of the actor, file import/exports or suggestions during the testing that can be used for improvements for the subsequent tests.

Preconditions: List the preconditions might be required to exist in the system in order for the triggers listed below will initiate the use case.

Triggers: Describe the event or events external, temporal or internal and the conditions to be met in order for the use case to be triggered.

Basic Flow: Describe the main flow of the event from start to end without any error states or alternative flows. It should be documented as a list, a conversation or a story.

Alternate Flow: Describe the alternative flows that might occur including the flow that might occur during error states.

Post Conditions: Describe the conditions in the systems that will exist after the use case has been executed successfully.

Activity Diagram: A diagram can be given of the flow of events to illustrate the use case if required.

Notes: Information required that has not been listed anywhere else in the use case and that might be useful for the analysis.

Resources: Describe the resources that must be available or configured in order for the use case to be successfully executed. These are a type of secondary actors and include data and services and the systems that can offer them. They are listed as data, modeling services, event notification services, application services and other resources. These could be services such as the Internet or calling an application service such as Excel or Word or simulation software. These are most likely functions not build into the system under evaluation for the use case and will be external systems.

D. Experimentation

Experimentation is a core activity for the scientific process through which theories are tested, critical factors are being explored to bring new phenomena to light and to formulate and correct theories (Tichy, 1998). Often experimentation and testing are considered the same and confusion between their meanings. This confusion is compounded in practice through renaming test activities to “assessments” or “demonstrations” (Kass, 2008). Experiments are conducted in order to test a hypothesis through manipulation of variables whereas tests are conducted to determine the quality, presence or genuineness of anything (Kass, 2008).

As mentioned in the overview of this section, experimentation and testing was used to facilitate the observation phase as well as test the metrics based on the principles of Lean operations to determine the Lean nature of the modules. In order to determine the experimentation required it was necessary to consider the results from the gap analysis. The selected requirements from the selective literature review were categorized as requiring quantitative or qualitative analysis for experimentation:

1. Quantitative analysis: Time measured in the use case constitutes the primary measurement for the quantitative analysis by measuring the time before and after changes to the particular use case to eliminate waste. The experimentation denotes a quasi-experimental design where there is no control group and the subjects (in this case the processes to be tested) are measured before the treatment and after the treatment. The treatment in this design is the elimination of waste by some method available in the ERP module where the processes are tested. The experiments can be expressed using the Campbell and Stanley notations as follows (Zikmund, 2000, p. 276):

O_1 X O_2

X = Exposure of a group to an experimental treatment

O = Observation or measurement of a dependent variable.

Subscripts indicate the number of the observations taken.

2. Qualitative analysis: Not all the use cases identified in the gap analysis are testable using quantitative analysis and require being analyzed using qualitative analysis techniques. McLeod, MacDonell and Doolin (2011) describe qualitative analysis as meaning research that makes use of words and images rather than analyzing collected data using numbers and quantitative analysis. The basic flow and activity diagram section in the use case template forms an integral part of the qualitative analysis. Dittrich et al. (2007) mention qualitative research has a marginal status in the area of software engineering and is not often used in research even to date. They also felt that the research methodology was not addressing the methodology in much detail how a researcher would go about the day-to-day research activities. The previous methodologies left them with questions such as: 'How do Software development practitioners tackle their everyday work, especially the cooperation with users around the design of software?' and 'How can methods, processes, and tools be improved to address the problems experienced by practitioners?' (Dittrich et al., 2007). Dittrich et al. (2007) therefore expands the research done by Nunamaker et al. (1991)

adding a research design phase to what they call the Cooperative Method Development (CMD). This expanded method consists of three phases:

Phase 1 - Understanding Practice: The initial qualitative empirical phase to investigate the current and historical domain and the content of the problem or process being investigated. The research consists of two possible cycles of qualitative research conducted. The first being the qualitative research to test the functions as per the Lean functionalities identified through the literature review in Table 5.3. The second cycle of qualitative research conducted evaluating the Lean metrics as per Spear and Bowen (1999) as mentioned earlier. Quantitative research within the IS domain are predominantly around development of software and as part of the research methodology for design of software. None of the research using quantitative methods within the IS domain could be found being conducted on already existing software. Dittrich et al. (2007) are describing a few cases where they are applying their CMD method in organization with already existing software. However, none of these cases is testing the existing functionality according to certain criteria. For the purpose of this research, it is necessary to adapt their method to be post development for evaluation of off-the-shelf software such as Microsoft Dynamics AX 2012.

Phase 2 - Deliberate Improvements: Using the results from the previous phase, possible improvements were designed as well as measured for expected improvements.

Phase 3 - Implement and Observe Improvements: During this phase the implementation of the improvements proposed in the previous phase was made. The researcher applies tests and observations after the improvements in order to evaluate the results.

E. Observation

Observation was done using the selected use cases recording the performance of the functions within the software. Observations are often used in conjunction with experimentation and during testing. Nunamaker et al. (1991) describes observation as a research methodology that is helpful where very little is know of the subject or domain under study to form a general understanding of the research area. Methodologies classified as observation are typically case studies, field studies and surveys. Observation in the context of Nunamaker et al. (1991)'s research methodology plays an interactive role in theory building, system development and experimentation. In the extended phase three as proposed by Dittrich et al. (2007), mentioned in the previous section, observation of improvements are used in order to evaluate the results. Neither Nunamaker et al. (1991) nor Dittrich et al. (2007) give any explanation or details about the observational approach and how to conduct such observations. Basili (1996) gives a little more details defining an observational study as applying no treatment or there are no variables to control.

3.3 VALIDITY AND RELIABILITY

Selecting a multi-methodological method as the research approach for this study bring some complexity to the topic of validity and reliability in the sense that both qualitative and quantitative research methods are used during this research combined with experimentation rather than surveys. Nunamaker et al. (1991) when describing the multi-methodological research method do not discuss validity and reliability other than that researchers might develop a system to demonstrate the validity of a solution where the research problem cannot be proven mathematically or by means of empirical testing. Validation could be done through the use of proof-by-demonstration and by defining the requirements of a system so they are measurable. This view, that a demonstration or proof of concept, can replace experimentation and therefore testing for validity and reliability is strongly criticized by Tichy (1998). The argument is that demonstrations are dependent on the observer's imagination and therefore can't be used as solid evidence. Evidence should only be obtained through conducting experiments, the replication of experiments and analysis of the collected data (Tichy, 1998).

Validity: Validity pertaining to experiments is measured as internal validity and external validity (Zikmund, 2000). Venkatesh and Brown (2013) states three broad categories of validity for quantitative research as:

- Measurement validity - an approximation of the measurement accuracy with which the instrument was designed.
- Design validity - the internal and external validity of an experiment:
    1. Internal validity - evidence presented of that the experimental treatment was the root effect of the changes in the dependent variable (Zikmund, 2000, p. 271).
    2. External validity - indicates the degree by which results can be applied to a larger population under study (Zikmund, 2000, p. 273).
- Inferential validity - the statistical interpretation of the quantitative study and correct application of an appropriate statistical method.

Venkatesh and Brown (2013) also classify validity for qualitative research as:

1. Design validity - referring to descriptive validity, credibility and transferability
2. Analytical validity - the theoretical validity, dependability, consistency and plausibility
3. Inferential validity - interpretive validity and confirmability.

Reliability: Reliability is an indication of the level whereby the measurements from an experiment is free from errors and repeatedly yields consistent results (Zikmund, 2000, p. 300). Golafshani (2003) refers to stability as the attribute of stability of an instrument to take measurements with. If the instrument yields a high degree of stable measures it indicates a high degree of reliability and therefore results are repeatable (Wiinberg, 2010). Reliability according to Venkatesh and Brown (2013) is considered if the measure or instrument used is yielding the same results over and over and is a precondition for validity of a measure. Replication of an experiment increases the validity and the reliability of the experiment (Juristo & Omar, 2012). For qualitative research reliability is established through consistency and dependability of the instrument (Venkatesh & Brown, 2013).

3.4 SAMPLING METHOD

1. Quantitative Sampling Method

The experimentation is to be done ten times before any changes to the current state and recorded on a results sheet. A random transaction calculator was prepared to generate the transactions to be tested. A Microsoft Excel model was prepared using master data exported from the Microsoft Dynamics AX database to Excel and building formulae with the random generator functionality of Excel as shown in Appendix C. The master data selected for each use case depends on the type of the transaction for example for use case PRUC#1 the master data required is the vendor code, item codes and item descriptions. Depending on the transaction type, a maximum number of five detail lines were randomly selected by the model. For each detail line a random number was generated for the quantity. Price values are automatically populated from the standard price list when available otherwise the researcher entered a value. The model does not take in consideration other values such as taxes or additional costs. The model was repeated ten times on a single worksheet generated for each selected use case. Once transactions are randomly generated an Excel file was saved with the use case identifier.

2. Qualitative Sampling Method

A literature review as the source for finding a number of requirements for the RA was chosen as an alternative to stakeholder for the following reasons. Firstly, in order to have academically well formulated requirements grounded in research from scholars and not simply that of users that might be subject to their particular work environment or their own understanding of the Lean philosophy. Secondly, a literature review would cover a number of years as well as the opinion of a number of scholars on similar requirements. Thirdly, a literature review would indicate requirements that might have been prevalent a decade ago and have now been added as functionality in ERP software and can therefore support the tested hypothesis and finally, the practical aspect of time as a literature review is less time consuming in filtering and justifying the requirements than conducting interviews.

The four rules of Lean operation as established by Spear and Bowen (1999) is used as the questionnaire for qualitative analysis to test for the evidence of the Lean philosophy applied in the ERP system.

3.5 DATA COLLECTION

1. Quantitative Data collection

The measurement of time was done using IOgraph software that is able to record the interaction between the user and the system through a graphic representation of the movements of the mouse. The user starts and stops the recording manually. The user can save the recorded graphics to a file at the end of the recording. The file name for the graphics is generated with the measured time for example: <<PRUC#1 - 21 IOGraphica - 3.7 minutes (from 13-50 to 13-53).png>>. The researcher recorded the relevant times next to each test in the Excel sheet with the random generated transactions. The same procedure was followed after improvements are made to eliminate waste and saved as a separate file. A comparison was done of the observations before and after the treatment to find the effect of the attempt to eliminate waste.

2. Qualitative Data Collection

The following articles listed in Table 3.5 were chosen from the literature review spanning the years 2000 until 2012:

TABLE 3.5
LITERATURE REVIEW OF LEAN FUNCTIONALITIES REQUIRED IN ERP (2000 – 2012)

Authors	Title	Year	Publisher
Nakashima (2000)	Lean and ERP: friend or foe?	2000	Advanced Manufacturing Magazine, 1–6
Maffett, Kwon and O'Gorman (2002)	Complex Adaptive Systems Design For Lean Manufacturing.	2002	*Academy of Information and Management Sciences* (Vol. 21, pp. 33–39).
Dixon (2004)	The truce between Lean and IT: Technology can help enable the elimination of waste.	2004	Industrial engineer, 36(6), 42–45
Miller (2004)	Lean and ERP: Can They Co-Exist?	2004	Technical Papers-Society of Manufacturing Engineers-All Series-, (158)
Krause (2007)	Wanted: Lean ERP and what to do about it.	2007	Access Your Biz.
Steger-Jensen and Hvolby (2008)	Review of an ERP System Supporting Lean Manufacturing.	2008	Lean Business Systems and Beyond, 257, 67–74.
Halgeri, McHaney and Pei (2010)	ERP Systems Supporting Lean Manufacturing in SMEs.	2010	IGI Global. doi:10.4018/978-1-60566-892-5.ch005
Powell, Riezebos and Strandhagen (2012)	Lean production and ERP systems in SMEs: ERP support for pull production.	2012	International Journal of Production Research, 1(15).

Source: Chalil du Plessis, 2013

The criteria for selecting these articles were for their relevance in discussing and in some cases listing specific requirements that the authors through their research, found to be criteria or functionalities that need to be in an ERP system to be supporting the Lean philosophy.

3. Use Case

For each observation, the use case sheet was completed as described for each section as in section 3.2 - Research Design in order to collect the observed data in an organized fashion for the data distillation process later during the research. The result from the Quantitative data collection as described in the above section was recorded on the use case sheet when applicable as “time measured” before improvement and “time measured” after improvements as described for the relevant use case.

3.6 DATA ANALYSIS

1. Quantitative Data Analysis

The results of the experimentation were recorded on an Excel sheet for each use case. After improvements were made, the same transactions were used to generate results after changes were made to eliminate waste. The results were tabulated and means calculated using XLSTAT, a statistical add-in for Excel 2010 using one sample T-test and z-test. Comparing the results of the experimentation before improvements and after improvements will give an indication of the improvements were successful in eliminating waste. A smaller reading of the means after improvement gives an indication whether applying particular improvements to the process could eliminate waste.

2. Qualitative Data Analysis

Combining the requirements from these articles resulted in a list of two-hundred-and-twenty-two requirements. Many of these were either the same or similar requirements and had to be filtered to exclude duplicated requirements from the different articles. To simply the filtering process each requirement could be classified according to a particular functional area in the ERP. The following functional areas were identified and requirements were categorized accordingly:

TABLE 3.6 FUNCTIONAL AREAS IDENTIFIED AND USED FOR CATEGORIZATION		
Production Purchasing All areas of ERP	Vendors Implementation Configuration	Design Quality Assurance Tools
Integration Financial Administration	Document Management Planning Quality Management	General Quality Control Inventory
Source: Chalil du Plessis, 2013		

In order to have a manageable number of requirements to test and that can be done within the timeframe and scope of this thesis, each of the requirements were evaluated for inclusion or exclusion. A final gap Analysis sheet was prepared with a motivation for exclusion or inclusion. Appendix B: *Gap Analysis from literature with items for evaluation* reflects the requirements that were evaluated to be included will be used during the observation phase using use case to evaluate the “current state”.

3.7 SUMMARY OF CHAPTER THREE

The research methodology used for the research is following a multi-methodological approach consisting of four research strategies: theory building, experimentation, observation and system development. From the result of the gap analysis third paradigm of mixed method research was applied using qualitative and quantitative methods during the experimentation phase. This was found to be suitable for testing the Lean nature of an ERP system. The gap analysis as mentioned earlier was compiled based on a selected number of articles where authors have identified a number of weaknesses of ERP systems to support the Lean philosophy.

Each of the requirements collected in the gap analysis was classified as a qualitative or quantitative type to identify the type of method to use during sampling and experimentation. For the qualitative type the four rules of Lean operations established by Spear and Bowen (1999) were identified to test the existence of the Lean philosophy in an existing ERP system such as Microsoft Dynamics AX 2012. The quantitative requirements were identified where a quantitative measurement can be made through experiments to measure for evidence of Spear and Bowen's rules of Lean operations. A random transaction generator was constructed using an Excel model to generate the test transactions to be used during the experimentation. Furthermore, the technique of use case analysis was used to record the results of experimentation and observation during the data collection phase. Each section of the use case document was explained in detail and how the data will be collected for presentation in the following chapter.

CHAPTER FOUR

PRESENTATION OF THE DATA

CHAPTER FOUR – PRESENTATION OF THE DATA

4.0 PURPOSE STATEMENT

As stated previously, through the application of a multi-disciplinary research approach, the primary purpose of the research is:

> To examine and discover the differences between the Lean principles and ERP applied principles when designing, developing and implementing enterprise systems in organizations. Furthermore, to propose a possible framework that can reconcile these differences and bridge the gap between the two system philosophies.

4.1 REVIEW OF RESEARCH METHOD

As discussed in the previous chapter, the research methodology used for the research aimed to investigate if current ERP systems might contain a Lean nature. Due to the nature of ERP systems and the Lean principles consisting of quantitative as well as qualitative properties, a multi-methodological approach was found to be a suitable method consisting of four research strategies: theory building, experimentation, observation and system development. Mixed method research was applied using qualitative and quantitative methods during the experimentation phase. The research methodology was designed in order to isolate evidence found within an ERP system to support the requirements elucidated within the literature and the principles of lean operations as proposed by Spear & Bowen (1999).

4.2 REVIEW OF DESIGN AND DATA COLLECTION

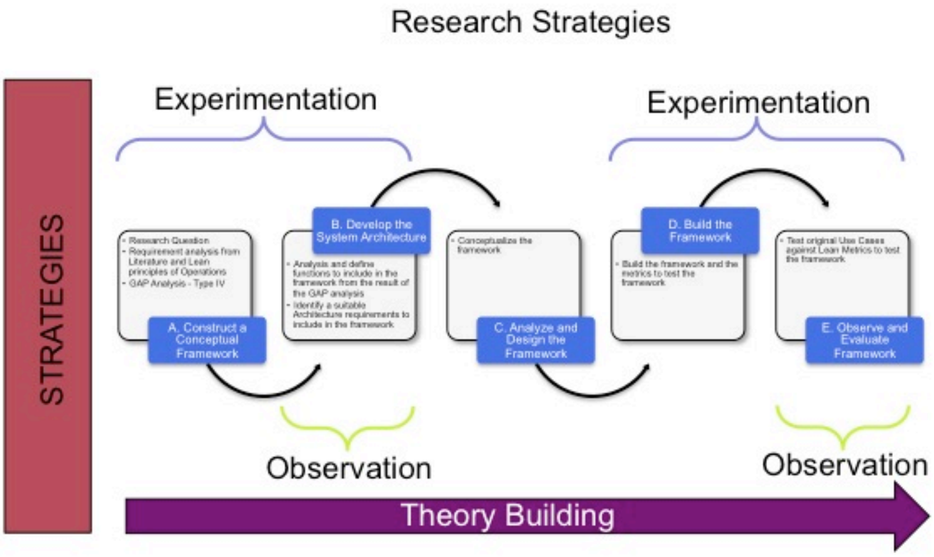
4.2.1 Research Design

In reference to the research design proposed in Chapter Three, data was collected using the following research strategies to collect the quantitative and qualitative data:

- Gap Analysis
- Requirement Analysis
- Use Cases
- Experimentation
- Observation

Figure 4.2.1 A illustrates the use of these strategies in the research design:

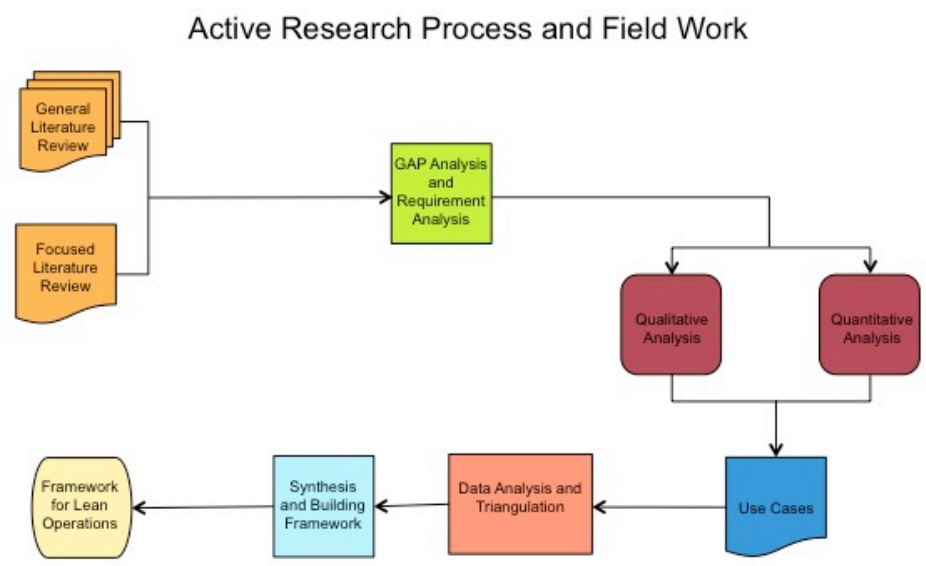
FIGURE 4.2.1 A
RESEARCH STRATEGIES



Source Adapted: Nunamaker et al. (1991)

Figure 4.2.1 B demonstrates the flow of the active research conducted:

FIGURE 4.2.1 B
ACTIVE RESEARCH PROCESS AND FIELD WORK



Source: Chalil du Plessis (2013)

4.2.2 Gap Analysis and Requirement Analysis

The gap analysis and requirement analysis were prepared using the articles as listed in Table 3.5. As discussed in the previous section, the articles were selected for their relevance in discussing and listing specific requirements that the author found to be suitable criteria for supporting the Lean philosophy in an ERP system. A total number of two-hundred-and-twenty-two requirements were collected from the listed articles. These were recorded on an Excel spreadsheet in order to further analyze and categorize, listing the following information in columns:

Use Case: The use case numbers assigned for each selected case for identification during the experimentation phase. The use case numbers were also used to identify electronic files generated with test results relevant to the particular use case.

Description: The description of the requirement collected from the relevant articles. Each requirement was recorded separately in each row.

Reference: The citation reference for the article from where the requirement was taken.

Functional Area: Each requirement was broadly classified according to the functional areas set out in Table 3.6 in the previous chapter. The functional areas can be used to understand the spread of the requirements across functional areas for further analysis.

Toolsets: A potential Lean toolset that can be associated with the requirement.

Qualitative/Quantitative: Categorization of the type of experimentation to be conducted as qualitative or quantitative testing.

What to evaluate: A description of the evaluation criteria that should be used during testing.

How to evaluate or test: A description of the test or evaluation to apply as a quantitative or qualitative test.

Evaluate Yes/No: Include this requirement for evaluation.

Motivation for Evaluation/Non-Evaluation: A brief motivation to explain the inclusion or exclusion of this requirement during this study. Requirements excluded from the study are not necessary without merit for testing. The researcher on the merit evaluated each requirement whether a test can be devised for the requirement in Microsoft Dynamics AX 2012 R2. The criteria were further based on the practicality of testing this particular requirement as well as whether testing the requirement contributes to supporting the null hypothesis. The gap analysis furthermore serves as the basis for future research.

4.2.3 Data Collection

Preparation for experimentation and observation: The researcher prepared a testing lab on a MacBook Pro and using VirtualBox software to run the Microsoft Dynamics AX 2012 R2 virtual machine as supplied for demonstration purposes by Microsoft Corporation (Appendix D). All tests and observations were conducted on the same demonstration software during testing. VirtualBox software allows taking of snapshots of the virtual machine that can then be re-loaded. These snapshots allow the virtual machine state to be restored to the state at the time of taking the snapshot. Where possible snapshots were used before and after test to restore the same state of the system before starting a new set of tests. This was done in order to ensure that data entry during the previous test will not have an effect on the outcome of subsequent tests for example in a case where master data is being added to the system during testing such as Customer name. In order to repeat the test with the same unique data this customer record will have to be added again during the second test. If the record will exist during the second test the readings of the second test will not be accurately reflected. Test and observations were done as per the gap analysis selection of tests for quantitative and qualitative tests.

1. Quantitative Testing: Use Case #1 presents the qualitative testing and observations that was done. Table 4.2.3 A lists the modules selected for testing:

TABLE 4.2.3 A MODULES SELECTED FOR QUANTITATIVE TESTING		
Modules	Module Reference	Use Case Reference
Accounts Payable	AP	APUC#1: Entering Vendor Invoice APUC#1a: Adding Vendor Master Data
Accounts Receivable	AR	ARUC#1: Entering a Customer Sales Order ARUC#1a: Adding Customer Master Data
General Ledger	GL	GLUC#1: Open and Post a General Journal
Fixed Assets	FA	FAUC#1: Acquisition of new Asset
Procurement and sourcing	PR	PRUC#1: Processing a Vendor Purchase Order
Product information management	PI	PIUC#1: Adding new Products
Source: Chalil du Plessis (2014)		

Basic transaction types were selected from each of the above modules that can be processed within the standard functionality of the system without any customization or special configuration of the source code of Microsoft Dynamics AX 2012 R2.

The ERP system should have functions to remove unnecessary mouse clicks, reduce navigation time and waiting time for the user to complete his/her task in the ERP system. Net throughput time of a transaction should be used as a metric to measure if waste has been reduced.

Testing Objective:

1. Throughput time to complete a task in the ERP system.
2. Test the function to reduce the throughput time of navigation in the ERP system if present.

Method:

For each of the selected transaction types a random transaction generator was prepared in Excel as described in the previous section 3.4 Sampling Method. For each test case two sheets were prepared in Excel, one sheet to record the test results before improvement and one sheet for recording the test results after improvement. Both these sheets contain the same data for testing. Two or three test transactions were done in the system before starting the tests to ensure that the researcher understands the procedure and that the researcher can follow the procedure without any interruption. The procedure was written down in the basic flow section of the use case analysis template.

Testing before improvements:

To start the test the researcher opens the Dynamics AX 2012 software on the opening menu displaying the available modules in the system. This is the starting point of all the use case tests. The next step is to also open the IOgraph software. The researcher starts the time test and recording of the mouse movement by selecting the start button in the IOgraph software. Immediately the researcher starts the data entry procedure by moving the mouse pointer and selects the relevant module in Dynamics AX. Following the data entry sheet the researcher enters the transactions. When available a relevant document is printed at the end of the transaction e.g. Invoice and saved as a PDF document. Once completed the researcher stops the recording in IOgraph by selecting the IOgraph icon and select the pause (||) button. Using the save image option the recorded time and image is saved in the format <<IOGraphica - Test *1 XY*UC#*x* before Improvement - *x* minutes (from *z* to *y*).png>>. The results of the test is digitally recoded next to each test in the Excel sheet and saved with the filename <<Random Tests for XXXX#1 Test Data.xlsx>>. For each use case a folder was created with subfolders for before improvement and after improvement. All the files generated were saved in a relevant folder for reference.

Improvements to eliminate waste:

The second part of the qualitative testing consists of using the same test cases after the researcher attempts to make improvements in order to reduce the throughput time of the transactions. Most of the cases could be improved using the build-in personalization function embedded within the Microsoft Dynamics AX 2012 R2 software as indicated in Table 4.2.3 B. Improvements were recorded using screenshot and a description of the improvement recorded on the use case sheet under the section: Applied improvements. Alternative method of data entry was used in one case where more than one option of data entry exists for the same transaction type.

TABLE 4.2.3 B IMPROVEMENT METHOD USED FOR QUANTITATIVE TESTING		
Use Case Reference	Name	Improvement Method
APUC#1	Entering Vendor Invoice	Personalization
APUC#1a	Adding Vendor Master Data	Personalization
ARUC#1	Entering a Customer Sales Order	Personalization
ARUC#1a	Adding Customer Master Data	Personalization
GLUC#1	Open and Post a General Journal	Personalization
FAUC#1	Acquisition of new Asset	Personalization
PRUC#1	Processing a Vendor Purchase Order	Personalization
PIUC#1	Adding new Products	Alternative method of data entry
Source: Chalil du Plessis (2014)		

Before applying the improvements, the earlier snapshot of the virtual machine was loaded for the relevant test case. The earlier snapshot was loaded in order to measure the effect of the improvement as accurately as possible. It is necessary to cancel the effect of the previous testing in the database before improvement on the database in order to repeat the same transactions with the same master data.

Once the improvements have been done a screenshot was taken of the improvements where possible. The same procedure was followed as described previously to do the testing and the testing results from IOgraph time recording saved in the format <<IOGraphica - Test *1 XY*UC#*x* after Improvement - *x* minutes (from *z* to *y*).png>>. The results of the second test was digitally recoded in a new

Excel sheet and saved with the filename <<Random Tests for XXXX#1 Test Data after Improvement.xlsx>>.

The IOgraph results from each test represent the mouse movements as well as the waiting time or stops of the mouse movements by the user as shown in Appendix V. The spaghetti lines represent the movement of the mouse as the user manipulates the cursor across the scene. The dots represent every click of the mouse when the user makes a selection on the screen. The circles around the dots represent the waiting time before the cursor was moved to select a new option.

Flow chart diagrams were prepared for the processes using the build-in task recording function to represent the value stream of the process. Traditional value stream mappings were not used as they represent a macro view of a flow process. A flow chart diagram is more representative of the process for the purpose of the research. These diagrams were generated in Microsoft Visio format and exported into PDF format. The basic flow of the procedures was also generated from the same task recording function in Microsoft Word format.

2. Qualitative Testing: Use Case #1 to Use Case #11 represents the qualitative testing that was done for the use cases as per the gap analysis done earlier. These results were included in the qualitative analysis. A use case sheet was prepared for each use case in Scrivener. The testing for each qualitative test required the researcher to attempt in finding and executing a single transaction using the required functionality in

the Microsoft Dynamics AX 2012 R2 software based on the selected requirements from the gap analysis. After processing the transaction using the functionality, the researcher recorded his observations during the experiment for each section of the use case sheet. These tests were all conducted in the lab environment that was prepared for the quantitative testing. Each completed use case sheet was numbered according to the use case number and saved in Scrivener Software for later analysis.

Testing Objective:

Table 4.2.3 C summarizes the testing objective for the qualitative use cases UC#1 through to UC#11 and Table 4.2.3 D lists the modules of Microsoft Dynamics AX selected for qualitative testing:

TABLE 4.2.3 C TESTING OBJECTIVES FOR QUALITATIVE TESTING	
Use Case Reference	Testing objective
UC#1:	1) Evaluate the throughput time to complete a task in the ERP system. 2) Test the function to reduce the throughput time of navigation in the ERP system if present.
UC#2: Simplify integration of Internal and External Data	Evaluate the integration facilities of the ERP system, internal and external including integration to global lean systems.
PCUC#3: Once off production order	The person responsible for scheduling production order wish to schedule a production order outside of a standard production schedule. This is useful in a lean environment where standard production orders are not used in principle.
MPUC#4: Support for pull production	1) How the software measures and record information related to production performance such as lead times. 2) How are lead times and inventory levels used to support pull production.
MPUC#5: Support for flow scheduling	Analyze the scheduling algorithms to evaluate if scheduling is supporting pull production according to lean. Apply use case analysis and possible simulation to analyze scheduling.
MPUC#6: Support for cellular manufacturing	Test through use case the function of cellular manufacturing. Look for configuration options to facilitate cellular manufacturing information in the database or software.
PCUC#7-1: Support for Production Routing and data capture	Analyze through use case to test functionality available for: 1) Production routing 2) Mapping of item to lines and cells 3) Point to record data for transactions and costs
PCUC#7-2: Scheduling from Delivery Due Dates	Analyze through use case to test functionality available for scheduling production backwards from delivery due dates.
MPUC#8 and MPUC#9: Purchasing based on Kanban	In order to test then use case the ERP system should be able to make use of the concept of Kanban to pull information between modules and systems to automatically generate a purchase order to a vendor once a sales order is placed by the customer.
MPUC#10: Workflow Engineering changes	Test for the existence of a specified workflow and alerts could possibly indicate that the some of the principles of lean operations are applied in the system.
UC#11: Process mapping and training	Testing for the existence of process mapping, training modules and help functions could indicate that the principles of lean operations are being applied.
Source: Chalil du Plessis (2014)	

Method:

The task recorder function within the Microsoft Dynamics AX 2012 R2 software was used to record procedures during the testing. The detailed procedures were auto generated into a Microsoft Word document as well as a Microsoft Visio document. The Visio documents were also converted to PDF format. The objective of the qualitative tests was to observe the functionality within the Microsoft Dynamics AX 2012 R2 software and document the observations. The data collected as observations as per the four rules of Lean operations were used for further data distillation in the following section 4.3 using NVIVO 10 software. Time tests were not conducted for the qualitative tests and no improvements were done or tested.

TABLE 4.2.3 D
MODULES SELECTED FOR QUALITATIVE TESTING

Modules	Module Reference	Use Case Reference
None	None	UC#2: Simplify integration of Internal and External Data
Production control	PC	PCUC#3: Once off production order
Master planning	MP	MPUC#4: Support for pull production
Master planning	MP	MPUC#5: Support for flow scheduling
Master planning	MP	MPUC#6: Support for cellular manufacturing
Production control	PC	PCUC#7-1: Support for Production Routing and data capture
Production control	PC	PCUC#7-2: Scheduling from Delivery Due Dates
Master planning	MP	MPUC#8 and MPUC#9: Purchasing based on Kanban
Master planning	MP	MPUC#10: Workflow Engineering changes
None	None	UC#11: Process mapping and training

Source: Chalil du Plessis (2014)

4.3 DATA DISTILLATION

This section will give a detailed explanation of the data that was collected using the instruments as previously described in Chapter Three: Research Methodology. The use cases used during testing were apportioned in two groups of testing:

4.3.1 Quantitative Use Cases

The quantitative data was collected from eight selected use cases with a total of one hundred and sixty tests conducted. The tests were conducted in two parts before and after improvements as described in the method in the previous section. The following use case summaries and tables summarizes the collected results from the quantitative use cases:

<u>APUC#1: Entering Vendor Invoice:</u> Use case APUC#1 consists of test data exported from the sample database provided with Microsoft Dynamics AX 2012 R2. Table 4.3.1 A lists the data fields that were exported from the CEU database. Ten transactions were randomly generated from the exported data using the Excel Random Transaction generator.

TABLE 4.3.1 A APUC#1 DATA FIELDS EXPORTED	
Vendor	General Ledger Database Fields
Vendor Account	Main Account
Name	Name
Vendor Hold	Main Account Type
Phone	Main Account Category
Source: Chalil du Plessis (2014)	

Table 4.3.1 B1 and Table 4.3.1 B2 use case extractions describes the improvements that were applied during the experimental phase in order to improve the processing time of processing the test transactions:

TABLE 4.3.1 B1 USE CASE AP#1 DATA SHEET BEFORE IMPROVEMENT
Use Case Name Creditors Clerk enters invoice details against an existing vendor account
Basic Flow Creditors clerk receives an approved invoice The creditors clerk log into the AX system with a valid user name and password The user navigates to the Accounts Payable module of the ERP system From the group “Journals” select Invoice journal The system loads the required data entry form From the top menu the user selects “New” A data entry grid is displayed In the first field on the grid the user select from a drop-down menu the name of the journal The journal batch number is generated by the system and the description is displayed Select “Lines” from the top menu to display the data entry form for the detail distribution The user completes the detail line information with the vendor account, invoice number, description, debit or credit, amount and offset account for the general ledger The user completes the details lines containing item codes, description, quantity and cost Select Post from the top menu Flow diagram: Appendix E
Source: Chalil du Plessis (2014)

TABLE 4.3.1 B2 USE CASE AP#1 DATA SHEET APPLIED IMPROVEMENT
Use Case Name Creditors Clerk enters invoice details against an existing vendor account
Applied improvement Improvement was made through the personalization function available to the user in Axapta AX 2012. Using the function the user can hide fields by switching of the visible and/or skip options. Visibility was removed and skip option were switched on for the following fields in the subgroup “OverviewGrid”: Account Type Account Debit Offset account Type Offset Account The same batch of random transaction was processed and the time measured after the improvement. Screenshot: Appendix F
Source: Chalil du Plessis (2014)

Times for processing the transactions before and after the improvement have been recorded using IOgraph software. The resulted graphical representation of the mouse movements and stops were recorded in table 4.3.1 C. These results will be used in the following chapter for the synthesis.

TABLE 4.3.1 C
APUC#1 OBSERVED TIMES DURING TESTING

Test #	Observed Time before Improvement	Observed Stops before Improvement	Observed Time after Improvement	Observed Stops after Improvement
1	2.6	21	1.3	13
2	1.8	18	1	6
3	1.7	14	1.1	2
4	2.1	16	1	4
5	1.9	17	1	6
6	1.7	13	0.97	3
7	4.2	32	1	6
8	1.6	12	1.2	9
9	1.4	12	0.95	5
10	1.4	11	1	5

Source: Chalil du Plessis (2014)

APUC#1a: Adding Vendor Master Data: Use case APUC#1a consists of test data exported from the sample database provided with Microsoft Dynamics AX 2012 R2. Table 4.3.1 D lists the data fields that were exported from the CEU database. Ten transactions were randomly generated from the exported data using the Excel Random Transaction generator.

TABLE 4.3.1 D APUC#1A DATA FIELDS EXPORTED		
Vendor	Terms	Group
Vendor Account	Terms of Payment	Vendor Group
Name	Description	Description
Vendor Hold		Terms of Payment
Phone		Settle Period
		Default Tax Group
Source: Chalil du Plessis (2014)		

Table 4.3.1 E1 and Table 4.3.1 E2 use case extraction describes the improvements that were applied during the experimental phase in order to improve the time during processing the test transactions:

TABLE 4.3.1 E1 USE CASE AP#1A DATA SHEET BEFORE IMPROVEMENT
Use Case Name Creditors Clerk enters vendor's details for a new vendor account in the system
Basic Flow The Creditors clerk received the approved Vendor's data form The Creditors clerk log into the AX system with a valid user name and password The user navigates to the Accounts Payable module in the ERP system From the group "Common" the user selects Vendors The user selects the subgroup All Vendors The system loads the data entry form From the top menu select New Vendor A data entry form is displayed The data entry field "Vendor account" is automatically filled with the next sequence number available for the vendor account The record type is selected from a drop-down list A vendor name is entered by the user in the "Name" field which is marked in red as a required field A search name is automatically generated from the Name field The user selects the "Group" from a drop-down list that is marked as a required field. The following non-mandatory information is entered by the user: • Addresses • Contact information • Miscellaneous details • Vendor Profile • Purchasing demographics • Invoice and delivery information • Purchase order defaults • Payments • Tax 1099 • Retail • Financial Dimensions User selects close button once all relevant information has been entered. Flow diagram: Appendix G
Source: Chalil du Plessis (2014)

TABLE 4.3.1 E2 USE CASE AP#1A DATA SHEET APPLIED IMPROVEMENT
Use Case Name Creditors Clerk enters vendor's details for a new vendor account in the system
Applied improvement Improvement was made through the personalization function available to the user in Axapta AX 2012. Using the function the user can hide fields by switching of the visible and/or skip options. A number of fields were moved from the subgroups to the main group. Visibility was removed and skip option were switched on for a number of the fields that were not used for data entry. The same batch of random vendor details were processed and the time measured after the improvement. Screenshot: Appendix H
Source: Chalil du Plessis (2014)

Times for processing the transactions before and after the improvement have been recorded using IOgraph software. The resulted graphical representation of the mouse movements and stops were recorded in Table 4.3.1 F. These results will be used in the following chapter for the synthesis.

TABLE 4.3.1 F APUC#1A OBSERVED TIMES DURING TESTING				
Test #	Observed Time before Improvement	Observed Time after Improvement	Observed Stops before Improvement	Observed Stops after Improvement
1	7	4	40	14
2	6	4	31	12
3	6	4	24	12
4	7	4	34	13
5	5	4	21	13
6	7	2	36	8
7	5	3	23	11
8	11	3	51	14
9	7	3	27	16
10	5	3	19	10
Source: Chalil du Plessis (2014)				

ARUC#1: Entering a Customer Sales Order: Use case ARUC#1 consists of test data exported from the sample database provided with Microsoft Dynamics AX 2012 R2. Table 4.3.1 G lists the data fields that were exported from the CEU database. Ten transactions were randomly generated from the exported data using the Excel Random Transaction generator.

TABLE 4.3.1 G ARUC#1 DATA FIELDS EXPORTED	
Customer	Items
Customer Account	Item Number
Name	Product Name
Telephone	Search Name
Extension	Product Type
Extension2	Product Subtype
	Product Dimension Group
	Production Type
Source: Chalil du Plessis (2014)	

Table 4.3.1 H1 and Table 4.3.1 H2 use case extraction describes the improvements that were applied during the experimental phase in order to improve the processing time during processing the test transactions:

TABLE 4.3.1 H1 USE CASE ARUC#1 DATA SHEET BEFORE IMPROVEMENT
<u>Use Case Name</u> Salesperson enters purchasing details to produce an Order Confirmation after receiving an order from a customer.
<u>Basic Flow</u> A salesperson receives an approved purchase order from the customer for items to be sold The salesperson log into the AX system with a valid user name and password The user navigates to the “Account Receivables” module of the ERP system The user selects “common” then Sales Order and then “all sales orders” Select from the group “new” the option “Sales order” Create sales order data entry form is open. The user has to enter the Customer number. Select “Ok” and the sales order line entry data form is opened. The user completes the details lines containing item codes, description, quantity and cost Check the total of the sales order Select “sell” from the tab and in the group “generate sales order” select “sales Order Confirmation Preview or print the sales order to a printer or export to PDF format Send the sales order confirmation to the customer Flow diagram: Appendix I
Source: Chalil du Plessis (2014)

TABLE 4.3.1 H2 USE CASE ARUC#1 DATA SHEET APPLIED IMPROVEMENT
Use Case Name Salesperson enters purchasing details to produce an Order Confirmation after receiving an order from a customer.
Applied improvement Improvement was made through the personalization function available to the user in Axapta AX 2012. Using the function the user can hide fields by switching of the visible and/or skip options. Visibility was removed and skip option were switched on for the following fields in the line specs subgroup: The same batch of random transaction was processed and the time measured after the improvement. Screenshot: Appendix J
Source: Chalil du Plessis (2014)

Times for processing the transactions before and after the improvement have been recorded using IOgraph software. The resulted graphical representation of the mouse movements and stops were recorded in Table 4.3.1 I. These results will be used in the following chapter for the synthesis.

TABLE 4.3.1 I ARUC#1 OBSERVED TIMES DURING TESTING				
Test #	Observed Time before Improvement	Observed Time after Improvement	Observed Stops before Improvement	Observed Stops after Improvement
1	6.8	4.5	51	30
2	3.4	2.6	32	20
3	5.6	3	50	24
4	4.8	3.2	37	22
5	5.7	3.8	48	24
6	6.4	3.4	57	25
7	3.8	2.3	31	13
8	3.8	2.9	28	27
9	5.1	3.4	41	29
10	6.9	4.4	52	35
Source: Chalil du Plessis (2014)				

ARUC#1a: Adding Customer Master Data: Use case ARUC#1a consists of test data exported from the sample database provided with Microsoft Dynamics AX 2012 R2. Table 4.3.1 J lists the data fields that were exported from the CEU database. Ten transactions were randomly generated from the exported data using the Excel Random Transaction generator.

TABLE 4.3.1 J ARUC#1A DATA FIELDS EXPORTED		
Customer	Terms	Group
Name	Terms of Payment	Customer Group
Telephone	Description	Description
Extension		Terms of Payment
		Settle Period
		Default Tax Group
		Prices include Sales Tax
Source: Chalil du Plessis (2014)		

Table 4.3.1 K1 and Table 4.3.1 K2 use case extraction describes the improvements that were applied during the experimental phase in order to improve the processing time of processing the test transactions:

TABLE 4.3.1 K1 USE CASE ARUC#1A DATA SHEET BEFORE IMPROVEMENT
Use Case Name Adding Customer account details to the system for future transactions.
Basic Flow The Accounts Receivables clerk receive an appropriate completed customer application form The AR clerk logs into the AX system with a valid user name and password The user navigates to the Accounts Receivable module in the ERP system From the group “Common” the user selects Customers The user selects the subgroup All Customers The system loads the Accounts Receivables grid From the top menu select New Customer A new sub data entry form is displayed The data entry field “Customer account” is automatically filled with the next sequence number available for the customer account: Select Record type, Enter Customer Name, Enter Customer Group, Select Currency, Select Terms of Payment, Select Delivery Terms, Select Mode of Delivery, Select Sales Tax group, Select Tax Exempt Number, Select Country/Region, Select Zip/Postal Code, Enter Street Address, Select City, Select State, Select Country, Enter Phone number, Enter Extension, Enter Fax, Enter E-mail Address, Select Save and Open then Select Customer Main Customer form is loaded with the new customer information and tabs for: General, Addresses, Contact Information, Miscellaneous details, Sales demographics, Credit and collections, Sales Order defaults, Payment defaults, Financial Dimensions, Invoice and delivery, Retail After completing additional information under the tabs the user select close to update the customer tables and return to the main data entry form for customers. Flow diagram: Appendix K
Source: Chalil du Plessis (2014)

TABLE 4.3.1 K2 USE CASE ARUC#1A DATA SHEET APPLIED IMPROVEMENT
<u>Use Case Name</u> Adding Customer account details to the system for future transactions.
<u>Alternate Flow</u> The Accounts Receivables clerk receive an appropriate completed customer application form The AR clerk logs into the AX system with a valid user name and password The user navigates to the Accounts Receivable module in the ERP system From the group “Common” the user selects Customers The user selects the subgroup All Customers The system loads the Accounts Receivables grid From the top menu maintain customer, select the option edit in grid A new grid is displayed with customer accounts From the top menu select new customer Note: the quick data entry form for Accounts Receivables is not displayed in this method and allows for personalization of the data entry forms Main Customer form is loaded with the new customer information and tabs for: General, Addresses, Contact Information, Miscellaneous details, Sales demographics, Credit and collections, Sales Order defaults, Payment defaults, Financial Dimensions, Invoice and delivery, Retail. After completing additional information under the tabs the user select close to update the customer tables and return to the main data entry form for customers.
<u>Applied improvement</u> Improvement was made through the personalization function available to the user in Axapta AX 2012. Using the function the user can hide fields by switching of the visible and/or skip options. A number of fields were moved from the subgroups to the main group. Visibility was removed and skip option were switched on for a number of the fields that were not used for data entry. The same batch of random customer details were processed and the time measured after the improvement. Screenshot: Appendix L
Source: Chalil du Plessis (2014)

Times for processing the transactions before and after the improvement have been recorded using IOgraph software. The resulted graphical representation of the mouse movements and stops were recorded in Table 4.3.1 L. These results will be used in the following chapter for the synthesis.

TABLE 4.3.1 L
ARUC#1A OBSERVED TIMES DURING TESTING

Test #	Observed Time before Improvement	Observed Time after Improvement	Observed Stops before Improvement	Observed Stops after Improvement
1	5	2.8	48	15
2	3.7	3.1	33	18
3	3.6	2.4	28	11
4	3.6	2.2	22	8
5	3.5	2.8	29	15
6	3.6	3.1	23	15
7	3	2	21	12
8	3	2.3	21	10
9	3.9	2.7	28	11
10	3.8	2.7	30	18

Source: Chalil du Plessis (2014)

GLUC#1: Open and Post a General Journal: Use case GLUC#1 consists of test data exported from the sample database provided with Microsoft Dynamics AX 2012 R2. Table 4.3.1 M lists the data fields that were exported from the CEU database. Ten transactions were randomly generated from the exported data using the Excel Random Transaction generator.

TABLE 4.3.1 M GLUC#1 DATA FIELDS EXPORTED	
General Ledger Accounts	
Main Account	Main Account Type
Name	Main Account Category
Source: Chalil du Plessis (2014)	

Table 4.3.1 N1 and Table 4.3.1 N2 use case extraction describes the improvements that were applied during the experimental phase in order to improve the processing time of processing the test transactions.

TABLE 4.3.1 N1
USE CASE GLUC#1 DATA SHEET BEFORE IMPROVEMENT

Use Case Name

General Journal Clerk enters general journal details to the general ledger directly without affecting the sub-ledgers.

Basic Flow

The General Journal Clerk receives an approved journal voucher to be entered to the system.
The General Journal Clerk logs into the AX system with a valid user name and password
The user navigates to the “General Ledger” module of the ERP system
The user selects the option of “General Journal” from the group “Journal”
A data Entry form open and the user select “New” from the top menu.
Select a journal name from the drop down menu in the field “Name”
From the top menu select Setup and enter the offset account code
From the top menu select the option of “Lines” and a new data entry Form is shown
Enter the following:
Date, Account type select “ledger”, Account code, Description, Debit, Credit and Offset Account
Select “New” from the top menu for saving the current line and adding a new line
When all the lines are entered for the journal then select “Validate” from the top menu
If validation is successful then chose the option “Post” from the top menu.
If posting or validation is not successful the return and edit the necessary fields for the correction as indicated by the error messages.
After posting use the close button at the bottom of the form to close the data entry screen.
From the Overview tab select the journal to print.
Choose Print and then “Journal” from the top menu to print a screen copy of the journal. From here the option can be selected to print to printer or to print an electronic copy typically in PDF format.

Flow diagram: Appendix M

Source: Chalil du Plessis (2014)

TABLE 4.3.1 N2 USE CASE GLUC#1 DATA SHEET APPLIED IMPROVEMENT
Use Case Name General Journal Clerk enters general journal details to the general ledger directly without affecting the sub-ledgers.
Applied improvement Improvement was made through the personalization function available to the user in Axapta AX 2012. Using the function the user can hide fields by switching of the visible and/or skip options. Visibility was removed and skip option were switched on for the following fields in the overview subgroup: Use Deposit Slip Reversing Entry Reversing Date Offset Account Type Voucher The same batch of random transaction was processed and the time measured after the improvement. Screenshot: Appendix N
Source: Chalil du Plessis (2014)

TABLE 4.3.1 O GLUC#1 OBSERVED TIMES DURING TESTING				
Test #	Observed Time before Improvement	Observed Time after Improvement	Observed Stops before Improvement	Observed Stops after Improvement
1	3.8	2.7	31	19
2	3.5	2.5	22	18
3	3.8	2.3	32	18
4	3.9	2.8	33	20
5	4.1	2.1	29	12
6	3	2.1	20	13
7	3.5	2.1	18	14
8	2.9	2	14	13
9	2.9	2	17	12
10	3.3	1.9	17	13
Source: Chalil du Plessis (2014)				

Times for processing the transactions before and after the improvement have been recorded using IOgraph software. The resulted graphical representation of the mouse movements and stops were recorded in Table 4.3.1 O. These results will be used in the following chapter for the synthesis.

FAUC#1: Acquisition of new Asset: Use case FAUC#1 consists of test data exported from the sample database provided with Microsoft Dynamics AX 2012 R2. Table 4.3.1 P lists the data fields that were exported from the CEU database. Ten transactions were randomly generated from the exported data using the Excel Random Transaction generator.

TABLE 4.3.1 P FAUC#1 DATA FIELDS EXPORTED		
Fixed Assets Items		
Fixed Asset Group	Type	Current
Fixed Asset Number	Location	Operations
Name	Responsible	Tax
Source: Chalil du Plessis (2014)		

Table 4.3.1 Q1 and Table 4.3.1 Q2 use case extraction describes the improvements that were applied during the experimental phase in order to improve the processing time of processing the test transactions:

TABLE 4.3.1 Q1
USE CASE FAUC#1 DATA SHEET BEFORE IMPROVEMENT

Use Case Name

Adding Fixed Assets master data to the ERP database.

Basic Flow

The Fixed Assets Clerk receives an approved instruction for adding a new Fixed Asset to the system.
The Fixed Assets Clerk logs into the AX system with a valid user name and password
The user navigates to the "Fixed Assets" module of the ERP system
The user selects the option of "Fixed Assets Acquired" from the group "Common"
The Fixed Assets acquired list is shown. From the top menu "New" select Fixed Asset.
A form "New record" is displayed with the following subsections:

General, Technical Information, Insurance, Location, Report Sorting, Reference and Notes as well as Structure.

In the General tab, select the Fixed asset group and enter the asset number. Enter the description. The search name is defaulted to part of the name entered. Select Type, Major type, Property Type, Quantity, Unit of measure and Unit Cost. Enter the Asset activity code and property group. In the Technical Information Tab enter the Make and model. Select location and enter the location using the drop down menu. In the Report Sorting Tab enter the sort field 1. Ignore the Reference Notes and structure tabs.

From the top menu select Value model from the group "Books". Select "New". A line will be added to the displayed grid. Select the value model for Book depreciation and enter the life of the asset in "Service life" field. Repeat the same for the tax depreciation value using the "new" option from the top menu to add an additional line. Select "close" to close the form. Select close again to close the "new record" form. Select the back arrow in the top left hand side corner to return to the Fixed assets main menu.

To print the Product base data, select "Fixed asset listing" report from the "Reports" group.
Choose Select; enter the Fixed asset Number for the field "Fixed asset number" in the "Criteria" field. Select "OK" and "OK" again to produce the report.
Select export to PDF to prepare a PDF copy of the report.

Flow diagram: Appendix O

Source: Chalil du Plessis (2014)

TABLE 4.3.1 Q2 USE CASE FAUC#1 DATA SHEET APPLIED IMPROVEMENT
Use Case Name Adding Fixed Assets master data to the ERP database.
Applied improvement Improvement to the process was done through the customization option in the "fixed assets acquired" menu option under the "Common" group from the option "New Assets". The following fields were combined in the general form: Make, Model, Location, Sorting and Department. And the following subgroups were made not visible: Technical Information, Insurance, Location, Report Sorting, Reference and Notes as well as Structure. Screenshot: Appendix P
Source: Chalil du Plessis (2014)

Times for processing the transactions before and after the improvement have been recorded using IOgraph software. The resulted graphical representation of the mouse movements and stops were recorded in Table 4.3.1 R. These results will be used in the following chapter for the synthesis.

TABLE 4.3.1 R FAUC#1 OBSERVED TIMES DURING TESTING				
Test #	Observed Time before Improvement	Observed Time after Improvement	Observed Stops before Improvement	Observed Stops after Improvement
1	4.5	1.9	46	14
2	3	2.5	26	14
3	3.1	2.1	20	10
4	2.5	2.3	20	15
5	4.2	2.2	34	14
6	2.7	1.9	18	10
7	2.2	2.3	17	11
8	2.6	1.9	16	13
9	2.2	1.7	16	11
10	2.5	2.3	20	15
Source: Chalil du Plessis (2014)				

PRUC#1: Processing a Vendor Purchase Order: Use case PRUC#1 consists of test data exported from the sample database provided with Microsoft Dynamics AX 2012 R2. Table 4.3.1 S lists the data fields that were exported from the CEU database. Ten transactions were randomly generated from the exported data using the Excel Random Transaction generator.

TABLE 4.3.1 S PRUC#1 DATA FIELDS EXPORTED	
Vendors	Items
Vendor Account	Item Number
Name	Product Name
Vendor Hold	Search Name
Phone	Product Type
Extension	Product Subtype
	Product Dimension Group
	Production Type
Source: Chalil du Plessis (2014)	

Table 4.3.1 T1 and Table 4.3.1 T2 use case extraction describes the improvements that were applied during the experimental phase in order to improve the processing time of processing the test transactions:

TABLE 4.3.1 T1 USE CASE PRUC#1 DATA SHEET BEFORE IMPROVEMENT
Use Case Name Purchase clerk enters purchasing details to produce a purchase order that can be send to the Vendor in printed format.
Basic Flow Purchase clerk receives an approved purchase requisition for items to be procured The purchase clerk log into the AX system with a valid user name and password The user navigates to the “procurement and sourcing” module of the ERP system The user selects “Purchase orders” under the common group The user selects option “All purchase orders” The purchase clerk selects from the group “New” the option Purchase Order The system loads the required data entry form The user select a predefined vendor from a drop down list The user accepts the option to transfer the Vendor information The user accepts the change by selecting “OK” and the Purchase Order lines form is displayed The user completes the details lines containing item codes, description, quantity and cost Check the total of the purchase order Confirm the purchase order Preview or print the purchase order to a printer or export to PDF format Send the purchase order to the vendor Flow diagram: Appendix Q
Source: Chalil du Plessis (2014)

TABLE 4.3.1 T2 USE CASE PRUC#1 DATA SHEET APPLIED IMPROVEMENT
Use Case Name Purchase clerk enters purchasing details to produce a purchase order that can be send to the Vendor in printed format.
Alternate Flow The vendor account does not exist in the system. The user is required to add a Vendor account from the Accounts Pay module, create new Vendor function. Item to be purchased does not exist in the system. The user must add the product code from the Product Information management module, new Product function.
Applied improvement Improvement was made through the personalization function available to the user in Axapta AX 2012. Using the function the user can hide fields by switching of the visible and/or skip options. Visibility was removed and skip option were switched on for the following fields in the line specs subgroup: Variant Number, Type, Budget check results, Line number, Procurement category, Inventory dimensions - Batch number, Inventory dimensions - Serial number, QtyUnitLine - CW quantity, QtyUnitLine - CW unit, Discount, Discount percent, Quality order status, Receive now, CW receive now and Vendor retention term. The same batch of random transaction was processed and the time measured after the improvement. Screenshot: Appendix R
Source: Chalil du Plessis (2014)

Times for processing the transactions before and after the improvement have been recorded using IOgraph software. The resulted graphical representation of the mouse movements and stops were recorded in Table 4.3.1 U. These results will be used in the following chapter for the synthesis.

TABLE 4.3.1 U PRUC#1 OBSERVED TIMES DURING TESTING				
Test #	Observed Time before Improvement	Observed Time after Improvement	Observed Stops before Improvement	Observed Stops after Improvement
1	6.7	3.7	60	29
2	9.3	5.4	74	45
3	5.4	2.8	58	24
4	5.3	3.7	41	34
5	5.3	3.4	49	25
6	4.4	2.1	48	15
7	4.8	3.3	42	22
8	3.3	2.8	25	23
9	7.7	10	65	63
10	5.8	4.2	46	25
Source: Chalil du Plessis (2014)				

PIUC#1: Adding new Products: Use case PIUC#1 consists of test data exported from the sample database provided with Microsoft Dynamics AX 2012 R2. Table 4.3.1 V lists the data fields that were exported from the CEU database. Ten transactions were randomly generated from the exported data using the Excel Random Transaction generator.

TABLE 4.3.1 V PIUC#1 DATA FIELDS EXPORTED	
Items	
ItemID	DataAreaID
Product Name	ProductType
NameAlias	ItemGroupName
ItemType	ItemGroupID
CostgroupID	ProductSubtype
ReqGroupID	ProductSubtypeName
BOMUnitID	
Source: Chalil du Plessis (2014)	

Table 4.3.1 W1 and Table 4.3.1 W2 use case extraction describes the improvements that were applied during the experimental phase in order to improve the processing time of processing the test transactions:

TABLE 4.3.1 W1 **USE CASE PIUC#1 DATA SHEET BEFORE IMPROVEMENT**
Use Case Name Adding a new product code to the system with relevant parameters to be used by all the subsystems and related companies.
Basic Flow The Stock Control Clerk receives an approved instruction for a new product to be added to the system. The Stock Control Clerk logs into the AX system with a valid user name and password The user navigates to the "Product Information Management" module of the ERP system The user selects the option of "Products" from the group "Common" A data Entry form opens to create a new product. Select the product type as "Item" and Product subtype as "Product" The product number defaults as a predefined number under the section identification and is locked for editing in this form. Enter the Product name and Search name. Select an appropriate Retail category. If the category is not available then leave the field blank. Mark the item as CW product if Catch weight is required. Click on "OK" to add the product code to the database and exist the entry form. The default product number was used to add the record to the database. In order to change the product number select the product line in the displayed product grid and double click. A form to edit the product is displayed. From the top menu select "rename". A submenu to change the product number is displayed. Enter the New product number. The product number entered is verified. Select "OK" if available as a unique number. Click Close to return to the product grid. Select "Refresh" from the top menu to display the changed code in the product grid. From the top menu select "Release products" A submenu is displayed to add or remove product to be released to selected companies. The selected item is displayed. Choose the option "Select companies" from the menu on the left and select the appropriate company name for which to add the product. Click on "OK" to add the product to the selected company. Click on "OK" to post the product release session batch. The user is returned to the Product grid with the added product code displayed in the grid. Use the left arrow in the top left hand side of the program to return to the main menu options for the Product information management module. Select "Released products" from the group "Common" Enter the newly created product code in the filter or scroll down in the displayed product grid for the newly added product code. Select the code and double click. A submenu is displayed with the following subsections: General, Purchase, Sell, Foreign Trade, Manage inventory, Engineer, Plan, Manage projects, Manage costs, Financial dimensions and Retail. Select edit from the top menu and complete the relevant sub-forms with the appropriate information. Click on close to update the database with the updated information. Click three times on the left arrow on the top left hand side corner of the form to return to the main menu of the Product Information Management module. To print the Product base data, select "Product base data" report from the "Reports" group. Choose Select, enter the product/Item Number for the field "Item number" in the "Criteria" field. Select "OK" and "OK" again to produce the report. Select export to PDF to prepare a PDF copy of the report. Flow diagram: Appendix S
Source: Chalil du Plessis (2014)

TABLE 4.3.1 W2
USE CASE PIUC#1 DATA SHEET APPLIED IMPROVEMENT

Use Case Name

Adding a new product code to the system with relevant parameters to be used by all the subsystems and related companies.

Applied improvement

Improvement to the process is made using an alternative method of initializing the new item directly as a released product selecting “release product” from the “common” group on the main menu. This option allows combining the initial steps from separate menu options into a single menu. The same data still have to be entered.

Screenshot: Appendix T

Source: Chalil du Plessis (2014)

TABLE 4.3.1 X
PIUC#1 OBSERVED TIMES DURING TESTING

Test #	Observed Time before Improvement	Observed Time after Improvement	Observed Stops before Improvement	Observed Stops after Improvement
1	7.6	6	68	41
2	7.8	5.3	66	28
3	8.2	5.6	74	39
4	9	4.7	74	28
5	7	4.9	55	33
6	7.3	6.8	58	46
7	6.4	4.5	46	32
8	6.5	4.1	57	31
9	5.2	4.1	39	23
10	7.9	5.3	76	38

Source: Chalil du Plessis (2014)

Times for processing the transactions before and after the improvement have been recorded using IOgraph software. The resulted graphical representation of the mouse movements and stops were recorded in Table 4.3.1 X. These results will be used in the following chapter for the synthesis.

4.3.2 Qualitative Use Cases

Qualitative data was collected across all the use cases UC#1 to UC#11. A total number of eighteen use case tests were conducted and the observation recorded. Observations by the researcher for each of the tested rules and its metrics recorded on the use case sheets were imported to NVIVO 10 software. The observations for each use case were then further analyzed, categorized and coded for each of the four rules. The results from the analysis were summarized in the tally charts presented in the following pages for each of the rules and metrics. Table 4.3.2 A indicates the categories that were used during the analysis of the observations using NVIVO 10 software.

TABLE 4.3.2 A METRICS AND CATEGORIES FOR RULE 1		
Metric	Category	Sub Category
Information to be entered is clear and specific	Information Clarity	Information clear
		Information not clear
	Specific Information	Specific
		Not specific
	No functionality found	
Procedures to perform a task are specified	Specific procedures	Procedure is specific
		Procedure not specific
	User guidance	User is guided through procedure
		User is not guided through procedure
	No functionality found	
Sequence of data entry steps are clear	Sequence	More than one sequence available
		Next step indicated
		Next steps not indicated
	Clarity	Steps clear
		Steps not clear
	No functionality found	
The time to perform a task in the software can be measured and optimized	Time measurement	Time can be measured
		Time cannot be measured
	Time optimization	Time can be optimized
		Time cannot be optimized
		Time not measured
	No functionality found	
Source: Chalil du Plessis (2014)		

Rule 1: All work must be highly specified as to content, sequence, timing and outcome. Table 4.3.2 A indicates the Metrics classified in categories and sub categories. This categorization was used to analyze the observations using NVIVO 10 software.

Tally charts were produced from the observation for each metric for rule 1. The observations were tallied for each category and sub category as per the classification in

Tables 4.3.2 A. The results are presented in the following tally charts for each of the metrics with its relevant categories and sub categories:

TABLE 4.3.2 B
METRICS AND CATEGORIES FOR RULE 1: INFORMATION TO BE ENTERED IS CLEAR AND SPECIFIC

UC#	A : Rule 1	B : Information to be entered is clear and specific	C : Information clarity	D : Information clear	E : Information not clear	F : No functionality found	G : Specific information	H : Not specific	I : Specific
APUC#1		2	1	1	0	0	1	0	1
APUC#1a		2	1	1	0	0	1	1	0
ARUC#1		2	1	1	0	0	1	0	1
ARUC#1a		2	1	1	0	0	1	0	1
FAUC#1		2	1	1	0	0	1	0	1
GLUC#1		2	1	1	0	0	1	0	1
PIUC#1		2	1	1	0	0	1	1	0
PRUC#1		2	1	1	0	0	1	0	1
UC#2		2	1	1	0	0	1	0	1
PCUC#3		2	1	1	0	0	1	0	1
MPUC#4		2	1	0	1	0	1	1	0
MPUC#5		2	1	0	1	0	1	1	0
MPUC#6		2	1	0	1	0	1	1	0
PCUC#7-1		2	1	1	0	0	1	0	1
PCUC#7-2		2	1	1	0	0	1	0	1
MPUC#8 and MPUC#9		2	1	1	0	0	1	0	1
MPUC#10		1	0	0	0	1	0	0	0
UC#11		2	1	1	0	0	1	1	0
Total #		35	17	14	3	1	17	6	11

Source: Chalil du Plessis (2014)

TABLE 4.3.2 C
METRICS AND CATEGORIES FOR RULE 1: PROCEDURES TO PERFORM A TASK ARE SPECIFIED

UC#	A : Rule 1	J : Procedures to perform a task are specified	K : No functionality found	L : Specific procedures	M : Procedure is specific	N : Procedure not specific	O : User guidance	P : User is guided through procedure	Q : User is not guided through procedure
APUC#1		2	0	1	0	1	1	0	1
APUC#1a		2	0	1	1	0	1	0	1
ARUC#1		2	0	1	0	1	1	0	1
ARUC#1a		1	0	1	1	0	0	0	0
FAUC#1		2	0	1	0	1	1	0	1
GLUC#1		2	0	1	0	1	1	0	1
PIUC#1		2	0	1	0	1	1	1	0
PRUC#1		2	0	1	0	1	1	0	1
UC#2		2	0	1	0	1	1	0	1
PCUC#3		2	0	1	0	1	1	1	0
MPUC#4		2	0	1	0	1	1	0	1
MPUC#5		2	0	1	0	1	1	0	1
MPUC#6		2	0	1	0	1	1	0	1
PCUC#7-1		2	0	1	1	1	1	1	0
PCUC#7-2		2	0	1	0	1	1	0	1
MPUC#8 and MPUC#9		2	0	1	0	1	1	0	1
MPUC#10		1	1	0	0	0	0	0	0
UC#11		2	0	1	1	0	1	0	1
Total #		34	1	17	4	14	16	3	13

Source: Chalil du Plessis (2014)

TABLE 4.3.2 D
METRICS AND CATEGORIES FOR RULE 1: SEQUENCE OF DATA ENTRY STEPS ARE CLEAR

UC#	A : Rule 1	R : Sequence of data entry steps are clear	S : Clarity	T : Steps clear	U : Steps not clear	V : No functionality found	W : Sequence	X : More than one sequence available	Y : Next step indicated	Z : Next steps not indicated
APUC#1		2	1	0	1	0	1	0	0	1
APUC#1a		2	1	0	1	0	1	0	0	1
ARUC#1		2	1	0	1	0	1	1	0	1
ARUC#1a		1	1	1	0	0	0	0	0	0
FAUC#1		3	1	0	1	0	2	1	0	1
GLUC#1		2	1	1	0	0	1	0	0	1
PIUC#1		2	1	0	1	0	1	0	0	1
PRUC#1		3	1	0	1	0	2	0	0	2
UC#2		2	1	0	1	0	1	0	0	1
PCUC#3		2	1	0	1	0	1	0	0	1
MPUC#4		2	1	0	1	0	1	0	0	1
MPUC#5		2	1	0	1	0	1	0	0	1
MPUC#6		2	1	0	1	0	1	0	0	1
PCUC#7-1		2	1	0	1	0	1	0	0	1
PCUC#7-2		2	1	0	1	0	1	0	0	1
MPUC#8 and MPUC#9		2	1	0	1	0	1	0	0	1
MPUC#10		1	0	0	0	1	0	0	0	0
UC#11		1	1	1	0	0	0	0	0	0
Total #		35	17	3	14	1	17	2	0	16

Source: Chalil du Plessis (2014)

TABLE 4.3.2 E
METRICS AND CATEGORIES FOR RULE 1: THE TIME TO PERFORM A TASK IN THE SOFTWARE CAN BE MEASURED AND OPTIMIZED

UC#	A : Rule 1	AA : The time to perform a task in the software can be measured and optimized	AB : No functionality found	AC : Time measurement	AD : Time can be measured	AE : Time cannot be measured	AF : Time optimization	AG : Time can be optimized	AH : Time cannot be optimized	AI : Time not measured
APUC#1		2	0	1	1	0	1	1	0	0
APUC#1a		2	0	1	1	0	1	1	0	0
ARUC#1		2	0	1	1	0	1	1	0	0
ARUC#1a		2	0	1	1	0	1	1	0	0
FAUC#1		2	0	1	1	0	1	1	0	0
GLUC#1		2	0	1	1	0	1	1	0	0
PIUC#1		2	0	1	1	0	1	1	0	0
PRUC#1		2	0	1	1	0	1	1	0	0
UC#2		3	0	1	1	0	2	1	0	1
PCUC#3		2	0	1	1	0	1	0	0	1
MPUC#4		1	0	0	0	0	1	0	0	1
MPUC#5		1	0	0	0	0	1	0	0	1
MPUC#6		1	0	0	0	0	1	0	0	1
PCUC#7-1		1	0	0	0	0	1	0	0	1
PCUC#7-2		1	0	0	0	0	1	0	0	1
MPUC#8 and MPUC#9		1	0	0	0	0	1	0	0	1
MPUC#10		1	0	0	0	0	1	0	0	1
UC#11		1	0	0	0	0	1	0	0	1
Total #		29	0	10	10	0	19	9	0	10

Source: Chalil du Plessis (2014)

Rule 2: Every customer-supplier connection must be direct with a yes-or-no method to send requests and receive responses.

TABLE 4.3.2 F METRICS AND CATEGORIES FOR RULE 2		
Metric	Category	Sub Category
Connecting processes or modules are direct and standardized	Connectivity	Modules connected directly
		Processes not connected directly
	Processes	Processes standardized
		Processes not standardized
	No functionality found	
Information is evaluated as correct before committed to the database	Information evaluated as correct	Auto evaluation of data
		Manual evaluation of data
	Information not evaluated as correct	
	No functionality found	
Time between each connecting process can be measured and optimized	Time measurement	Time can be measured
		Time cannot be measured
	Time optimization	Time can be optimized
		Time cannot be optimized
		Time not measured
	No functionality found	
Source: Chalil du Plessis (2014)		

The following tally charts were produced from the observation for each metric for rule 2. The observations were tallied for each category and sub category as per the classification in Tables 4.3.2 F. The results are presented below showing a separate tally chart for each of the metrics with its relevant categories and sub categories:

TABLE 4.3.2 G
METRICS AND CATEGORIES FOR RULE 2: CONNECTING PROCESSES OR MODULES ARE DIRECT AND STANDARDIZED

UC#	AJ : Rule 2	AK : Connecting processes or modules are direct and standardized	AL : Connectivity	AM : Modules connected directly	AN : Processes not connected directly	AO : No functionality found	AP : Processes	AQ : Processes not standardized	AR : Processes standardized
APUC#1		2	1	1	0	0	1	0	1
APUC#1a		3	1	1	0	0	2	1	1
ARUC#1		2	1	1	0	0	1	0	1
ARUC#1a		2	1	1	1	0	1	1	0
FAUC#1		1	1	0	1	0	0	0	0
GLUC#1		2	1	0	1	0	1	0	1
PIUC#1		2	1	1	0	0	1	0	1
PRUC#1		2	1	1	0	0	1	0	1
UC#2		2	2	1	1	0	0	0	0
PCUC#3		1	0	0	0	0	1	0	1
MPUC#4		2	1	1	0	0	1	0	1
MPUC#5		2	1	1	0	0	1	0	1
MPUC#6		2	1	0	1	0	1	0	1
PCUC#7-1		2	1	0	1	0	1	1	0
PCUC#7-2		2	1	1	1	0	1	0	1
MPUC#8 and MPUC#9		2	1	1	0	0	1	0	1
MPUC#10		1	0	0	0	1	0	0	0
UC#11		1	1	0	1	0	0	0	0
Total #		33	17	11	8	1	15	3	12

Source: Chalil du Plessis (2014)

TABLE 4.3.2 H METRICS AND CATEGORIES FOR RULE 2: INFORMATION IS EVALUATED AS CORRECT BEFORE COMMITTED TO THE DATABASE							
UC#	AJ : Rule 2	AS : Information is evaluated as correct before committed to the database	AT : Information evaluated as correct	AU : Auto Evaluation of data	AV : manual evaluation of data	AW : Information not evaluated as correct	AX : No functionality found
APUC#1		1	1	1	1	0	0
APUC#1a		2	1	1	0	1	0
ARUC#1		1	1	0	0	0	0
ARUC#1a		1	1	0	0	0	0
FAUC#1		1	1	1	0	0	0
GLUC#1		1	1	1	0	0	0
PIUC#1		1	1	0	0	0	0
PRUC#1		1	1	0	0	0	0
UC#2		1	1	0	0	0	0
PCUC#3		1	1	0	0	0	0
MPUC#4		1	1	0	0	0	0
MPUC#5		1	1	0	0	0	0
MPUC#6		1	1	0	0	0	0
PCUC#7-1		1	1	0	0	0	0
PCUC#7-2		1	1	0	0	0	0
MPUC#8 and MPUC#9		1	1	0	0	0	0
MPUC#10		0	0	0	0	0	0
UC#11		1	0	0	0	1	0
Total #		18	16	4	1	2	0
Source: Chalil du Plessis (2014)							

TABLE 4.3.2 I
METRICS AND CATEGORIES FOR RULE 2: TIME BETWEEN EACH CONNECTING PROCESS CAN BE MEASURED AND OPTIMIZED

UC#	AJ : Rule 2	AY : Time between each connecting process can be measured and optimized	AZ : No functionality found	BA : Time measurement	BB : Time can be measured	BC : Time cannot be measured	BD : Time optimization	BE : Time can be optimized	BF : Time cannot be optimized	BG : Time not measured
APUC#1		1	0	1	1	1	0	0	0	0
APUC#1a		2	0	1	1	0	1	1	0	0
ARUC#1		2	0	1	1	0	1	1	0	0
ARUC#1a		2	0	1	1	0	1	1	0	0
FAUC#1		2	0	1	1	0	1	1	0	0
GLUC#1		2	0	1	1	0	1	1	0	0
PIUC#1		2	0	1	1	0	1	1	0	0
PRUC#1		2	0	1	0	1	1	0	1	0
UC#2		1	0	0	0	0	1	0	0	1
PCUC#3		1	0	0	0	0	1	0	0	1
MPUC#4		1	0	0	0	0	1	0	0	1
MPUC#5		1	0	0	0	0	1	0	0	1
MPUC#6		1	0	0	0	0	1	0	0	1
PCUC#7-1		1	0	0	0	0	1	0	0	1
PCUC#7-2		1	0	0	0	0	1	0	0	1
MPUC#8 and MPUC#9		1	0	0	0	0	1	0	0	1
MPUC#10		2	1	0	0	0	1	0	0	1
UC#11		1	0	0	0	0	1	0	0	1
Total #		26	1	8	7	2	17	6	1	10

Source: Chalil du Plessis (2014)

Rule 3: The pathway for every product and service must be simple and direct.

TABLE 4.3.2 J METRICS AND CATEGORIES FOR RULE 3		
Metric	Category	Sub Category
Workflow through the system is simple and specific	Specific Workflow	Workflow is specific
		Workflow is not specific
	Workflow complexity	Workflow is simple
		Workflow is complex
	Workflow existing	Workflow exists
		Workflow does not exists
		No workflow but logic directional menu
	No functionality found	
The workflow can only change when redesigned	Workflow can be redesigned	
	Workflow cannot be redesigned	
	No functionality found	
Workflow is specific to identify the next procedure, module and person	Workflow specify next procedure	
	Workflow does not specify the next procedure	
	No functionality found	
Source: Chalil du Plessis (2014)		

The following tally charts were produced from the observation for each metric for rule 3. The observations were tallied for each category and sub category as per the classification in Tables 4.3.2 J. The results are presented below showing a separate tally chart for each of the metrics with its relevant categories and sub categories:

TABLE 4.3.2 K
METRICS AND CATEGORIES FOR RULE 3: WORKFLOW THROUGH THE SYSTEM IS SIMPLE AND SPECIFIC

UC#	BH : Rule 3	BQ : Workflow through the system is simple and specific	BR : No functionality found	BS : Specific workflow	BT : Workflow is not specific	BU : Workflow is specific	BV : Workflow complexity	BW : Workflow is complex	BX : Workflow is simple	BY : Workflow existing	BZ : No workflow but logic directional menu	CA : Workflow does not exists	CB : Workflow exists
APUC#1		3	0	1	1	0	0	0	0	2	1	1	0
APUC#1a		2	0	1	1	0	1	0	1	0	0	0	0
ARUC#1		3	0	1	0	1	1	0	1	1	0	1	0
ARUC#1a		3	0	1	1	0	1	0	1	1	0	1	0
FAUC#1		1	0	0	0	0	0	0	0	1	0	1	0
GLUC#1		3	0	1	1	0	1	1	0	1	0	1	0
PIUC#1		2	0	1	1	0	0	0	0	1	0	1	0
PRUC#1		2	0	1	1	0	0	0	0	1	0	1	0
UC#2		1	0	0	0	0	1	1	0	0	0	0	0
PCUC#3		4	0	2	1	1	1	1	0	1	0	0	1
MPUC#4		3	0	1	1	0	1	1	0	1	0	1	0
MPUC#5		4	0	2	1	1	2	1	1	0	0	0	0
MPUC#6		3	0	1	1	0	1	1	0	1	0	1	0
PCUC#7-1		2	0	1	1	0	0	0	0	1	0	1	0
PCUC#7-2		3	0	1	0	1	1	0	1	1	0	0	1
MPUC#8 and MPUC#9		2	0	1	1	0	1	1	0	0	0	0	0
MPUC#10		1	1	0	0	0	0	0	0	0	0	0	0
UC#11		3	0	1	0	1	1	0	1	1	0	0	1
Total #		45	1	17	12	5	13	7	6	14	1	10	3

Source: Chalil du Plessis (2014)

TABLE 4.3.2 L METRICS AND CATEGORIES FOR RULE 3: THE WORKFLOW CAN ONLY CHANGE WHEN REDESIGNED					
UC#	BH : Rule 3	BI : The workflow can only change when redesigned	BJ : No functionality found	BK : Workflow can be redesigned	BL : Workflow cannot be redesigned
APUC#1		1	0	0	1
APUC#1a		1	0	0	1
ARUC#1		1	0	0	1
ARUC#1a		1	0	0	1
FAUC#1		1	0	0	1
GLUC#1		1	0	0	1
PIUC#1		1	0	0	1
PRUC#1		1	0	0	1
UC#2		1	0	0	1
PCUC#3		1	0	0	1
MPUC#4		1	0	0	1
MPUC#5		1	0	0	1
MPUC#6		1	0	0	1
PCUC#7-1		1	0	0	1
PCUC#7-2		1	0	0	1
MPUC#8 and MPUC#9		1	0	0	1
MPUC#10		1	1	0	0
UC#11		1	0	0	1
Total #		18	1	0	17
Source: Chalil du Plessis (2014)					

TABLE 4.3.2 M METRICS AND CATEGORIES FOR RULE 3: WORKFLOW IS SPECIFIC TO IDENTIFY THE NEXT PROCEDURE, MODULE AND PERSON					
UC#	BH : Rule 3	BM : Workflow is specific to identify the next procedure, module and person	BN : No functionality found	BO : Workflow does not specify the next procedure	BP : Workflow specify next procedure
APUC#1		1	0	1	0
APUC#1a		1	0	1	0
ARUC#1		1	0	1	0
ARUC#1a		1	0	1	0
FAUC#1		1	0	1	0
GLUC#1		1	0	1	0
PIUC#1		1	0	1	0
PRUC#1		1	0	1	0
UC#2		1	0	1	0
PCUC#3		1	0	1	0
MPUC#4		1	0	0	1
MPUC#5		1	0	1	0
MPUC#6		1	0	1	0
PCUC#7-1		1	0	1	0
PCUC#7-2		1	0	1	0
MPUC#8 and MPUC#9		1	0	1	0
MPUC#10		1	1	0	0
UC#11		1	0	1	0
Total #		18	1	16	1
Source: Chalil du Plessis (2014)					

Rule 4: Any improvement must be made in accordance with the scientific method, under guidance of a teacher, at the lowest possible level in the organization.

TABLE 4.3.2 N METRICS AND CATEGORIES FOR RULE 4		
Metric	Category	Sub Category
Improvements are made scientifically and according to Rules 1- 3 for example changing the software	User improvements	Improvements can be done by a user
		Improvements cannot be done by a user
	Scientific method	Improvements can be done scientifically
		Improvements cannot be done scientifically
	No functionality found	
Source: Chalil du Plessis (2014)		

The following tally charts were produced from the observation for the metric for rule 4. The observations were tallied for each category and sub category as per the classification in Tables 4.3.2 N. The results are presented below showing a separate tally chart for the metric with its relevant categories and sub categories:

TABLE 4.3.2 O
METRICS AND CATEGORIES FOR RULE 4

UC#	CC : Rule 4	CD : Improvements are made scientifically and according to Rules 1- 3 for example changing the software configuration settings of the software.	CE : No functionality found	CF : Scientific method	CG : Improvements can be done scientifically	CH : Improvements cannot be done scientifically	CI : User improvements	CJ : Improvements can be done by a user	CK : Improvements cannot be done by a user
APUC#1		2	0	1	1	0	1	1	0
APUC#1a		2	0	1	1	0	1	1	0
ARUC#1		2	0	1	1	0	1	1	0
ARUC#1a		2	0	1	1	0	1	1	0
FAUC#1		2	0	1	1	0	1	1	0
GLUC#1		2	0	1	1	0	1	1	0
PIUC#1		1	0	0	0	0	1	1	1
PRUC#1		2	0	1	1	0	1	1	0
UC#2		2	0	1	0	1	1	0	1
PCUC#3		2	0	1	1	0	1	1	0
MPUC#4		2	0	1	1	0	1	1	0
MPUC#5		2	0	1	0	1	1	0	1
MPUC#6		2	0	1	0	1	1	0	1
PCUC#7-1		2	0	1	0	1	1	0	1
PCUC#7-2		2	0	1	0	1	1	0	1
MPUC#8 and MPUC#9		2	0	1	1	1	1	1	1
MPUC#10		1	1	0	0	0	0	0	0
UC#11		2	0	1	0	1	1	0	1
Total #		34	1	16	10	7	17	11	8

Source: Chalil du Plessis (2014)

4.5 SUMMARY OF CHAPTER FOUR

Using the methodology, instruments and research techniques as described in the previous chapter, a number of selected use cases were prepared in order to conduct testing and collect results from an ERP system. Each of these selected use cases and experiments were designed and conducted to generate data for the metrics presented for each of the four rules of Lean operations. Mixed method research was used to collect quantitative and qualitative data from each of the prepared use cases conducted. The quantitative and qualitative methods applied to collect the data were described in detail. The data collected from the qualitative and quantitative use cases were further analyzed, coded and categorized. In Chapter Five the presented result tables is being used to extract in greater details distilled information to interpolate and synthesize the findings. Furthermore, the following chapter will bridge the gap between the research findings by proposing a conceptual framework to bridge the gap between ERP applied principles and that of Lean operations.

CHAPTER FIVE

SYNTHESIS AND INTEGRATION

CHAPTER FIVE – SYNTHESIS AND INTEGRATION

5.0 OVERVIEW

The present research was conducted using Dynamics AX 2010 R2, an off-the-shelf ERP system from Microsoft Corporation. A total number of eighteen use cases were compiled based on requirements extracted from a literature review and identified as quantitative or qualitative test cases. Eight test cases were conducted as sampling for quantitative testing with one hundred and sixty test results divided equally between before and after improvement results. Qualitative observational data was generated from all the eighteen use cases that were conducted. Qualitative data was also extracted for the use cases conducted as quantitative tests. The data collected was analyzed, coded and categorized into tables in the previous chapter. This chapter will synthesize the findings, present the findings and attempt to construct a conceptual framework to bridge the gap between ERP applied principles and the principles of Lean operations within ERP systems.

5.1 IDENTIFICATION OF FINDINGS

The thesis attempts to answer the following main research question:

"What is the ERP systems framework that can be developed to incorporate Lean principles of operations, which will enable global Lean industry users to both reduce costs in their traditional ERP system while simultaneously reducing waste?"

Furthermore, to adequately respond to the main research question the following null hypothesis have been developed and presented earlier in Chapter Three:

H0: ERP systems have not been designed to support the principles of Lean operations.

H1: Vendors have already designed ERP modules to support the principles of Lean operations and therefore ERP modules can be developed based on Lean principles.

5.1.1 Quantitative findings

In order to further synthesize the findings from the previous chapter the quantitative data was statistically analyzed as set out in the summaries below for the measurements collected. To ensure that the data being analyzed has value it is important to understand that the effect of the improvements is significant enough to support or reject the original hypothesis. Student's two sample T-test for two paired samples or upper tailed test was selected for the purpose of comparing the two samples with paired values. The paired T-test considers the variations between paired values in two samples and calculates a single value known as the t-value. Furthermore, calculating the p-value determines the likelihood that the calculated t-value from two samples from the same population would produce a t-value with the same or bigger value indicating that the samples are statistically different. The two-sample T-test is recommended where the sample size is small (n<=30) and the population standard deviation is unknown (Zikmund, 2000, p. 506, p.524).

The following tables shows the means calculated using XLSTAT, statistical add-in software for Excel 2010, based on the data presented in Chapter Four. For the quantitative use cases the following null hypothesis has been developed to determine the confidence in the test results:

Q-H0: The difference between the means is equal to 0.

Q-H1: The difference between the means is greater than 0.

The following tables presents the statistical data that was calculated for each use case using Student’s paired sample T-test. Two paired sets of quantitative data for each test were statistically analyzed and have been divided into two sets of data namely Time and Stops.

APUC#1: Entering Vendor Invoice: Data for the paired sample T-test was prepared from the table for the use case presented in Table 4.3.1 C for observed time before improvement and observed time after improvement and observed stops before improvements and observed stops after improvement in in Table 5.1.1 A:

TABLE 5.1.1 A USE CASE APUC#1: T-TEST FOR OBSERVED TIME AND STOPS				
Variable	Observed Time before Improvement	Observed Time after Improvement	Observed Stops before Improvement	Observed Stops after Improvement
Observations	10	10	10	10
Observations with missing data	0	0	0	0
Observations without missing data	10	10	10	10
Minimum	1.400	0.950	11.000	2.000
Maximum	4.200	1.300	32.000	13.000
Mean	2.040	1.052	16.600	5.900
Standard deviation	0.837	0.114	6.257	3.143
Hypothesized difference (D):	0		0	
Significance level (%):	5		5	
Difference	0.988		10.700	
t (Observed value)	3.753		5.488	
t (Critical value)	1.833		1.833	
DF (Degree of Freedom=n-1)	9		9	
p-value (one-tailed)	0.002		0.000	
alpha	0.05		0.05	
Source: Chalil du Plessis (2014)				

<u>Observed Time:</u> The t-value of 3.753 falls within the critical region defined by the critical value of 1.833 and the p-value of 0.002 is smaller than the alpha of 0.05, therefore the null hypothesis is rejected in favor of the alternative hypothesis Q-H1. The mean of 1.052 and the Standard deviation of 0.114 of the observed time after improvement are statistically less than the observed mean time of 2.040 and standard deviation of 0.837 of the observed time before improvement. Furthermore, the risk to reject the null hypothesis Q-H0 while it is true is lower than 0.23%.

From these results, the improvements were effective in reducing the observed time before the improvements. It can be reasonably assumed that a possible explanation includes the applied improvement as described in Table 4.3.1 B.

<u>Observed Stops:</u> The t-value of 5.488 falls within the critical region defined by the critical value of 1.833 and the p-value of 0.000 is smaller than the alpha of 0.05, therefore the null hypothesis is rejected in favor of the alternative hypothesis Q-H1. The mean of 5.900 and the Standard deviation of 3.143 of the observed stops after improvement are statistically less than the observed mean stops of 16.600 and standard deviation of 6.257 of the observed stops before improvement. Furthermore, the risk to reject the null hypothesis Q-H0 while it is true is lower than 0.02%.

From these results, the improvements were effective in reducing the observed stops before the improvements. It can be reasonably assumed that a possible explanation includes the applied improvement as described in Table 4.3.1 B.

The above T-test results for the observed time and observed stops indicate that the null hypothesis should be rejected in both cases in favor of accepting the alternative hypothesis for use case APUC#1. The improvements applied to the process could reduce the time as well as reducing the number of stops in the data entry process.

APUC#1a: Adding Vendor Master Data

Data for the paired sample T-test was prepared from the table for the use case presented in Table 4.3.1 F for observed time before improvement and observed time after improvement and observed stops before improvements and observed stops after improvement in Table 5.1.1 B:

TABLE 5.1.1 B USE CASE APUC#1A: T-TEST FOR OBSERVED TIME AND STOPS				
Variable	Observed Time before Improvement	Observed Time after Improvement	Observed Stops before Improvement	Observed Stops after Improvement
Observations	10	10	10	10
Observations with missing data	0	0	0	0
Observations without missing data	10	10	10	10
Minimum	5.000	2.000	19.000	8.000
Maximum	11.000	4.000	51.000	16.000
Mean	6.600	3.400	30.600	12.300
Standard deviation	1.776	0.699	9.924	2.263
Hypothesized difference (D):	0		0	
Significance level (%):	5		5	
Difference	3.200		18.300	
t (Observed value)	4.951		6.004	
t (Critical value)	1.833		1.833	
DF (Degree of Freedom=n-1)	9		9	
p-value (one-tailed)	0.000			
alpha	0.05			
Source: Chalil du Plessis (2014)				

Observed Time: The t-value of 4.951 falls within the critical region defined by the critical value of 1.833 and the p-value of 0.000 is smaller than the alpha of 0.05, therefore the null hypothesis is rejected in favor of the alternative hypothesis Q-H1.

The mean of 3.400 and the Standard deviation of 0.699 of the observed time after improvement are statistically less than the observed mean time of 6.600 and standard deviation of 1.776 of the observed time before improvement. Furthermore, the risk to reject the null hypothesis Q-H0 while it is true is lower than 0.04%.

From these results, the improvements were effective in reducing the observed time before the improvements. It can be reasonably assumed that a possible explanation includes the applied improvement as described in Table 4.3.1 E.

<u>Observed Stops:</u> The t-value of 6.004 falls within the critical region defined by the critical value of 1.833 and the p-value of 0.000 is smaller than the alpha of 0.05, therefore the null hypothesis is rejected in favor of the alternative hypothesis Q-H1. The mean of 16.000 and the Standard deviation of 12.300 of the observed stops after improvement are statistically less than the observed mean stops of 30.600 and standard deviation of 9.924 of the observed stops before improvement. Furthermore, the risk to reject the null hypothesis Q-H0 while it is true is lower than 0.01%.

From these results, the improvements were effective in reducing the observed stops before the improvements. It can be reasonably assumed that a possible explanation includes the applied improvement as described in Table 4.3.1 E.

The above T-test results for the observed time and observed stops indicate that the null hypothesis should be rejected in both cases in favor of accepting the alternative

hypothesis for use case APUC#1a. The improvements applied to the process could reduce the time as well as reducing the number of stops in the data entry process.

ARUC#1: Entering a Customer Sales Order

Data for the paired sample T-test was prepared from the table for the use case presented in Table 4.3.1 I for observed time before improvement and observed time after improvement and observed stops before improvements and observed stops after improvement in Table 5.1.1 C:

TABLE 5.1.1 C
USE CASE ARUC#1: T-TEST FOR OBSERVED TIME AND STOPS

Variable	Observed Time before Improvement	Observed Time after Improvement	Observed Stops before Improvement	Observed Stops after Improvement
Observations	10	10	10	10
Observations with missing data	0	0	0	0
Observations without missing data	10	10	10	10
Minimum	3.400	2.300	28.000	13.000
Maximum	6.900	4.500	57.000	35.000
Mean	5.230	3.350	42.700	24.900
Standard deviation	1.275	0.718	10.242	6.008
Hypothesized difference (D):	0		0	
Significance level (%):	5		5	
Difference	1.880		17.800	
t (Observed value)	8.213		6.497	
t (Critical value)	1.833		1.833	
DF (Degree of Freedom=n-1)	9		9	
p-value (one-tailed)	< 0.0001		< 0.0001	
alpha	0.05		0.05	

Source: Chalil du Plessis (2014)

<u>Observed Time:</u> The t-value of 8.213 falls within the critical region defined by the critical value of 1.833 and the p-value of <0.0001 is smaller than the alpha of 0.05, therefore the null hypothesis is rejected in favor of the alternative hypothesis Q-H1.

The mean of 3.350 and the Standard deviation of 0.718 of the observed time after improvement are statistically less than the observed mean time of 5.230 and standard deviation of 1.275 of the observed time before improvement. Furthermore, the risk to reject the null hypothesis Q-H0 while it is true is lower than 0.01%.

From these results, the improvements were effective in reducing the observed time before the improvements. It can be reasonably assumed that a possible explanation includes the applied improvement as described in Table 4.3.1 H.

<u>Observed Stops:</u> The t-value of 6.497 falls within the critical region defined by the critical value of 1.833 and the p-value of <0.0001 is smaller than the alpha of 0.05, therefore the null hypothesis is rejected in favor of the alternative hypothesis Q-H1. The mean of 24.900 and the Standard deviation of 6.008 of the observed stops after improvement are statistically less than the observed mean stops of 42.700 and standard deviation of 10.242 of the observed stops before improvement. Furthermore, the risk to reject the null hypothesis Q-H0 while it is true is lower than 0.01%.

From these results, the improvements were effective in reducing the observed stops before the improvements. It can be reasonably assumed that a possible explanation includes the applied improvement as described in Table 4.3.1 H.

The above T-test results for the observed time and observed stops indicate that the null hypothesis should be rejected in both cases in favor of accepting the alternative hypothesis for use case ARUC#1. The improvements applied to the process could reduce the time as well as reducing the number of stops in the data entry process.

ARUC#1a: Adding Customer Master Data

Data for the paired sample T-test was prepared from the table for the use case presented in Table 4.3.1 L for observed time before improvement and observed time after improvement and observed stops before improvements and observed stops after improvement in Table 5.1.1 D:

TABLE 5.1.1 D USE CASE ARUC#1A: T-TEST FOR OBSERVED TIME AND STOPS				
Variable	Observed Time before Improvement	Observed Time after Improvement	Observed Stops before Improvement	Observed Stops after Improvement
Observations	10	10	10	10
Observations with missing data	0	0	0	0
Observations without missing data	10	10	10	10
Minimum	3.000	2.000	21.000	8.000
Maximum	5.000	3.100	48.000	18.000
Mean	3.670	2.610	28.300	13.300
Standard deviation	0.556	0.373	8.084	3.401
Hypothesized difference (D):	0		0	
Significance level (%):	5		5	
Difference	1.060		15.000	
t (Observed value)	6.713		6.753	
t (Critical value)	1.833		1.833	
DF (Degree of Freedom=n-1)	9		9	
p-value (one-tailed)	< 0.0001			
alpha	0.05			
Source: Chalil du Plessis (2014)				

<u>Observed Time:</u> The t-value of 6.713 falls within the critical region defined by the critical value of 1.833 and the p-value of <0.0001 is smaller than the alpha of 0.05, therefore the null hypothesis is rejected in favor of the alternative hypothesis Q-H1.

The mean of 2.610 and the Standard deviation of 0.373 of the observed time after improvement are statistically less than the observed mean time of 3.670 and standard deviation of 0.556 of the observed time before improvement. Furthermore, the risk to reject the null hypothesis Q-H0 while it is true is lower than 0.01%.

From these results, the improvements were effective in reducing the observed time before the improvements. It can be reasonably assumed that a possible explanation includes the applied improvement as described in Table 4.3.1 K.

Observed Stops: The t-value of 6.753 falls within the critical region defined by the critical value of 1.833 and the p-value of <0.0001 is smaller than the alpha of 0.05, therefore the null hypothesis is rejected in favor of the alternative hypothesis Q-H1. The mean of 13.300 and the Standard deviation of 3.401 of the observed stops after improvement are statistically less than the observed mean stops of 28.300 and standard deviation of 8.084 of the observed stops before improvement. Furthermore, the risk to reject the null hypothesis Q-H0 while it is true is lower than 0.01%.

From these results, the improvements were effective in reducing the observed stops before the improvements. It can be reasonably assumed that a possible explanation includes the applied improvement as described in Table 4.3.1 K.

The above T-test results for the observed time and observed stops indicate that the null hypothesis should be rejected in both cases in favor of accepting the alternative

hypothesis for use case ARUC#1a. The improvements applied to the process could reduce the time as well as reducing the number of stops in the data entry process.

GLUC#1: Open and Post a General Journal

Data for the paired sample T-test was prepared from the table for the use case presented in Table 4.3.1 O for observed time before improvement and observed time after improvement and observed stops before improvements and observed stops after improvement in Table 5.1.1 E:

TABLE 5.1.1 E USE CASE GLUC#1: T-TEST FOR OBSERVED TIME AND STOPS				
Variable	Observed Time before Improvement	Observed Time after Improvement	Observed Stops before Improvement	Observed Stops after Improvement
Observations	10	10	10	10
Observations with missing data	0	0	0	0
Observations without missing data	10	10	10	10
Minimum	2.900	1.900	14.000	12.000
Maximum	4.100	2.800	33.000	20.000
Mean	3.470	2.250	23.300	15.200
Standard deviation	0.435	0.314	7.212	3.155
Hypothesized difference (D):	0		0	
Significance level (%):	5		5	
Difference	1.220		8.100	
t (Observed value)	10.859		4.721	
t (Critical value)	1.833		1.833	
DF (Degree of Freedom=n-1)	9		9	
p-value (one-tailed)	< 0.0001		0.001	
alpha	0.05		0.05	
Source: Chalil du Plessis (2014)				

Observed Time: The t-value of 10.859 falls within the critical region defined by the critical value of 1.833 and the p-value of <0.0001 is smaller than the alpha of 0.05, therefore the null hypothesis is rejected in favor of the alternative hypothesis Q-H1.

The mean of 2.250 and the Standard deviation of 0.314 of the observed time after improvement are statistically less than the observed mean time of 3.470 and standard deviation of 0.435 of the observed time before improvement. Furthermore, the risk to reject the null hypothesis Q-H0 while it is true is lower than 0.01%.

From these results, the improvements were effective in reducing the observed time before the improvements. It can be reasonably assumed that a possible explanation includes the applied improvement as described in Table 4.3.1 N.

Observed Stops: The t-value of 4.721 falls within the critical region defined by the critical value of 1.833 and the p-value of 0.001 is smaller than the alpha of 0.05, therefore the null hypothesis is rejected in favor of the alternative hypothesis Q-H1. The mean of 15.200 and the Standard deviation of 3.155 of the observed stops after improvement are statistically less than the observed mean stops of 23.300 and standard deviation of 7.212 of the observed stops before improvement. Furthermore, the risk to reject the null hypothesis Q-H0 while it is true is lower than 0.05%.

From these results, the improvements were effective in reducing the observed stops before the improvements. It can be reasonably assumed that a possible explanation includes the applied improvement as described in Table 4.3.1 N.

The above T-test results for the observed time and observed stops indicate that the null hypothesis should be rejected in both cases in favor of accepting the alternative

hypothesis for use case GLUC#1. The improvements applied to the process could reduce the time as well as reducing the number of stops in the data entry process.

FAUC#1: Acquisition of new Asset

The Data for the paired sample T-test was prepared from the table for the use case presented in Table 4.3.1 R for observed time before improvement and observed time after improvement and observed stops before improvements and observed stops after improvement in Table 5.1.1 F:

TABLE 5.1.1 F USE CASE FAUC#1: T-TEST FOR OBSERVED TIME AND STOPS				
Variable	Observed Time before Improvement	Observed Time after Improvement	Observed Stops before Improvement	Observed Stops after Improvement
Observations	10	10	10	10
Observations with missing data	0	0	0	0
Observations without missing data	10	10	10	10
Minimum	2.200	1.700	16.000	10.000
Maximum	4.500	2.500	46.000	15.000
Mean	2.950	2.110	23.300	12.700
Standard deviation	0.796	0.251	9.684	2.003
Hypothesized difference (D):	0		0	
Significance level (%):	5		5	
Difference	0.840		10.600	
t (Observed value)	3.144		3.726	
t (Critical value)	1.833		1.833	
DF (Degree of Freedom=n-1)	9		9	
p-value (one-tailed)	0.006		0.002	
alpha	0.05		0.05	
Source: Chalil du Plessis (2014)				

Observed Time: The t-value of 3.144 falls within the critical region defined by the critical value of 1.833 and the p-value of 0.006 is smaller than the alpha of 0.05, therefore the null hypothesis is rejected in favor of the alternative hypothesis Q-H1.

The mean of 2.110 and the Standard deviation of 0.251 of the observed time after improvement are statistically less than the observed mean time of 2.950 and standard deviation of 0.796 of the observed time before improvement. Furthermore, the risk to reject the null hypothesis Q-H0 while it is true is lower than 0.59%.

From these results, the improvements were effective in reducing the observed time before the improvements. It can be reasonably assumed that a possible explanation includes the applied improvement as described in Table 4.3.1 Q.

Observed Stops: The t-value of 3.726 falls within the critical region defined by the critical value of 1.833 and the p-value of 0.002 is smaller than the alpha of 0.05, therefore the null hypothesis is rejected in favor of the alternative hypothesis Q-H1. The mean of 12.700 and the Standard deviation of 2.003 of the observed stops after improvement are statistically less than the observed mean stops of 23.300 and standard deviation of 9.684 of the observed stops before improvement. Furthermore, the risk to reject the null hypothesis Q-H0 while it is true is lower than 0.24%.

From these results, the improvements were effective in reducing the observed stops before the improvements. It can be reasonably assumed that a possible explanation includes the applied improvement as described in Table 4.3.1 N.

The above T-test results for the observed time and observed stops indicate that the null hypothesis should be rejected in both cases in favor of accepting the alternative

hypothesis for use case FAUC#1. The improvements applied to the process could reduce the time as well as reducing the number of stops in the data entry process.

PRUC#1: Processing a Vendor Purchase Order

Data for the paired sample T-test was prepared from the table for the use case presented in Table 4.3.1 V for observed time before improvement and observed time after improvement and observed stops before improvements and observed stops after improvement in Table 5.1.1 G:

TABLE 5.1.1 G USE CASE PRUC#1: T-TEST FOR OBSERVED TIME AND STOPS				
Variable	Observed Time before Improvement	Observed Time after Improvement	Observed Stops before Improvement	Observed Stops after Improvement
Observations	10	10	10	10
Observations with missing data	0	0	0	0
Observations without missing data	10	10	10	10
Minimum	3.300	2.100	25.000	15.000
Maximum	9.300	10.000	74.000	63.000
Mean	5.800	4.140	50.800	30.500
Standard deviation	1.717	2.244	13.943	13.954
Hypothesized difference (D):	0		0	
Significance level (%):	5		5	
Difference	1.660		20.300	
t (Observed value)	3.136		5.147	
t (Critical value)	1.833		1.833	
DF (Degree of Freedom=n-1)	9		9	
p-value (one-tailed)	0.006		0.000	
alpha	0.05		0.05	
Source: Chalil du Plessis (2014)				

Observed Time: The t-value of 3.136 falls within the critical region defined by the critical value of 1.833 and the p-value of 0.006 is smaller than the alpha of 0.05, therefore the null hypothesis is rejected in favor of the alternative hypothesis Q-H1.

The mean of 4.140 and the Standard deviation of 2.244 of the observed time after improvement are statistically less than the observed mean time of 5.800 and standard deviation of 1.717 of the observed time before improvement. Furthermore, the risk to reject the null hypothesis Q-H0 while it is true is lower than 0.60%.

From these results, the improvements were effective in reducing the observed time before the improvements. It can be reasonably assumed that a possible explanation includes the applied improvement as described in Table 4.3.1 U.

Observed Stops: The t-value of 5.147 falls within the critical region defined by the critical value of 1.833 and the p-value of 0.000 is smaller than the alpha of 0.05, therefore the null hypothesis is rejected in favor of the alternative hypothesis Q-H1. The mean of 30.500 and the Standard deviation of 13.954 of the observed stops after improvement are statistically less than the observed mean stops of 50.800 and standard deviation of 13.943 of the observed stops before improvement. Furthermore, the risk to reject the null hypothesis Q-H0 while it is true is lower than 0.03%.

From these results, the improvements were effective in reducing the observed stops before the improvements. It can be reasonably assumed that a possible explanation includes the applied improvement as described in Table 4.3.1 U.

The above T-test results for the observed time and observed stops indicate that the null hypothesis should be rejected in both cases in favor of accepting the alternative hypothesis for use case PRUC#1. The improvements applied to the process could reduce the time as well as reducing the number of stops in the data entry process.

PIUC#1: Adding new Products

Data for the paired sample T-test was prepared from the table for the use case presented in Table 4.3.1 Y for observed time before improvement and observed time after improvement and observed stops before improvements and observed stops after improvement in Table 5.1.1 H:

TABLE 5.1.1 H USE CASE PIUC#1: T-TEST FOR OBSERVED TIME AND STOPS				
Variable	Observed Time before Improvement	Observed Time after Improvement	Observed Stops before Improvement	Observed Stops after Improvement
Observations	10	10	10	10
Observations with missing data	0	0	0	0
Observations without missing data	10	10	10	10
Minimum	5.200	4.100	39.000	23.000
Maximum	9.000	6.800	76.000	46.000
Mean	7.290	5.130	61.300	33.900
Standard deviation	1.072	0.855	12.499	6.999
Hypothesized difference (D):	0		0	
Significance level (%):	5		5	
Difference	2.160		27.400	
t (Observed value)	6.682		7.484	
t (Critical value)	1.833		1.833	
DF (Degree of Freedom=n-1)	9		9	
p-value (one-tailed)	< 0.0001		< 0.0001	
alpha	0.05		0.05	
Source: Chalil du Plessis (2014)				

Observed Time: The t-value of 6.682 falls within the critical region defined by the critical value of 1.833 and the p-value of <0.0001 is smaller than the alpha of 0.05, therefore the null hypothesis is rejected in favor of the alternative hypothesis Q-H1.

The mean of 5.130 and the Standard deviation of 0.855 of the observed time after improvement are statistically less than the observed mean time of 7.290 and standard deviation of 1.072 of the observed time before improvement. Furthermore, the risk to reject the null hypothesis Q-H0 while it is true is lower than 0.01%.

From these results, the improvements were effective in reducing the observed time before the improvements. It can be reasonably assumed that a possible explanation includes the applied improvement as described in Table 4.3.1 X.

<u>Observed Stops:</u> The t-value of 7.484 falls within the critical region defined by the critical value of 1.833 and the p-value of <0.0001 is smaller than the alpha of 0.05, therefore the null hypothesis is rejected in favor of the alternative hypothesis Q-H1. The mean of 33.900 and the Standard deviation of 6.999 of the observed stops after improvement are statistically less than the observed mean stops of 61.300 and standard deviation of 12.499 of the observed stops before improvement. Furthermore, the risk to reject the null hypothesis Q-H0 while it is true is lower than 0.01%.

From these results, the improvements were effective in reducing the observed stops before the improvements. It can be reasonably assumed that a possible explanation includes the applied improvement as described in Table 4.3.1 X.

The above T-test results for the observed time and observed stops indicate that the null hypothesis should be rejected in both cases in favor of accepting the alternative hypothesis for use case PIUC#1. The improvements applied to the process could reduce the time as well as reducing the number of stops in the data entry process.

Summary of Quantitative Use Cases:

TABLE 5.1.1 I
MEAN TIMES AND STOPS: QUANTITATIVE USE CASE TESTING

Test #	Observed Time before Improvement	Observed Time after Improvement	Difference	% Improvement	Observed Stops before Improvement	Observed Stops after Improvement	Difference	% less stops
APUC#1	2.04	1.05	0.99	48.45	16.6	5.9	10.70	64.46
APUC#1a	6.6	3.4	3.2	48.48	30.6	12.3	18.30	59.80
ARUC#1	5.23	3.35	1.88	35.95	42.7	24.9	17.80	41.69
ARUC#1a	3.67	2.61	1.06	28.88	28.3	13.3	15.00	53.00
FAUC#1	2.95	2.11	0.84	28.47	23.3	12.7	10.60	45.49
GLUC#1	3.47	2.25	1.22	35.16	23.3	15.2	8.10	34.76
PIUC#1	7.29	5.13	2.16	29.63	61.3	33.9	27.40	44.70
PRUC#1	5.8	4.14	1.66	28.62	50.8	30.5	20.30	39.96
Mean	4.631	3.005	1.626	35.110	34.613	18.588	16.025	46.298

Source: Chalil du Plessis (2014)

Table 5.1.1 I summarizes the quantitative use cases as presented in Chapter Four. The differences between the observed times and observed stops are indicated. The mean time for each column was calculated.

TABLE 5.1.1 J MEAN TIMES: T-TEST FOR OBSERVED TIME AND STOPS				
Variable	Observed Time before Improvement	Observed Time after Improvement	Observed Stops before Improvement	Observed Stops after Improvement
Observations	8	8	8	8
Observations with missing data	0	0	0	0
Observations without missing data	8	8	8	8
Minimum	2.040	1.052	16.600	5.900
Maximum	7.290	5.130	61.300	33.900
Mean	4.631	3.005	34.613	18.588
Standard deviation	1.870	1.277	15.474	9.934
Hypothesized difference (D):	0		0	
Significance level (%):	5		5	
Difference	1.626		16.025	
t (Observed value)	5.842		7.197	
t (Critical value)	1.895		1.895	
DF (Degree of Freedom=n-1)	7		7	
p-value (one-tailed)	0.000		< 0.0001	
alpha	0.05		0.05	
Source: Chalil du Plessis (2014)				

Data for the paired sample T-test was prepared from the summary table for the use cases presented in Table 5.1.1 I for observed time before improvement and observed time after improvement and observed stops before improvements and observed stops after improvement in Table 5.1.1 J.

Observed Time: The t-value of 5.842 falls within the critical region defined by the critical value of 1.895 and the p-value of 0.000 is smaller than the alpha of 0.05, therefore the null hypothesis is rejected in favor of the alternative hypothesis Q-H1. The mean of 3.005 and the Standard deviation of 1.277 of the observed time after improvement are statistically less than the observed mean time of 4.631 and standard deviation of 1.870 of the observed time before improvement. Furthermore, the risk to reject the null hypothesis Q-H0 while it is true is lower than 0.03%.

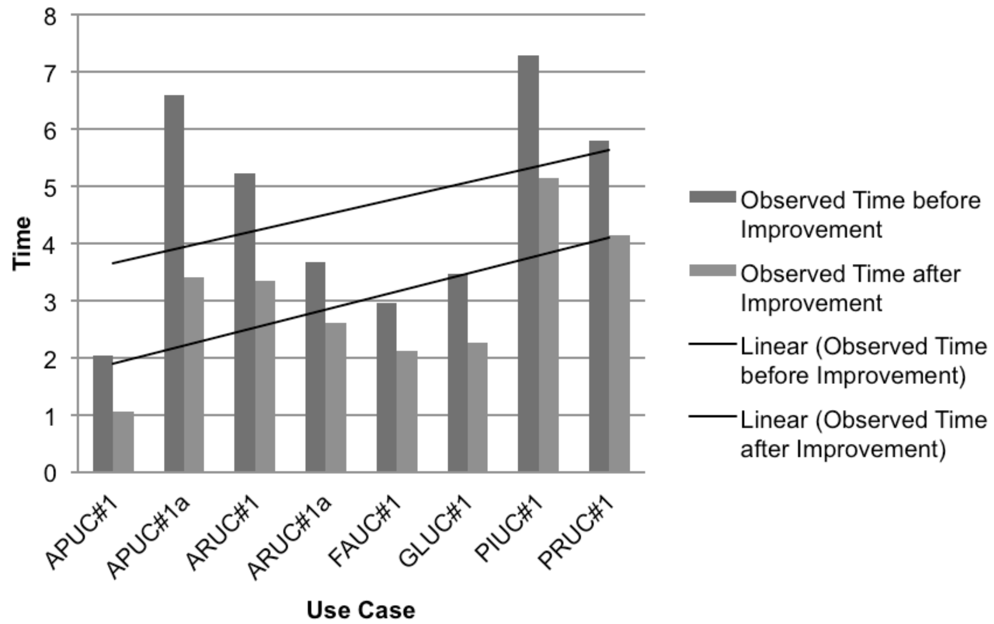
From these results, the improvements were effective in reducing the observed time before the improvements. It can be reasonably assumed that a possible explanation includes the applied improvements applied to all use cases.

Observed Stops: The t-value of 7.197 falls within the critical region defined by the critical value of 1.895 and the p-value of <0.0001 is smaller than the alpha of 0.05, therefore the null hypothesis is rejected in favor of the alternative hypothesis Q-H1. The mean of 18.588 and the Standard deviation of 9.934 of the observed stops after improvement are statistically less than the observed mean stops of 34.613 and standard deviation of 15.474 of the observed stops before improvement. Furthermore, the risk to reject the null hypothesis Q-H0 while it is true is lower than 0.01%.

From these results, the improvements were effective in reducing the observed stops before the improvements. It can be reasonably assumed that a possible explanation includes the applied improvement applied to all use cases.

The above T-test results for the observed time and observed stops indicate that the null hypothesis should be rejected in both cases in favor of accepting the alternative hypothesis for the means of all the use cases. The improvements applied to the all the processes could reduce the time as well as reducing the number of stops in the data entry process.

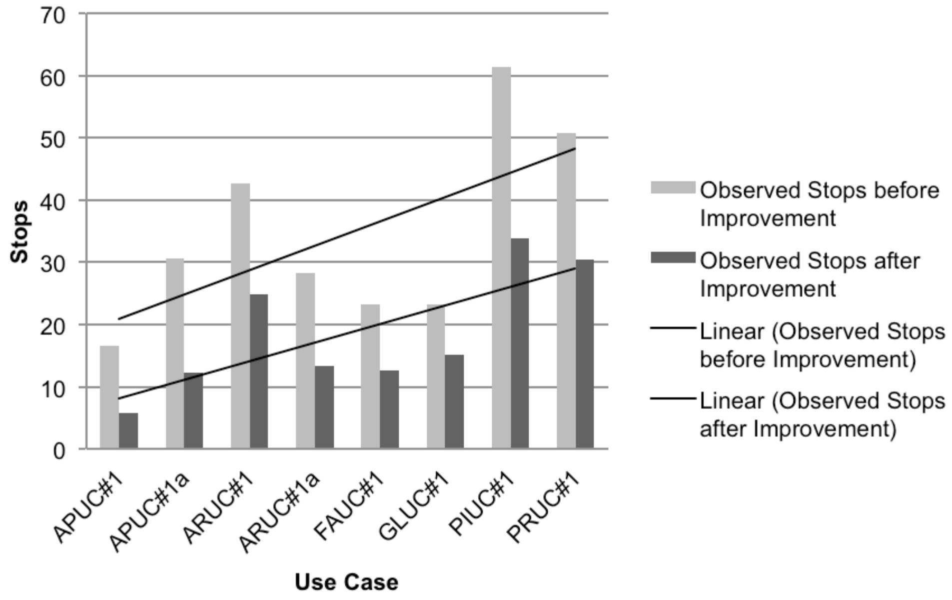
FIGURE 5.1.1 A
OBSERVED TIME BEFORE AND AFTER IMPROVEMENT FOR ALL QUANTITATIVE USE CASES



Source: Chalil du Plessis (2014)

The bar graphs, Figure 5.1.1 A and Figure 5.1.1 B, prepared from Table 5.1.1 I show the observations before and after improvements for Time and Stops as two almost parallel linear lines across all the use cases measured. This is matching the statistical data as shown earlier that in all the use cases the null hypothesis Q-H0 should be rejected in favor of the alternative hypothesis Q-H1.

FIGURE 5.1.1 B
OBSERVED STOPS BEFORE AND AFTER IMPROVEMENT FOR ALL QUANTITATIVE USE CASES



Source: Chalil du Plessis (2014)

5.1.2 Qualitative findings

Considering the null hypotheses developed as stated earlier, the qualitative data collected and presented in the previous chapter was further analyzed using visual and statistical analysis for the four rules and its sub categories. Basic visual analysis of each rule and its categories and sub-categories were done drawing pie charts for each set of data. The pie charts give a proportional visualization of the data that was coded for each rule and the relevant categories and sub-categories. The tally charts presented in the previous chapter are all binary in nature with their subcategories containing 0 or 1 as a value. The value of 0 represents the absence of a feature and 1 represents the presence of a feature. In order to understand if there is any form of association of the subcategories proximity tables were calculated for Jaccard's Coefficient using XLSTAT software. Jaccard's Coefficient is specifically suited for determining the similarity of binary cluster data sets and if there are any significant associations amongst the data sets (Everitt, 2006; M. Saeed, Maqbool, Babri, Hassan, & Sarwar, 2003). Jaccard's coefficients can be calculated using the following formula:

$$\frac{a}{a+b+c}$$

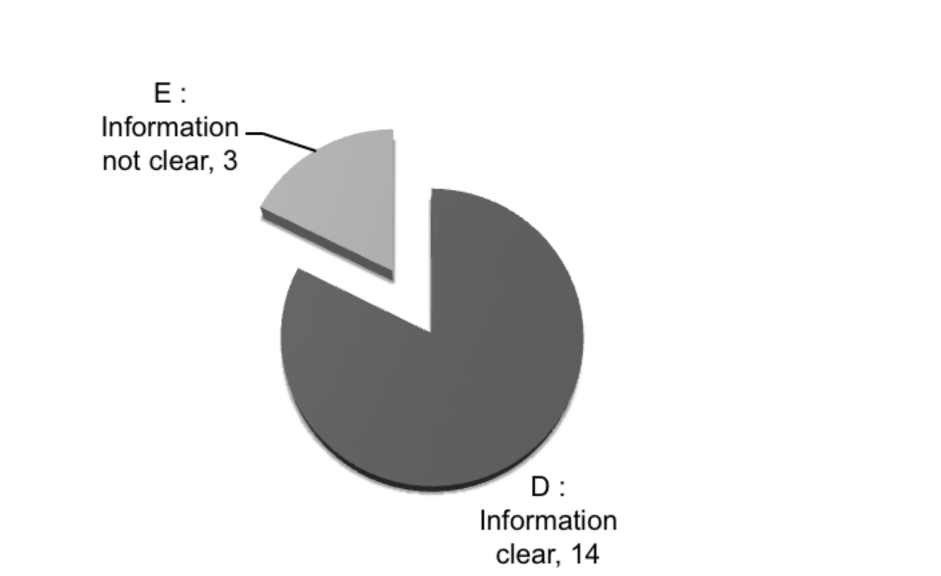
To determine a, b, and c it is supposed that there are two clusters of data sets X and Y. From these two datasets the number of features in both datasets are represented as the value 1 in the tally charts, b and c represents the number of features that are present in one but not the other using the values 1 and 0 in the tally charts (Naseem, Maqbool, & Muhammad, 2010).

Rule 1: All work must be highly specific as to content, sequence, timing and outcome:

Rule 1A Metric: Information to be entered is clear and specific.

Observations were done to evaluate whether data entry fields for the particular data entry forms in the process are marked clearly as to what type of information should be entered in the field. Typical functionality that the researcher was looking for during the observations were field labels that are unambiguous in the meaning for data to be entered, lookup and drop down lists where data are associated with master data tables and the use of the help function - F1. During the coding process in NVivo 10 software, the metric was further categorized into *Information clarity*, *Specific information* and *No functionality found* as per Table 4.3.2 B. A total number of thirty-five codings were done for the eighteen use cases. No functionality was found within the system for use case MPUC#10.

FIGURE 5.1.2 A
RULE 1A: INFORMATION CLARITY



Source: Chalil du Plessis (2014)

Information Clarity: Three cases were coded as *Information not clear* and fourteen cases as *Information clear* as indicated in figure 5.1.2 A.

The majority of the use cases were found to contain clear information with the data fields in the entry forms for the user to enter the correct information. Terms used to identify *clear information* are summarized in Table 5.1.2 A:

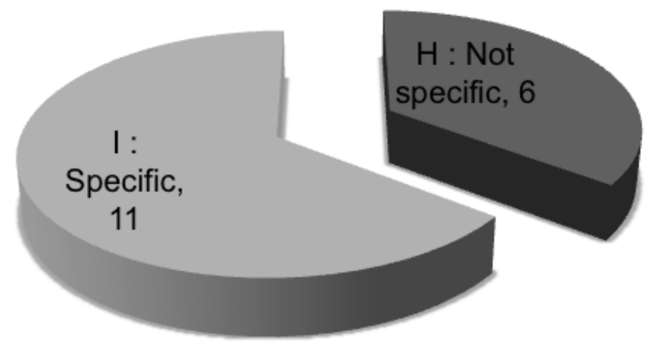
TABLE 5.1.2 A TYPICAL TERMS USED FOR INFORMATION CLEAR DURING USE CASE OBSERVATION	
Information required is clear and specific from the data field labels.	Information to be entered within each data entry from is clear and specific.
Information to be entered in the new record form is clearly indicated.	Using F1 help function on any field will open the on-screen help.
Information to be entered is assumed to be clear and specific.	Field labels are generally descriptive.
The fields are marked clearly as to the required information.	Within each form it is clear for most of the data entry fields.
Information to be entered is marked clearly through labels on the data entry fields.	Required fields are indicated with a red uneven line.
The information to be entered is indicated clearly with field labels.	Fields are linked to tables a drop down option is provided.
The information is clear and specific where the F1 function is invoked.	Recording of data was found to be clear and specific when the data is recorded and exported to a Word document.
Extract existing database information into Excel that can be a guideline as to the information required	Following the existing data as a guideline gives a reasonable indication of the data that requires to be entered.
Source: Chalil du Plessis (2014)	

The following remarks were extracted for the cases coded as *Information not clear*:

- MPUC#1: The labels within the forms identify the information required but several of the labels do not identify the measure of the values to be entered such as coverage period and time fence values.
- MPUC#5: Without suitable documentation for explanation, the user finds it difficult to know the function and effect of data that has to be entered e.g. EPE cycle in Production control.
- MPUC#6: Other than the brief label descriptions, there is no other clear explanation or help function to what the data should be that must be entered.

Specific Information: Eleven cases were coded as *Specific* and six cases as *Not specific* as indicated in Figure 5.1.2 B:

FIGURE 5.1.2 B
RULE 1A: SPECIFIC INFORMATION



Source: Chalil du Plessis (2014)

The majority of the use cases were found to contain specific information with the data fields in the entry forms for the user to enter the correct information. The researcher interpreted the use of the term specific to refer to data to be restricted to specific lists, code or terms to be used. These are typically predefined through master data tables in the system. Terms used to identify specific information are summarized in Table 5.1.2 B:

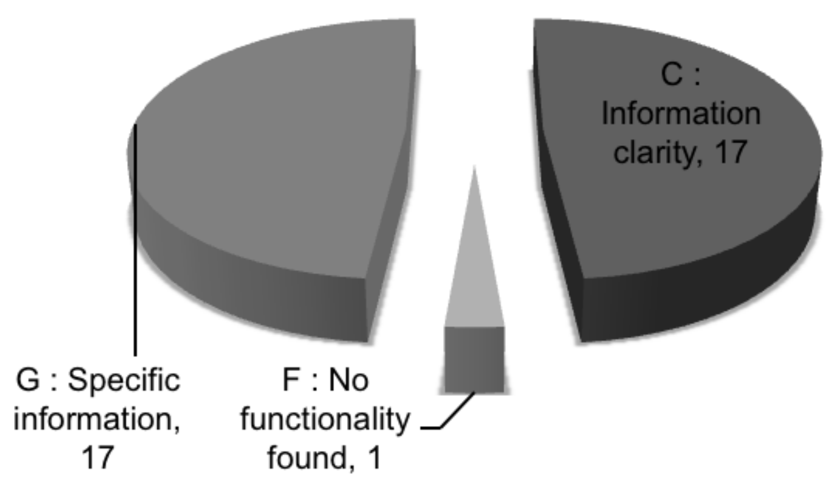
TABLE 5.1.2 B TYPICAL TERMS USED FOR INFORMATION SPECIFIC DURING USE CASE OBSERVATION	
The system provides drop down functions for lookup and selection of the appropriate data.	Where applicable a selection option in the form of a drop down menu is available.
The customers and items are required to exist in the master database.	The drop down options for the method of scheduling simplifies entering the information required for scheduling the production order backwards from the delivery date.
Information to be entered within each data entry from is clear and specific with a number of fields with lookup and drop-down functions where the fields are connected to tables.	A further function in the Dynamics AX add-in is the option of field lookup that will display a lookup form populated from the Dynamics AX configuration tables for the possible information configured e.g. Currency codes or account numbers.
Labels can be customized through right click option> personalize.	
Source: Chalil du Plessis (2014)	

The following remarks were extracted for the cases coded as *Not Specific*:

- <u>APUC#1a:</u> The remaining sections are hidden.

- MPUC#4: These would be assumed to be days or months however lesser values such as hours or part of days cannot be entered.
- MPUC#5: The system does highlight some key fields that needs to be entered but does not indicate if this will effect a process or further configuration steps.
- MPUC#6: Other than the brief label descriptions, there is no other clear explanation or help function to what the data should be that must be entered.
- PIUC#1: It is not clear to the user which information would be required to complete in the sub menus.
- UC#11: The Visio flow chart generated is confusing in the naming of the steps and uses the internal process names rather than the common user interface names.

FIGURE 5.1.2 C
RULE 1A: INFORMATION TO BE ENTERED IS CLEAR AND SPECIFIC



Source: Chalil du Plessis (2014)

The metric *Information to be entered is clear and specific* is summarized in Figure 5.1.2 C for the total of eighteen cases, seventeen cases were evaluated for *Specific information* and *Information clarity* with one case where *No functionality* was found to evaluate.

TABLE 5.1.2 C
PROXIMITY MATRIX (JACCARD'S COEFFICIENT) FOR RULE 1A

	E : Information not clear	H : Not specific	F : No functionality found	D : Information clear	I : Specific
E : Information not clear	**1**				
H : Not specific	0.500	**1**			
F : No functionality found	0.000	0.000	**1**		
D : Information clear	0.000	0.176	0.000	**1**	
I : Specific	0.000	0.000	0.000	0.786	**1**

Source: Chalil du Plessis (2014)

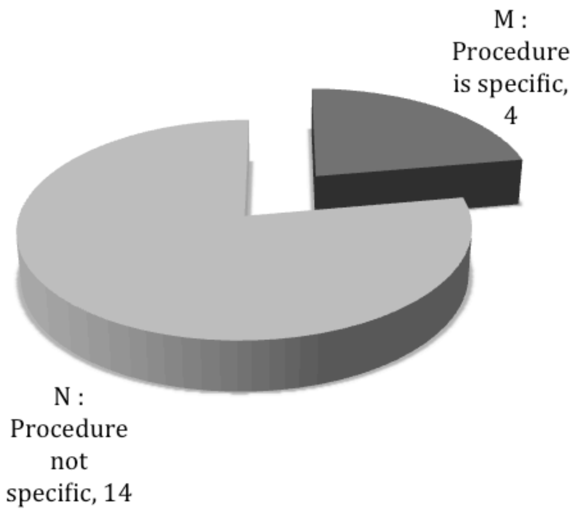
The proximity matrix presented in Table 5.1.2 C was calculated using the collected data from Table 4.3.2 B.

From the visual analysis as presented in Figure 5.1.2 A and Figure 5.1.2 B the expectation is that there might be a possible relationship between the sub-categories of *D: Information clear* and *I: Specific* and *E: Information not clear* and *H: Not specific* however, from the Jaccard's coefficient test as presented in Table 5.1.2 C none of the categories and sub-categories were found to be similar within the set dissimilarity threshold of 0.95. Therefore one can assume that the observations under the metric of *Information to be entered is clear and specific, Information clarity* does not have a statistical association with *Specific information entered* and *vice versa*. These categories have to be measured independently and exist independently as categories within the metric.

Rule 1B Metric: Procedures to perform a task are specific.
Observation were recorded to evaluate if the procedures to enter data in the system are clear and specific as well as if the user is being guided through the procedure. Typical functionality that the researcher was looking for during the observations were on-screen guidance to the user as to the type of transactions available and where to start the data entry procedure and where the process is ending. Furthermore, the procedure should be descriptive for the user to understand what will be achieved with the process. During the coding process in NVIVO 10 software, the metric was further categorized into *Specific procedures*, *User guidance* and *No functionality found* as per Table 4.3.2 C. A total number of thirty-four codings were done for the eighteen use cases. One use case was found where no relevant functionality was found to evaluate. No functionality was found within the system for use case MPUC#10.

Specific Procedures: Four cases were coded as *Procedure is specific* and fourteen cases as *Procedure not specific* as indicated in figure 5.1.2 D.

FIGURE 5.1.2 D
RULE 1B: SPECIFIC PROCEDURES



Source: Chalil du Plessis (2014)

The majority of the use cases were found to not have specific procedures indicated to the user. Terms used to identify *Procedure is specific* are summarized in Table 5.1.2 D:

TABLE 5.1.2 D
TYPICAL TERMS USED FOR PROCEDURE IS SPECIFIC DURING USE CASE OBSERVATION

The procedure is specified.	The procedure was found to be specific and reasonably simple.
The descriptions of the procedures are in some cases explained with examples.	The procedures are specific and can only be done as prescribed by the vendor procedure.

Source: Chalil du Plessis (2014)

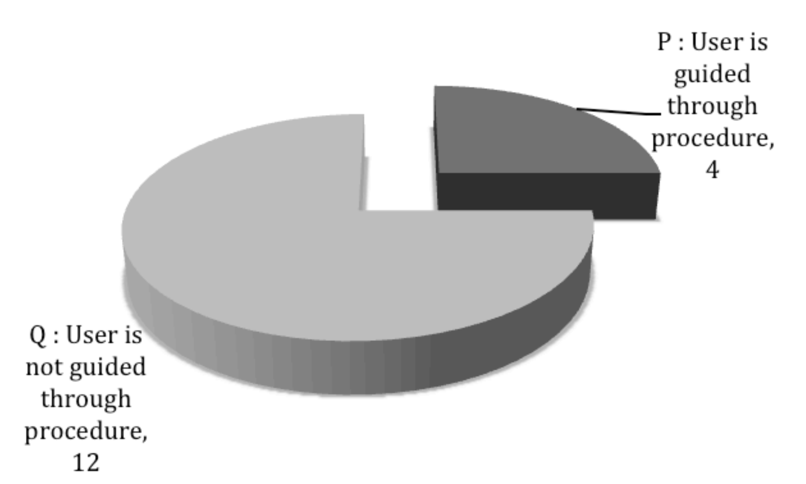
The following remarks were extracted for the cases coded as *Procedure not specific*:

4. APUC#1: The procedures to perform the task were found not to be clear and specific.
5. ARUC#1: The procedure to enter a customer order is not specified to the user as a simple sequence.
6. FAUC#1: The procedure to perform the task is not clear to the user.
7. GLUC#1: The procedures to perform the task were found to be vague and not clear.
8. MPUC#4: As with the sequence of the data entry steps, the procedure is not clear from the system where to start and where to stop.
9. MPUC#5: The procedures for configuring the system for pull action is vague.
10. MPUC#6: Procedures are not clear to the user and requires to complete a number of input forms.
11. MPUC#8 & 9: The procedures that were tested are not clear and not specified.
12. PCUC#3: The remaining procedures are not clear from the options.
13. PCUC#7-1: The procedure is not clear and the help functionality gives guidance on procedures for specific tasks but does not indicate the preceding or following procedure.
14. PCUC#7-2: The procedure is not indicated to the user as to where the information should be entered for the scheduling method.
15. PIUC#1: The procedure to perform the task was found to be not specified.
16. PRUC#1: The procedure is not specified from within the module and seems to have multiple options or sub procedures that can be followed by the user without any prompts, direction or messages to assist the user.

17. <u>UC#2:</u> Literature on the procedure and how to perform the task was found to be limited.

User guidance: Four cases were coded as *User is guided through procedure* and twelve cases as *User is not guided through procedure* as indicated in Figure 5.1.2E:

FIGURE 5.1.2 E
RULE 1B: USER GUIDANCE



Source: Chalil du Plessis (2014)

The majority of the use cases were found to not guide the user through the procedure. Typical functionality that the researcher was looking for during the observations of procedures were how the arrangement of menu options from left to right or top to bottom can guide the user throughout the procedure or any form of wizard that will serve as a guide. Terms used to identify specific information are summarized in Table 5.1.2 E:

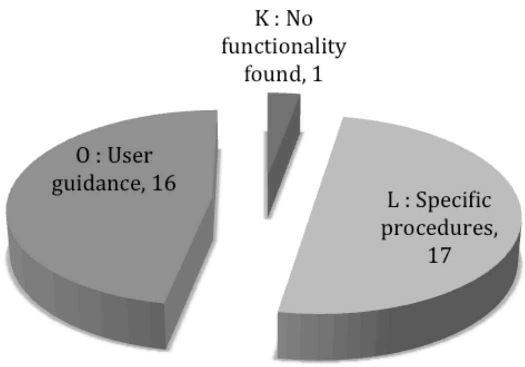
TABLE 5.1.2 E TYPICAL TERMS USED FOR USER GUIDANCE DURING USE CASE OBSERVATION	
Following the menu options from left to right have some indication of the process.	The descriptions of the procedures are in some cases explained with examples.
The first option of New product allows the user to add a new product that opens a wizard type of data entry form to complete only the minimum required information.	The options should be followed top to bottom left to right.
Source: Chalil du Plessis (2014)	

The following remarks were extracted for the cases coded as *User is not guided through procedure*:

- APUC#1: There is no indication to the user what the procedure is to complete the task.
- APUC#1a: The user is not guided through the process.
- ARUC#1: On entering the line details there is no indication to the user as where to complete the order.
- FAUC#1: The user is not guided that the process requires adding the asset to the database.
- GLUC#1: There is no indication in the procedure for the user to select the lines option from the menu ribbon.
- MPUC#4: The procedure does not guide the user as to the next step of the process.
- MPUC#5: The procedures for configuring the system for pull action is vague.

- MPUC#6: The help files give some vague indication but not clear enough as to what is the complete procedure required.
- MPUC#8 & 9: The procedures that were tested are not clear and not specified.
- PCUC#7-2: The procedure is not indicated to the user as to where the information should be entered for the scheduling method.
- PRUC#1: The procedure is not specified from within the module and seems to have multiple options or sub procedures that can be followed by the user without any prompts, direction or messages to assist the user.
- UC#2: Most of the useful information was found in blog by developers. In these cases the procedures are stated however often the same case simply copied from one blog to another not giving much insight into the logical steps of the procedure.

FIGURE 5.1.2 F
RULE 1B: PROCEDURES TO PERFORM A TASK ARE SPECIFIED



Source: Chalil du Plessis (2014)

The metric *Procedures to perform a task are specific* is summarized in Figure 5.1.2 F for the total of eighteen cases, seventeen cases were evaluated for *Specific procedures* and *Specific procedures* with one case where *No functionality* was found to evaluate.

TABLE 5.1.2 F PROXIMITY MATRIX (JACCARD COEFFICIENT) FOR RULE 1B					
	Q : User is not guided through procedure	N : Procedure not specific	P : User is guided through procedure	K : No functionality found	M : Procedure is specific
Q : User is not guided through procedure	**1**				
N : Procedure not specific	0.688	**1**			
P : User is guided through procedure	0.000	0.214	**1**		
K : No functionality found	0.000	0.000	0.000	**1**	
M : Procedure is specific	0.133	0.059	0.167	0.000	**1**
Source: Chalil du Plessis (2014)					

The proximity matrix presented in Table 5.1.2 F was calculated using the collected data from Table 4.3.2 C.

From the visual analysis as presented in Figure 5.1.2 D and Figure 5.1.2 E the expectation is that there might be a possible relationship between the sub-categories of *M: Procedure is specific* and *P: User is guided through procedure* and *N: Procedure not specific* and *Q: User is not guided through procedure* however, from the Jaccard's coefficient test as presented in Table 5.1.2 F none of the categories and sub-categories were found to be similar within the set dissimilarity threshold of 0.95. Therefore one can assume that the observations under the metric of

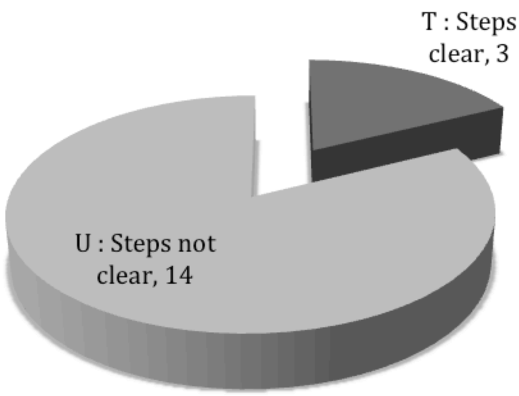
Procedures to perform a task are specific, Specific procedures does not have a statistical association with *User guidance* and *vice versa*. These categories have to be measured independently and exist independently as categories within the metric.

Rule 1C Metric: Sequence of data entry steps is clear.

Observations were recorded to evaluate the sequence of data entry steps are clear within the system. Typical functionality that the researcher was looking for during the observations if the data entry steps are following a logical sequence when entering data or following some pattern from top to bottom and left to right. During the coding process in Nvivo10 software, the metric was further categorized into *Clarity*, *Sequence* and *No functionality found* as per Table 4.3.2 D. A total number of thirty-five codings were done for the eighteen use cases. All use cases were found to have relevant functionality that could be evaluated.

Clarity: Three cases were coded as *Steps are clear* and fourteen cases as *Steps not clear* as indicated in figure 5.1.2 F.

FIGURE 5.1.2 G
RULE 1C: CLARITY



Source: Chalil du Plessis (2014)

The majority of the use cases were found not to have clear steps in the procedure that was evaluated. Terms used to identify *Steps clear* are summarized in Table 5.1.2 G:

TABLE 5.1.2 G
TYPICAL TERMS USED FOR CLARITY DURING USE CASE OBSERVATION

The data entry steps are clear for the basic information required.	The sequence of the data entry step is simple with only three steps to reach the data entry form.
The processes itself are very simple to invoke and can only be done in the specific functions as provided by the vendor.	

Source: Chalil du Plessis (2014)

The following remarks were extracted for the cases coded as *Steps not clear*:

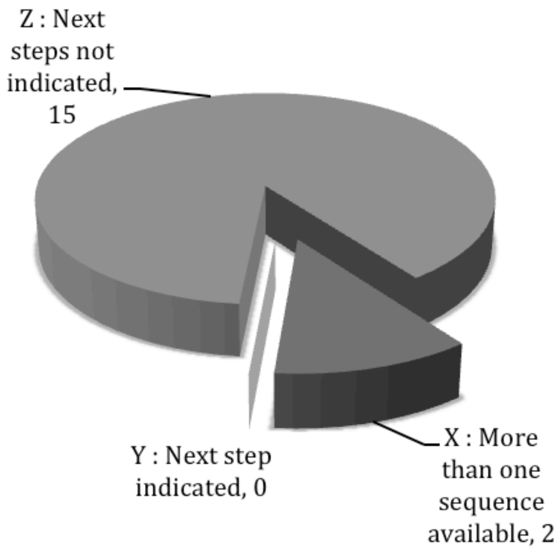
- APUC#1: The sequence of the data entry steps was found to be not very clear.
- APUC#1a: Data entry steps were found to be somewhat unclear to the user where to start the process of adding a new vendor.
- ARUC#1: The data entry sequence is not shown clearly to the user for entering a sales order.
- FAUC#1: The sequence of the data entry steps is not clear to the user in order to add the information for a new asset.
- PUC#4: The sequence of the data entry steps and procedure to add lead times and minimum/maximum keys are not sequential and not contained in a single procedure in the Master Planning module.
- MPUC#5: In order to prepare the system for a pull action from the sales order to production a number of configurations steps has to be completed. The system does not guide the user as to what these steps are.
- MPUC#6: The starting point of the sequence of the data entry steps is not clear.
- MPUC#8 & 9: The sequence of the data entry steps are not clear within the system. Data entry steps are spread across five modules.
- PCUC#3: A new Production Order or editing of a current open Production order is conducted through the same menu option of All production orders.
- PCUC#7-1: Data entry steps are spread across three modules. The sequence is not clear to the user or indicated in the software or menu items for example configuring route groups is the second step in the procedure and appears under the Production control >Setup > Routes as the third option out of a group

of five items and not the first option as would be expected as part of the sequence.

- PCUC#7-2: The sequence of data entry steps to enter the production order does not indicate the scheduling option at first.
- PIUC#1: The sequence of data entry steps to add a new product to the database is not clear.
- PRUC#1: The sequence for data entry is somewhat unclear. On opening the application it is unclear as to the location of where the user would enter a new purchase order. The sequence of data entry is only clear in the line detail grid where the user can use the tab key to move from left to right.
- UC#2: Not much literature was found that could clearly describe the sequence of the steps to configure and perform the integration between Excel and Dynamics AX. Information on the particular services exposed through AIF is very sparse and seems to rely on reverse engineering from the users.

Sequence: Two cases were coded as *More than one sequence available* and fifteen cases as *Next step not indicated* as indicated in Figure 5.1.2 H:

FIGURE 5.1.2 H
RULE 1C: SEQUENCE



Source: Chalil du Plessis (2014)

The majority of use cases were found not to indicate the next step in the procedure. A third coding category was identified as *More than one sequence available*, which was coded to two use cases. None of the cases were coded for *Next step indicated* and therefore there are no terms found that were coded to the use cases. However, Table 5.1.2 H indicates the terms used for coding the category *More than one sequence available*:

TABLE 5.1.2 H
TYPICAL TERMS USED FOR MORE THAN ONCE SEQUENCE DURING USE CASE OBSERVATION

The sales order can be entered from Account Receivables module as well as from the Sales and marketing module.	The user could start the data entry choosing any one of three options under Fixed assets > Common > Fixed Assets.

Source: Chalil du Plessis (2014)

The following remarks were extracted for the cases coded as *Next steps not indicated*:

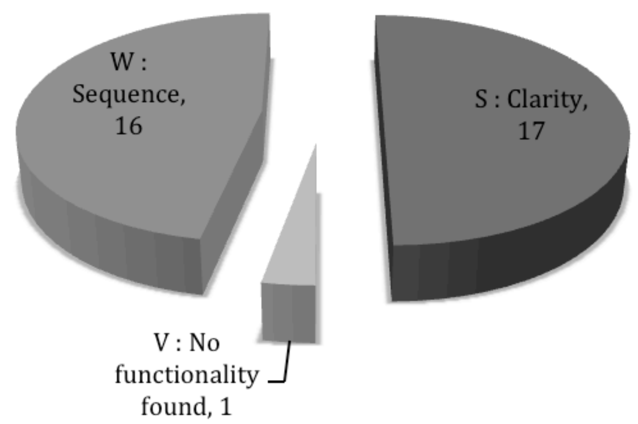
- APUC#1: No indication to the user to select line details from the menu ribbon to continue with the transaction.
- APUC#1a: The user have to navigate through four steps Accounts Payable > Common > Vendors > All Vendors then select from the ribbon menu the option of New Vendor in order to reach the data entry screen to add a new vendor.
- ARUC#1: The data entry sequence is not shown clearly to the user for entering a sales order.
- FAUC#1: The sequence of the data entry steps is not clear to the user in order to add the information for a new asset.
- GLUC#1: Entering the data lines is not clear.
- MPUC#4: The sequence of the data entry steps and procedure to add lead times and minimum/maximum keys are not sequential and not contained in a single procedure in the Master Planning module.
- MPUC#5: No specific documentation or internal help function exists that is clear enough to guide the user for the configuration steps or the scheduling and completion of the production through the Kanban boards.
- MPUC#6: The starting point of the sequence of the data entry steps is not clear to start as a value stream located under the group Setup. This is the second last option on the interface. The expectation would be that the sequence would

be more organized sequentially e.g. from top to bottom for the user to complete.

- MPUC#8 & 9: The sequence of the data entry steps are not clear within the system. Data entry steps are spread across five modules. The user is not guided as to the next data entry steps from one module to the next.
- PCUC#3: There is not a particular sequence of how the data should be entered in the form.
- PCUC#7-1: Data entry steps are spread across three modules. The start of the procedure is not obvious from within the software starting from the resource capabilities to be configured. The sequence is not clear to the user or indicated in the software or menu items for example configuring route groups is the second step in the procedure and appears under the Production control >Setup > Routes as the third option out of a group of five items and not the first option as would be expected as part of the sequence.
- PCUC#7-2: The sequence of data entry steps to enter the production order does not indicate the scheduling option at first. Once the basic production order information has been entered and saved, the user has to re-open the production order to be able to enter the information related to scheduling the production order backwards from the delivery date.
- PIUC#1: The sequence of data entry steps to add a new product to the database is not clear. The user is required to navigate to Product information management > Common > Products > Products.

- PRUC#1: The sequence for data entry is somewhat unclear. On opening the application it is unclear as to the location of where the user would enter a new purchase order. The sequence of data entry is only clear in the line detail grid where the user can use the tab key to move from left to right.
- UC#2: Not much literature was found that could clearly describe the sequence of the steps to configure and perform the integration between Excel and Dynamics AX. Information on the particular services exposed through AIF is very sparse and seems to rely on reverse engineering from the users.

FIGURE 5.1.2 I
RULE 1C: SEQUENCE OF DATA ENTRY STEPS ARE CLEAR



Source: Chalil du Plessis (2014)

The metric *Sequence of data entry steps are clear* is summarized in the Figure 5.1.2 I for the total of eighteen cases, seventeen cases were evaluated for *Specific procedures* and *Specific procedures* with one case where *No functionality* was found to evaluate.

The following proximity matrix was calculated using the collected data from Table 4.3.2 D.

TABLE 5.1.2 I PROXIMITY MATRIX (JACCARD COEFFICIENT) FOR RULE 1C						
	Z : Next steps not indicated	V : No functionality found	X : More than one sequence available	Y : Next step indicated	U : Steps not clear	T : Steps clear
Z : Next steps not indicated	**1**					
V : No functionality found	0.000	**1**				
X : More than one sequence available	0.133	0.000	**1**			
Y : Next step indicated	0.000	0.000	0.000	**1**		
U : Steps not clear	0.933	0.000	0.143	0.000	**1**	
T : Steps clear	0.059	0.000	0.000	0.000	0.000	**1**
Source: Chalil du Plessis (2014)						

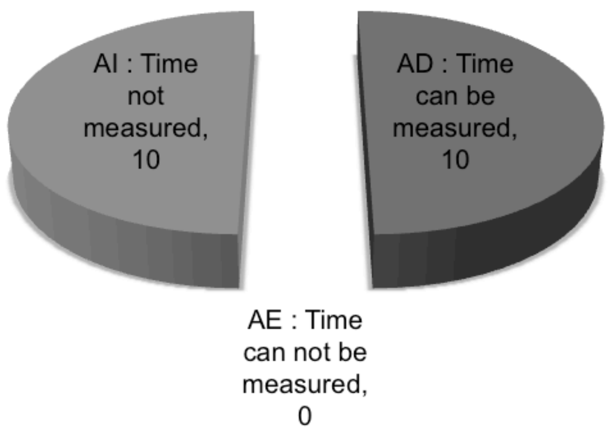
From the visual analysis as presented in Figure 5.1.2 I the expectation is that there might be a possible relationship between the sub-categories of *W: Sequence and S: Clarity.* Jaccard's coefficient proximity matrix does not indicate any similarities for the datasets. Two of the objects on Jaccard's coefficient matrix, U and Z (0.933), are very close to the dissimilarity threshold of 0.95 and would be reasonable to accept if the threshold would be set at 0.90. One can assume that the observations under the sub-categories of the metric of *Sequence of data entry steps are clear,* does not have a statistical association with each other. These categories have to be measured independently and exist independently as categories within the metric.

Rule 1D Metric: The time to perform a task in the software can be measured and optimized.

Observations to measure the time to perform a task in the software and *optimize the time of performing a task* are covered in details in the previous Section 5.1.1 for the quantitative findings and analysis. However to complete the qualitative findings for the complete set of Lean operational rules, all of the use cases were evaluated and analyzed using Nvivo 10 software. The metric was further categorized into *Time measurement* and *Time optimization* as presented in Table 4.3.2 E. A total number of twenty-nine observations were coded with ten codings for *Time measurement* and nineteen codings for *Time optimization*. There were no cases coded as *No functionality found*.

Time measurement: Ten cases were coded as *Time can be measured* and none of the cases were coded as *Time cannot be measured* as indicated in Figure 5.1.2 J.

FIGURE 5.1.2 J
RULE 1D: TIME MEASUREMENT



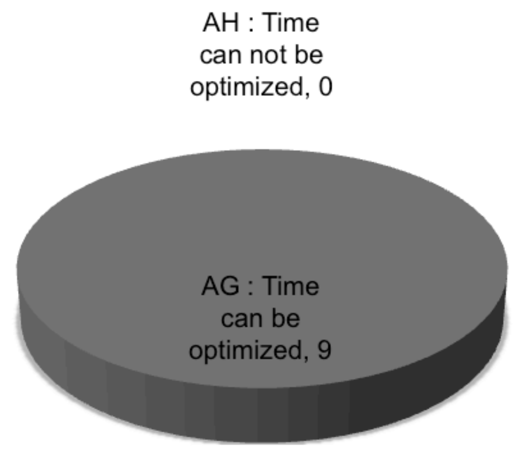
Source: Chalil du Plessis (2014)

The ten cases that were code as *Time can be measured* are all represented by the quantitative use cases including UC#2 and PCUC#3. These two use cases are transactional and procedural in nature and time can be measured with the same procedure as applied for measuring time for the quantitative use cases. The ten use cases that were used during the qualitative testing were coded as *Time not measured* as indicated in Figure 5.1.2 J. The quantitative use cases were design to test functionality within the system. Terms used to identify *Time measurement* are summarized in Table 5.1.2 J:

TABLE 5.1.2 J TYPICAL TERMS USED FOR TIME MEASUREMENT	
The time to enter the transaction was measured with IOgraph software and recorded.	The processing time was measured during testing and recorded using IOgraph software.
The time for each task was recorded on the test sheets before and after improvements were made.	The time to perform the step was measured using IOgraph software. No build in function was found to be able to measure the time.
The time to enter Fixed asset data was measured for ten test items using IOgraph software and recorded for analysis.	Time was measured and recorded using IOgraph software to test before and after improvements.
The time can be measured physically through observation of the steps.	The time to enter a new item code was measured for ten test items using IOgraph software and recorded for analysis.
The researcher has to use external software to measure the process. However the process is measurable.	The time can be measured physically through observation of the steps.
Source: Chalil du Plessis (2014)	

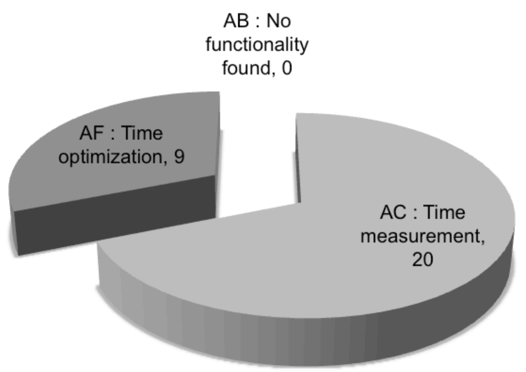
Time optimization: A total number of nine cases were coded as *Time can be optimized*. The nine cases represents all the quantitative use cases including use case UC#2 which was classified as a qualitative use case for the purpose of this research however it is procedural in nature and time could be optimized though adjustment of the procedure. None of the cases were coded as *Time cannot be optimized* as illustrated in Figure 5.1.2 K. As indicated in the previous section 5.1.1 the research indicated that all of the quantitative use cases time can be optimized and all of the qualitative use cases were coded as *Time not measured* because time tests were not conducted as a quantitative test for these use cases.

FIGURE 5.1.2 K
RULE 1D: TIME OPTIMIZATION



Source: Chalil du Plessis (2014)

FIGURE 5.1.2 L
RULE 1D: THE TIME TO PERFORM A TASK IN THE SOFTWARE CAN BE MEASURED AND OPTIMIZED



Source: Chalil du Plessis (2014)

The metric *The time to perform a task in the software can be measured and optimized* is summarized in Figure 5.1.2 L for the total of twenty-nine codings that were done. Ten codings were done for *Time measurement* and nine codings were done for *Time optimization*. No codings were done for *No functionality found*.

The matrix in Table 5.1.2 K was calculated using the collected data from Table 4.3.2 E.

TABLE 5.1.2 K
PROXIMITY MATRIX (JACCARD COEFFICIENT) FOR RULE 1D

	AB : No functionality found	AD : Time can be measured	AE : Time cannot be measured	AG : Time can be optimized	AH : Time cannot be optimized	AI : Time not measured
AB : No functionality found	**1**					
AD : Time can be measured	0.000	**1**				
AE : Time cannot be measured	**1.000**	0.000	**1**			
AG : Time can be optimized	0.000	0.900	0.000	**1**		
AH : Time cannot be optimized	**1.000**	0.000	**1.000**	0.000	**1**	
AI : Time not measured	0.000	0.111	0.000	0.056	0.000	**1**

Source: Chalil du Plessis (2014)

From the visual analysis as presented in Figure 5.1.2 L the expectation is that there might be a possible relationship between some of the sub-categories of *AF: Time* *optimization* and *AC: Time measurement.* Jaccard's coefficient proximity matrix indicates a number of similarities for the dataset with the dissimilar threshold set at 0.95. On closer inspection of Table 4.3.2 E one can analyze the similarities found between the subcategories of *AB: No functionality found*, *AE: Time cannot be measured* and *AH: Time cannot be optimized* as a false similarity since all of them are coded with 0 for all the use cases. The sub-categories that are expected to be similar are *AD: Time can be measured* and *AG: Time can be optimized*. At a dissimilarity threshold of 0.90 these two categories are indeed shown to be similar as expected and also supported by the quantitative tests as discussed in section 5.1.1.

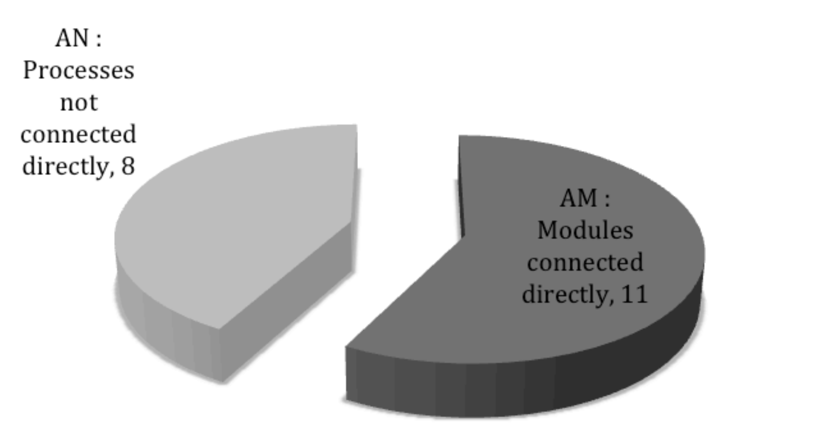
Rule 2: Every customer-supplier connection must be direct with a yes-or-no method to send requests and receive responses.

Rule 2A Metric: Connecting processes or modules are direct and standardized. Observations were recorded to evaluate if the processes are organized to follow each other and can be described as a flowing process. Furthermore, the modules should be connected to facilitate the flow of information between modules during a process and that the information remains standardized. Typical functionality that the researcher was looking for during the observations were integration of modules through lookup and drop down lists connected to master data from other relevant modules e.g. Invoice entry connected to the chart of accounts details in the general ledger. The process of data entry and posting should flow automatically between modules when transactions are entered to eliminate the duplication of data entry.

During the coding process in Nvivo 10 software, the metric was further categorized into *Connectivity*, *Processes* and *No functionality found* as per Table 4.3.2 G. A total number of thirty-three codings were done for the eighteen use cases. One use case was found where no relevant functionality was found to evaluate. No functionality was found within the system for use case MPUC#10.

Connectivity: Eleven cases were coded as *Modules connected directly* and eight cases as *Processes not connected directly* as indicated in figure 5.1.2 M.

FIGURE 5.1.2 M
RULE 2A: CONNECTIVITY



Source: Chalil du Plessis (2014)

The majority of the use cases were found to contain connected modules. Terms used to identify *Connectivity* are summarized in Table 5.1.2 L:

TABLE 5.1.2 L TYPICAL TERMS USED FOR CONNECTIVITY	
The process of entering an invoice directly for a vendor was found to be standard process and is directly connected to the account payable module and data such as vendor codes. The general modules are connected through the data entry form as the offset account and verified using a lookup on the general ledger account codes.	Connections to other modules such as Purchase orders are defaults with connecting tables to select values already in the system to preserve the integrity of the data.
The connecting processes and modules that are integrated within the same procedure are directly connected such as information from the inventory module.	Other modules such as sales and marketing uses the customer database once the master information has been added.
Entering data for Coverage groups, Minumum/maximum keys and item coverage are connected to the relevant items.	The automatic generation of the production Kanban is direct and standardized to the entry of the sales order provided the item on the sales order has been configured correctly.
Processes and information flow between the five modules are direct and standardized.	The processes of checking the availability of the resources is connected and direct once the method has been selected and the schedule date entered.
It was found that the connecting processes and modules are direct and standardized. Relevant information are available on the data entry fields through drop down options on fields for example term codes, retail categories etc.	Processes between sub systems are direct and standardized and does not require an interaction from the user. The data is updated to the relevant database (CEU) and tables on the user completing the data entry process.
The integration through the AIF exposed services from Dynamics AX to Microsoft Excel gives the user direct access to updating or adding records to the database.	
Source: Chalil du Plessis (2014)	

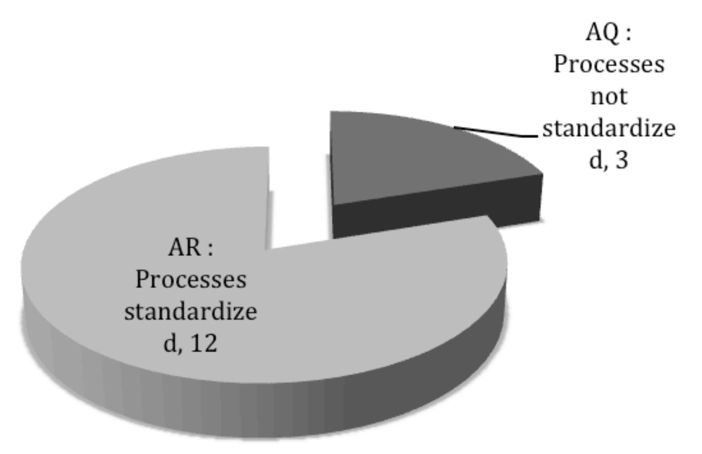
The following remarks were extracted for the cases coded as *Processes not connected directly*:

5. ARUC#1a: There are no connecting processes found other than the process of adding the customer code that is auto generated.
6. FAUC#1: There are no other connected processes and modules found for the process of adding the master data for a Fixed Asset. All data is from the same database within the Fixed Assets module.
7. GLUC#1: The journal entry data form is only related to the General Ledger module and there are no connecting processes or modules found to evaluate as a General Ledger journal.
8. MPUC#6: Connected processes are not indicated to the user. A part of the process is direct and standardized through the use of a wizard to Create new plan activity.
9. PCUC#7-1: Connecting processes or modules are not indicated throughout the procedure. The procedure remains the same and standardized for the process tested during the use case. As mentioned earlier, the procedure is spread across several modules and there is no indication to the user as to the next step to perform in the procedure. The steps seem to be loose standing islands of information to be completed however certain tables are connected within the forms and require to be completed in a sequence. This sequence is not clear from the software menus or help function.
10. PCUC#7-2: The connecting process of scheduling is not available at the initial entry of the production and has to be done as a second step in the process.

11. <u>UC#11:</u> There are no connected processes found from the F1 and task recorder functions.
12. <u>UC#2:</u> No standardization was found to indicate for example the required database fields that need to be selected in order to establish a successful integration. Some indication exists for key fields and asterisks for required fields. These were found to be of little or no use to ensure a successful integration of a General Ledger voucher that was attempted by the author during testing of the use case.

Processes: Twelve cases were coded as *Processes standardized* and three cases as *processes not standardized* as indicated in Figure 5.1.2 N:

FIGURE 5.1.2 N
RULE 2A: PROCESSES



Source: Chalil du Plessis (2014)

The majority of the use cases were found to contain connected processes. Terms used to identify *Processes* are summarized in Table 5.1.2 M:

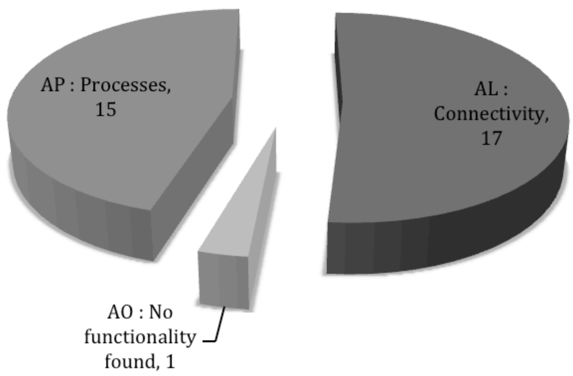
TABLE 5.1.2 M TYPICAL TERMS USED FOR PROCESSES	
The process of entering an invoice directly for a vendor was found to be standard process.	The initial steps of the process are standardized and direct however only the general tab is marked as required.
The connecting processes and modules that are integrated within the same procedure are directly connected such as information from the inventory module.	The journal entry data form is only related to the General Ledger module.
The setup for Item coverage when completed through the wizard "Item coverage wizard guides the user to complete the relevant information in the forms.	The automatic generation of the production Kanban is direct and standardized to the entry of the sales order provided the item on the sales order has been configured correctly.
A part of the process is direct and standardized through the use of a wizard to Create new plan activity.	Processes and information flow between the five modules are direct and standardized.
The process for updating the production order seems to be standard.	The processes of checking the availability of the resources is connected and direct once the method has been selected and the schedule date entered.
It was found that the connecting processes and modules are direct and standardized. Relevant information are available on the data entry fields through drop down options on fields for example term codes, retail categories etc.	Processes between sub systems are direct and standardized and does not require an interaction from the user. The data is updated to the relevant database (CEU) and tables on the user completing the data entry process.
Source: Chalil du Plessis (2014)	

The following remarks were extracted for the cases coded as *Processes not standardized*:

- APUC#1a: All other data can be entered in any sequence or left out.
- ARUC#1a: All customer information required is through a standard data entry form and standard fields to be completed. Only the customer name and customer group are marked as required fields and allows all other information be omitted. This can cause a lack of information for example at the time of delivery to have the correct contact details.
- PCUC#7-1: The procedure remains the same and standardized for the process tested during the use case. The procedure is spread across several modules and there is no indication to the user as to the next step to perform in the procedure. The steps seem to be loose standing islands of information to be completed however certain tables are connected within the forms and require to be completed in a sequence. This sequence is not clear from the software menus or help function.

The metric *Connecting processes or modules are direct and standardized* is summarized in Figure 5.1.2 O for the total of eighteen cases, seventeen cases were evaluated for *Connectivity* and fifteen cases for *Processes* with one case where *No functionality* was found to evaluate.

FIGURE 5.1.2 O
RULE 2A: CONNECTING PROCESSES OR MODULES ARE DIRECT AND STANDARDIZED



Source: Chalil du Plessis (2014)

The following proximity matrix was calculated using the collected data from Table 4.3.2 G.

TABLE 5.1.2 N PROXIMITY MATRIX (JACCARD COEFFICIENT) FOR RULE 2A					
	AR : Processes standardized	AM : Modules connected directly	AO : No functionality found	AQ : Processes not standardized	AN : Processes not connected directly
AR : Processes standardized	**1**				
AM : Modules connected directly	0.643	**1**			
AO : No functionality found	0.000	0.000	**1**		
AQ : Processes not standardized	0.071	0.167	0.000	**1**	
AN : Processes not connected directly	0.176	0.188	0.000	0.222	**1**
Source: Chalil du Plessis (2014)					

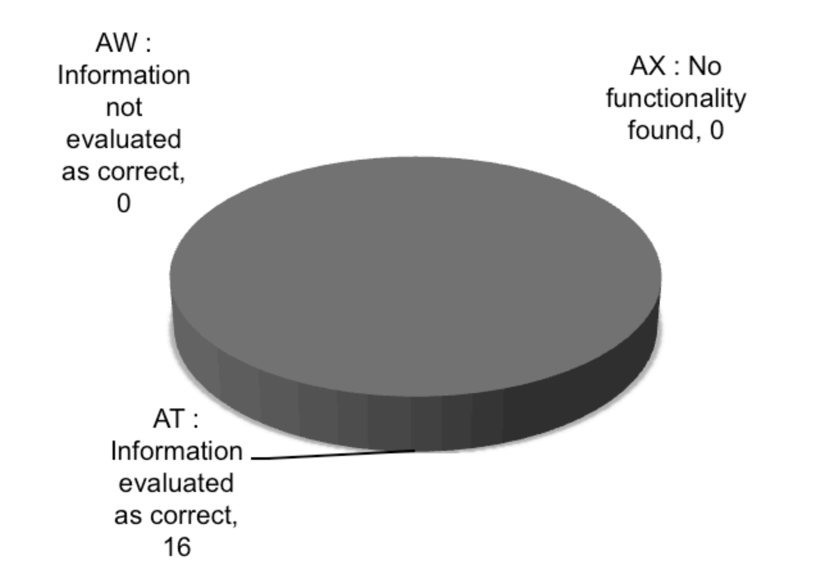
From the visual analysis as presented in Figure 5.1.2 M and Figure 5.1.2 N the expectation is that there might be a possible relationship between the sub-categories of *AM: Modules connected directly* and *AR: Processes standardized* and *AN: Processes not connected directly* and *AQ: Processes not standardized* however, from the Jaccard's coefficient test as presented in Table 5.1.2 N none of the categories and sub-categories were found to be similar within the set dissimilarity threshold of 0.95. Therefore one can assume that the observations under the metric of *Connecting processes or modules are direct and standardized, Connectivity* does not have a statistical association with *Processes* and *vice versa*. These categories have to be measured independently and exist independently as categories within the metric.

Rule 2B Metric: Information is evaluated as correct before committed to the database.

Observations were recorded to evaluate if the information that needs to be entered can be selected from a drop down list from a predefined table. Typical functionality that the researcher was looking for during the observations were verification of data using drop down lists, algorithms that verifies entered information and data entry fields highlighted for data entry errors or omission of data and lookup functions on data entry fields. Other functions were found to exist where the user can do a manual validation of data and in some cases there is an automated process of validation as presented in Table 5.1.2 O. These were sub coded as part of the category of *Information evaluated as correct before committed to the database.* During the coding process in NVIVO 10 software, the metric was further categorized into *Information evaluated as correct*, *Information not evaluated as correct* and *No functionality found* as per Table 4.3.2 H. A total number of eighteen codings were done for the eighteen use cases. One use case was found where no relevant functionality was found to evaluate. Use cases MPUC#10 and UC#11 were not coded as these use cases do not have data entry procedures.

Information evaluated as correct before committed to the database: Sixteen cases were coded as *Information evaluated as correct*, two case as *Information not evaluated as correct* and there were no cases found to evaluate as *No functionality found* as indicated in figure 5.1.2 P.

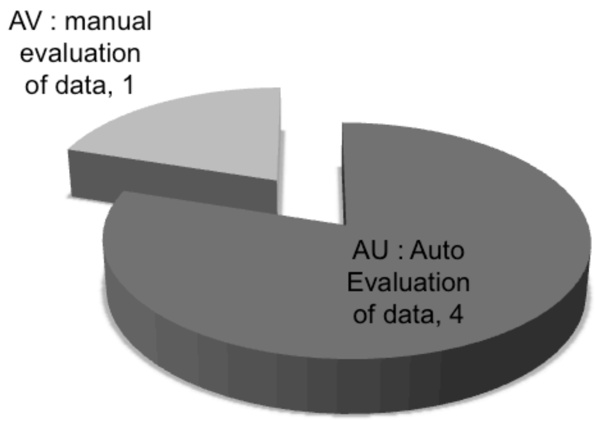
FIGURE 5.1.2 P
RULE 2B: INFORMATION IS EVALUATED AS CORRECT BEFORE COMMITTED TO THE DATABASE



Source: Chalil du Plessis (2014)

Information evaluated as correct was further sub-categorized for five use cases where four cases were coded as *Auto evaluation of data* and one case as *Manual evaluation of data* as indicated in Figure 5.1.2 Q:

FIGURE 5.1.2 Q
RULE 2B: INFORMATION EVALUATED AS CORRECT



Source: Chalil du Plessis (2014)

The majority of the use cases were found to evaluate information as correct before committed to the database. Terms used to identify *Information is evaluated as correct before committed to the database* are summarized in Table 5.1.2 O:

TABLE 5.1.2 O INFORMATION IS EVALUATED AS CORRECT BEFORE COMMITTED TO THE DATABASE	
Information entered in data fields that are connected to tables in the system for example vendor code and ledger account codes are verified before committed to the database using drop down fields.	Drop down lists are available where data fields are associated with tables and verified once data has been entered before data is committed to the database.
Data is evaluated against the master data on fields such as customer code, item codes and warehouses.	It was found that most of the data fields are evaluated to be correct through a drop down menu and extended functionality exists on address fields for country and zip/postal code, city, district, state and county.
Where data fields are associated with tables with existing data, the data entered are verified.	Information was found to being evaluated as correct through the Validate function.
Information is identified as correct and where required information is omitted, the system would generate an info log.	The function to Publish data within the Dynamics AX add-in would verify the data from the Excel sheet for validity before committing to the database.
Information is evaluated using drop down menus where required however the evaluation of information is not always evaluated in context of other data and can cause the system not to give correct results.	Information that is connected with tables within the system is verified through lookups and drop-down option within the data entry forms.
On selecting an Item Number when creating a new production order, the item number is verified against a Bill of Materials (BOM). If a BOM is not found an error message is displayed and the system prevents the user from continuing with the incorrect item number.	Not all the essential information seems to be evaluated where the data is connected with a drop down list to the related database. However, where information was entered incorrectly or not completed, the system communicated through an info log for example Critical stop error.
The information required to be entered for the scheduling is simplified by using a drop down for the method and the date can be entered manually or from a calendar.	Data fields associated with tables within the Product information management module as well as other relevant modules such as Accounts Payable, Accounts Receivables, General ledger, Sales and Purchases are validated. The user is able to select information from a drop down list.
Information is checked in a data entry field before accepted. Error messages communicate an incorrect entry to the user and the curser returns to the data entry field for correction. Some fields have drop-down lists from where the user can select available data.	
Source: Chalil du Plessis (2014)	

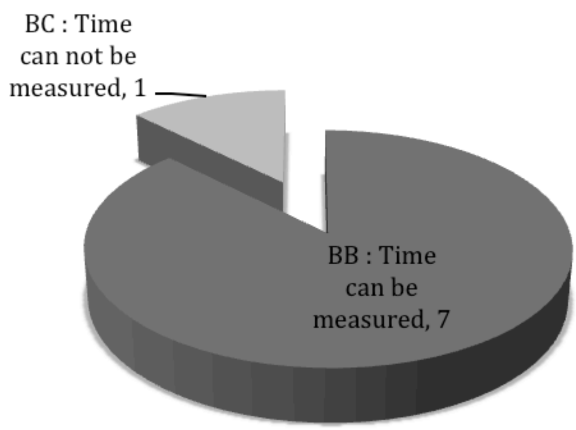
From the visual analysis as presented in Figure 5.1.2 P and Figure 5.1.2 Q all use cases have been coded as *Information evaluated as correct* with the exception of use cases MPUC#10 and UC#11as explained earlier.

<u>Rule 2C Metric:</u> Time between each connecting process can be measured and optimized.

Observations were recorded to evaluate if the processes can be connected together to minimize or being organized as groups to be executed together to minimize time between processes. Typical functionality that the researcher was looking for during the observations was methods to measure and record time between connected processes and functions within the software to optimize the processes and possibly reduce time. The use cases that were evaluated are all the quantitative use cases as described in the previous section 5.1.1. During the coding process in NVIVO 10 software, the metric was further categorized into *Time measurement* and *Time optimization* as per Table 4.3.2 I. A total number of twenty-six codings were done for the eighteen use cases. One use case was found where no relevant functionality was found to evaluate.

Time measurement: Seven use cases were coded as *Time can be measured* and one use case as *Time cannot be measured* as indicated in figure 5.1.2 R.

FIGURE 5.1.2 R
RULE 2C: TIME MEASUREMENT



Source: Chalil du Plessis (2014)

The majority of the use cases that were evaluated for time measurement were found that time can be measured. Terms used to identify *Time measurement* are summarized in Table 5.1.2 P:

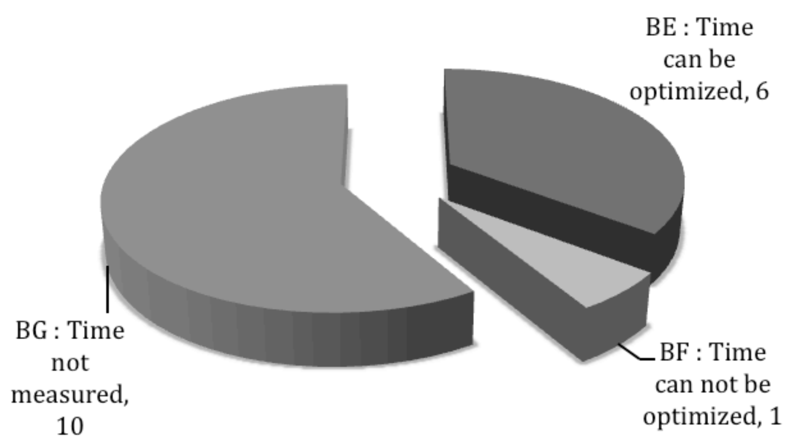
TABLE 5.1.2 P TYPICAL TERMS USED FOR TIME MEASUREMENT	
The time to enter the transaction was measured with IOgraph software and recorded.	The processing time was measured during testing and recorded using IOgraph software.
The time measured during the testing includes the connecting processes. These cannot be measured separately in the software as they are integrated through the vendor software code.	The time to perform the step was measured using IOgraph software. No build in function was found to be able to measure the time.
The time to enter Fixed asset data was measured for ten test items using IOgraph software and recorded for analysis.	Time was measured and recorded using IOgraph software for tests before and after improvements. These have been recorded and analyzed.
The time to enter a new item code was measured for ten test items using IOgraph software and recorded for analysis.	
Source: Chalil du Plessis (2014)	

The following remark was extracted for the use case coded as *Time cannot be measured*:

PRUC#1: Connecting processes are not measurable as it is embedded within the data entry process. Optimizing the connecting processes requires access to the source of the software that is not available to end-users and optimization is therefore not accessible directly through the source code.

Time optimization: Six use cases were coded as *Time can be optimized*, one case as *Time cannot be optimized* and ten use cases as *Time not measured* as indicated in Figure 5.1.2 S:

FIGURE 5.1.2 S
RULE 2C: TIME OPTIMIZATION



Source: Chalil du Plessis (2014)

For the majority of use cases that time were measured it was found that the time could be optimized. Table 5.1.2 Q indicates the terms used for coding the category *Time optimization*:

TABLE 5.1.2 Q
TYPICAL TERMS USED FOR TIME OPTIMIZATION

The process was optimized using the personalization option with the Dynamics AX software.	The process was measured as an end-to-end process or value stream.
The task could be optimized using the personalization function within Dynamics AX 2012.	The procedure was optimized using an alternative method of data entry and tested again for data entry time using IOgraph.
The time to perform the journal entry was optimized using the personalization option available to the user in Dynamics AX 2012.	The procedure was optimized using an alternative method of data entry and tested again for data entry time using IOgraph.

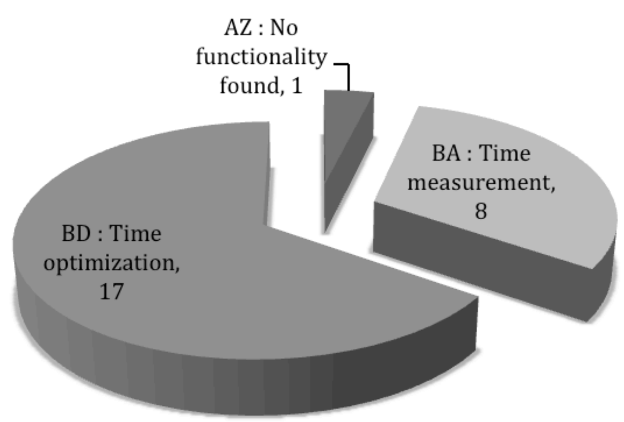
Source: Chalil du Plessis (2014)

The following remarks were extracted for the cases coded as *Time cannot be optimized*:

PRUC#1: Connecting processes are not measurable as it is embedded within the data entry process. Optimizing the connecting processes requires access to the source of the software that is not available to end-users and optimization is therefore not accessible directly through the source code.

The metric *Time between each connecting process can be measured and optimized* is summarized in Figure 5.1.2 T for the total of eighteen use cases, seventeen use cases were evaluated for *Time optimization* and eight use cases for *Time measurement* with one case where *No functionality* was found to evaluate.

FIGURE 5.1.2 T
RULE 2C: TIME BETWEEN EACH CONNECTING PROCESS CAN BE MEASURED AND OPTIMIZED



Source: Chalil du Plessis (2014)

The following proximity matrix was calculated using the collected data from Table 4.3.2 I.

TABLE 5.1.2 R PROXIMITY MATRIX (JACCARD COEFFICIENT) FOR RULE 2C						
	BG : Time not measured	AZ : No functionality found	BC : Time cannot be measured	BF : Time cannot be optimized	BE : Time can be optimized	BB : Time can be measured
BG : Time not measure d	**1**					
AZ : No functionality found	0.100	**1**				
BC : Time cannot be measured	0.000	0.000	**1**			
BF : Time cannot be optimized	0.000	0.000	**1.000**	**1**		
BE : Time can be optimized	0.000	0.000	0.000	0.000	**1**	
BB : Time can be measured	0.000	0.000	0.000	0.000	0.857	**1**
Source: Chalil du Plessis (2014)						

From the visual analysis as presented in Figure 5.1.2 R and Figure 5.1.2 S the expectation is that there might be a possible relationship between the sub-categories of *BB: Time can be measured* and *BE: Time can be optimized* however, from the

Jaccard's coefficient test as presented in Table 5.1.2 R there was only one similarity found between BC: Time cannot be measured and BF: Time cannot be optimized within the set dissimilarity threshold of 0.95. On closer inspection of the tally chart presented in Table 4.3.2 I the similarity is based on a single use case PRUC#1 coded to these two categories. Even though the similarity is very high it is only based on a single use case. Therefore one can assume that the observations under the metric of *Time between each connecting process can be measured and optimized, Time measurement* does not have a statistical association with *Time optimization* and *vice versa*. These categories have to be measured independently and exist independently as categories within the metric.

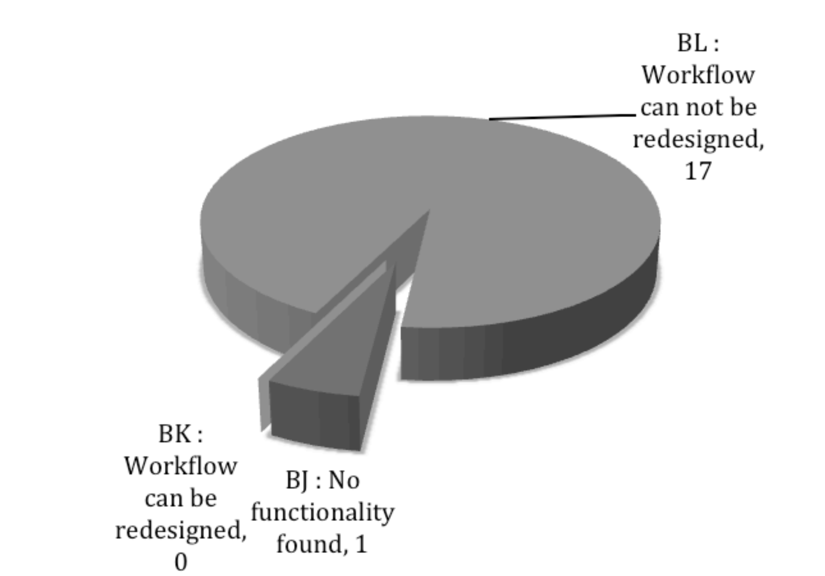
<u>Rule 3:</u> The pathway for every product and service must be simple and direct.

<u>Rule 3A Metric:</u> The workflow can only change when redesigned.
Observations were done to evaluate the workflow to be free of multiple options that can cause confusion or cause the work to be done differently every time. Furthermore the workflow should have functionality to be redesigned by a user. The functionality that the researcher was looking for during the observations was the ability to change the current workflow of a transaction during testing. During the coding process in NVivo 10 software, the metric was further categorized into *Workflow can be redesigned*, *Workflow cannot be redesigned* and *no functionality found* as per Table 4.3.2 L. A total number of eighteen codings were done for the

eighteen use cases. No functionality was found within the system for use case MPUC#10.

The workflow can only change when redesigned: Seventeen use cases were coded as *Workflow cannot be redesigned,* none of the use case were coded as *Workflow can be redesigned* and one use case as *No functionality found* as indicated in figure 5.1.2 U:

FIGURE 5.1.2 U
RULE 3A: THE WORKFLOW CAN ONLY CHANGE WHEN REDESIGNED



Source: Chalil du Plessis (2014)

All of the use cases were coded as *workflow cannot be redesigned*.

The following remarks were extracted for the cases coded as *Workflow cannot be redesigned*:

- APUC#1: The basic workflow in the system is already predefined by the software vendor and cannot be changed by the user. The basic flow consist of adding a new journal and type, select lines option from the menu and enter the lines, verify the journal voucher and post and transfer.
- APUC#1a: The workflow was found to be predefined by the vendor of the software and cannot be changed
- ARUC#1: The workflow is predefined by the vendor and was not found to be able to redesign the workflow.
- ARUC#1a: There is no automated workflow associated with the process of adding a new cutover to the system. The workflow cannot be changed by the user and is predefined by the vendor.
- FAUC#1: Since there is no workflow associated with the process of acquiring a new asset and adding the data to the database it is not possible to change the workflow by the user.
- GLUC#1: The workflow associated with the general ledger is only for designing an approval workflow and does not accommodate the data entry process (General Ledger > Setup > General Ledger Workflows).
- MPUC#4: The item coverage wizard cannot be changed by the user.
- MPUC#5: The workflow defined in the system for configuration of the Kanban setup and the workflow between the Sales order and the production Kanban is predefined in the business logic by the software vendor. The business logic

cannot be redesigned by the user. However the system can be configured with different activities that can be associated with a Kanban for a particular product.

- MPUC#6: The workflow to configure the system for cellular manufacturing is predetermined by the vendor and cannot be redesigned.
- MPUC#8 & MPUC#9: The vendor predefines the workflow and it was found not to be flexible for any change.
- PCUC#3: The workflow through the system has been configured to follow what would normally be perceived as the best practice for a production order. The workflow itself cannot be redesigned as it is established in the core business process.
- PCUC#7-1: The workflow is not predefined however it was attempted in the system to change from the workflow as used in the current use case. Starting the workflow from Organization administration >Common >Resources >Resources adding a resource as the first step in the workflow. Using the function to add data on the fly using the right hand mouse button> view detail > new to add a required record. Using this change however did not allow the process to be completed since procedures on a sub-level can’t be opened where a cost category added requires a shared category to be predefined. The workflow seems to be specific as intended by the vendor and seems not to be able to change or redesigned.
- PCUC#7-2: The workflow as a standard function is predefined by the software and does not have the option to reconfigure the workflow.

- PIUC#1: The workflow is not defined in the system therefore the workflow cannot be redesigned.
- PRUC#1: The workflow is fixed in the system and not able to change for the process of entering a purchase order.
- UC#11: There is no option provided to the user to change the workflow. The functions are hard coded by the software vendor.
- UC#2: The workflow is not able to change from within Excel or Dynamics AX. The change to the workflow requires the vendor to redesign to methods in order to change the integration method.

The following proximity matrix was calculated using the collected data from Table 4.3.2 L.

TABLE 5.1.2 S
PROXIMITY MATRIX (JACCARD COEFFICIENT) FOR RULE 3A

	BJ : No functionality found	BL : Workflow cannot be redesigned	BK : Workflow can be redesigned
BJ : No functionality found	**1**		
BL : Workflow cannot be redesigned	0.000	**1**	
BK : Workflow can be redesigned	0.000	0.000	**1**

Source: Chalil du Plessis (2014)

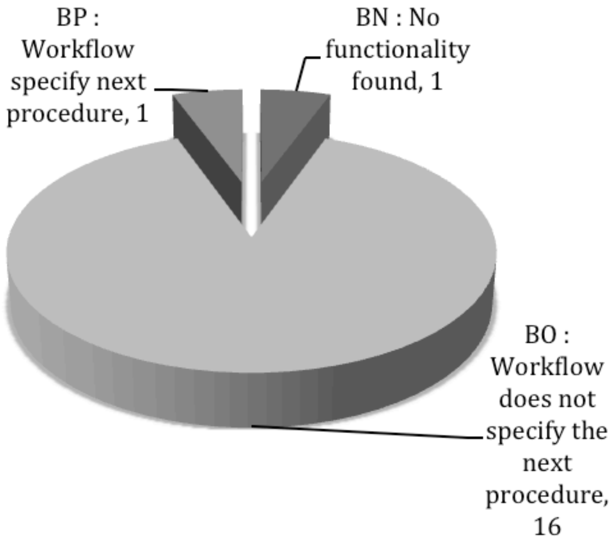
From the visual analysis as presented in Figure 5.1.2 U and from the Jaccard's coefficient test as presented in Table 5.1.2 S none of the categories and sub-categories were found to be similar within the set dissimilarity threshold of 0.95. Therefore one can assume that the observations under the metric of *The workflow can only change when redesigned* none of the sub-categories have a statistical association with each other. These categories have to be measured independently and exist independently as categories within the metric.

<u>Rule 3B Metric:</u> Workflow is specific to identify the next procedure, module and person.

Observations were done to evaluate that the workflow indicates to the user and prompt the user for the next procedure or module. During the coding process in NVivo 10 software, the metric was further categorized into *Workflow specify next procedure*, *Workflow does not specify the next procedure* and *no functionality found* as per Table 4.3.2 M. A total number of eighteen codings were done for the eighteen use cases. No functionality was found within the system for use case MPUC#10.

Workflow is specific to identify the next procedure, module and person: Sixteen use cases were coded as *Workflow does not specify the next procedure,* one use case was coded as *Workflow specify next procedure* and one use case as *No functionality found* as indicated in figure 5.1.2 V.

FIGURE 5.1.2 V
RULE 3B: WORKFLOW IS SPECIFIC TO IDENTIFY THE NEXT PROCEDURE, MODULE AND PERSON



Source: Chalil du Plessis (2014)

Only one use case was coded as *Workflow specify next procedure* with the following remark extracted from the coding:

MPUC#4: Assuming that the Item coverage wizard constitutes the workflow for the process then the workflow identifies the next procedures and modules.

The following remarks were extracted for the cases coded as *Workflow does not specify the next procedure*:

- <u>APUC#1:</u> The workflow is not specified and therefore the next procedure, module or person is not specified.

- APUC#1a: The user is not guided by the workflow to identify the next procedure, module or person in the process of adding a new vendor.
- ARUC#1: The workflow is not automated to indicate or guide the user to the next procedure, module or person.
- ARUC#1a: The workflow does not indicate a next procedure, module or person other than adding and editing the master information. Once the customer has been added to the system several options are available to the user from the menu ribbon to perform editing, transactions or inquiries.
- FAUC#1: The workflow is not designed to indicate the next procedure, mode or users.
- GLUC#1: Since there was no workflow found associated with the data entry process but only to facilitate the approval process. Therefore there is no indication to the user to identify the next procedure, module or person in the workflow.
- MPUC#4: As mentioned earlier, the workflow does not indicate the next procedure. The system also has no indication as to the next module or the next person within the workflow.
- MPUC#5: The workflow does not identify the next procedure, module or person in the system. The workflow is not documented for the user and the help function does not describe the workflow to user but only specific functions and data input required on forms.
- MPUC#6: The workflow does not indicate the next procedure. The system also has no indication as to the next module or the next person within the workflow.

- MPUC#8 & MPUC#9: The workflow was found to be complex with no indications or direction to the user to identify the next procedure, module or person within the workflow.
- PCUC#3: The workflow does not identify the next procedure, module or person.
- PCUC#7-1: No known documentation was found provided by the vendor that describes the workflow in detail. The software also does not contain any indication of the workflow that must be followed. No function was found such as a wizard to assist the user.
- PCUC#7-2: The workflow is not specific to identify the next procedure when the user creates the new production order. There is no indication or direction as to the next step for the user once the production order has been added to the system. Also there is no indication to the user as to where the scheduling can be controlled or that it is required to complete the information for the scheduling. The scheduling is not enforced in the system.
- PIUC#1: There was no workflow found to indicate the next procedure, module or person. The user has several options once the item has been added from the same data entry screen from the menu ribbon including inquiries as well as editing the information on existing items.
- PRUC#1: The workflow does not specify the next procedure, module or person.
- UC#11: The F1 and task recorder functions are not connected within a workflow and do not connect to a next procedure, module or person.

- UC#2: The workflow does not identify the next procedure and the user has to rely on documentation to understand the next step in the procedure. Modules for the integration are not identified neither the next person in the procedure.

The following proximity matrix was calculated using the collected data from Table 4.3.2 M.

TABLE 5.1.2 T
PROXIMITY MATRIX (JACCARD COEFFICIENT) FOR RULE 3B

	BP : Workflow specify next procedure	BN : No functionality found	BO : Workflow does not specify the next procedure
BP : Workflow specify next procedure	**1**		
BN : No functionality found	0.000	**1**	
BO : Workflow does not specify the next procedure	0.000	0.000	**1**

Source: Chalil du Plessis (2014)

From the visual analysis as presented in Figure 5.1.2 V and from the Jaccard's coefficient test as presented in Table 5.1.2 T none of the categories and sub-categories were found to be similar within the set dissimilarity threshold of 0.95. Therefore one can assume that the observations under the metric of *Workflow is specific to identify the next procedure, module and person* none of the sub-categories have a statistical association with each other. These categories have to be measured independently and exist independently as categories within the metric.

Rule 3C Metric: Workflow through the system is simple and specific.

Observations were done to evaluate that the workflow is clear for the user as to what is the next step in the process. The workflow should also have a limited number of steps supported by configuration settings. The functionality that the researcher was looking for during the observations were if the number of steps are limited, are there functions for the user to assist him in the execution of the workflow and does configuration setting assist the user to simplify the workflow. During the coding process in NVivo 10 software, the metric was further categorized into *Specific workflow*, *Workflow complexity*, Workflow existing and *no functionality found* as per Table 4.3.2 K. A total number of forty-five codings were done for the eighteen use cases. No functionality was found within the system for use case MPUC#10.

Specific workflow: Twelve use cases were coded as *Workflow is not specific* and five use cases as *Workflow is specific* as indicated in figure 5.1.2 W.

FIGURE 5.1.2 W
RULE 3C: SPECIFIC WORKFLOW

Source: Chalil du Plessis (2014)

The majority of the use cases were coded as *Workflow is not specific*. Terms used to identify *Workflow is specific* are summarized in Table 5.1.2 U:

TABLE 5.1.2 U **TYPICAL TERMS USED FOR WORKFLOW IS SPECIFIC**	
The workflow was found to be simple and specific. The user has several tab options available with some of them related to the line details and others related to the completion of the sales order.	Once the configuration is complete, the automatic generation of the production Kanban is simple and specific according to the rules set in the configuration.
The workflow was found to be confusing and cumbersome initially however once the user has a clear understanding of the process, it seems to be less complex and specific.	The workflow for entering the production order is simple and contained within the same module. However, it is required as a pre-requisite to have a route set up with the required times in order to be able to schedule the start date.
The workflow is simple and specific for invoking the F1 function and task recorder.	The workflow for adding a new customer to the database was found to be simple consisting only of a few steps.
Source: Chalil du Plessis (2014)	

The following remarks were extracted for the cases coded as *Workflow is not specific*:

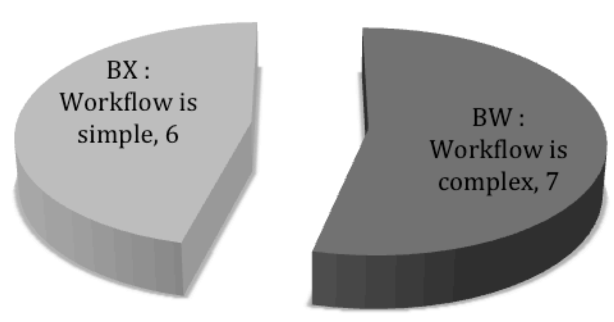
- APUC#1: The workflow is not specified to the user and requires the user to select functions from the menu ribbon and tabs.
- APUC#1a: The initial workflow steps are found to be simple and specific however there is not a formal workflow that will guide the user.
- GLUC#1: The user is not guided in a formal workflow through the process of data entry or the sequence of steps. There is no indication to the user when the data entry process is complete.

- MPUC#4: The workflow is not simple and specific and there is no clear indication or guidance for the user to complete the information in a particular order or process. The Item Coverage Wizard does assist the user to complete and connect the item with the configurations to achieve lead times and inventory levels but is not complete and requires the user to prepare certain pre-requisites. If these have not been configured the wizard cannot be completed until configured in the setup.
- MPUC#5: However, the workflow between the Kanban boards is not specific. Once the user select a Kanban card, the system displays in the menu ribbon a simple workflow of Start and Complete. The workflow that will be associated with the Kanban is defined in the Production control>setup>Lean Manufacturing>Production flows>Activities. A total number of actions recorded for the setup of the Kanban were one-hundred-and-seventy-two steps. The steps were recorded using the build task recorder. Configuration of the Kanban pull from the Sales Order is not simple and specific and rather a tedious process.
- MPUC#6: The workflow is complex to complete and is not indicated in the system. The user has to complete a number of unconnected forms without any indication of the workflow required.
- MPUC#8 & MPUC#9: The workflow was found to be complex and not clearly defined. The workflow spans across several modules and the user is not guided in any way e.g. through messages or info logs to know what the next step is within the workflow.

- PCUC#3: However, information that would be expected to be readily displayed such as current BOM components on hand can only be found through enquiry on Productions Details>BOM menu and will only display on-hand inventory for a single item at a time. This can be extremely cumbersome for the user to check line-by-line should there be a problem in insufficient inventory at the time or if the user needs to check the availability of the components before releasing the production order from the system. The release of the production order can be selected and an error message displayed should the order not be scheduled for production. Typically this will result in a “not enough capacity” error.
- PCUC#7-1: With no clear procedure the workflow is also unclear. The workflow was found to be scattered across several modules as well as having to alternate between modules several times to complete the procedure. There is no clear indication where the procedure should start and where the procedure will end. There is no guidance to the user to indicate if the workflow exists.
- PIUC#1: There was no workflow found to be present for adding a new product to the Product information management module. The workflow was found to be vague to the user as to where to start and when the process is complete. The user seems to be able to stop at any point within the process.
- PRUC#1: The workflow is not obvious for some of the steps in the process of preparing a purchase order. Selecting the option of “all purchase orders” does not imply that the option of preparing a new purchase order is embedded in this option.

Workflow complexity: Six cases were coded as *Workflow is simple* and seven cases as *Workflow is complex* as indicated in Figure 5.1.2 X:

FIGURE 5.1.2 X
RULE 3C: WORKFLOW COMPLEXITY



Source: Chalil du Plessis (2014)

The majority of the use cases were coded as *Workflow is complex*. Terms used to identify *Workflow is simple* are summarized in Table 5.1.2 V:

TABLE 5.1.2 V TYPICAL TERMS USED FOR WORKFLOW COMPLEXITY	
The initial workflow steps are found to be simple and specific however there is not a formal workflow that will guide the user.	The workflow was found to be simple and specific. The user has several tab options available with some of them related to the line details and others related to the completion of the sales order. There is no indication to the user as the direction of the workflow and whether the process has been completed or not.
The workflow for adding a new customer to the database was found to be simple consisting only of a few steps.	Once the configuration is complete, the automatic generation of the production Kanban is simple and specific according to the rules set in the configuration.
The workflow for entering the production order is simple and contained within the same module. However, it is required as a pre-requisite to have a route set up with the required times in order to be able to schedule the start date.	The workflow is simple and specify for invoking the F1 function and task recorder.
Source: Chalil du Plessis (2014)	

The following remarks were extracted for the cases coded as *Workflow is complex*:

- GLUC#1: A formal workflow was not found that was simple and specific.
- MPUC#4: The workflow is not simple and specific and there is no clear indication or guidance for the user to complete the information in a particular order or process. The Item Coverage Wizard does assist the user to complete and connect the item with the configurations to achieve lead times and inventory levels but is not complete and requires the user to prepare certain pre-requisites. If these have not been configured the wizard cannot be completed until configured in the setup.

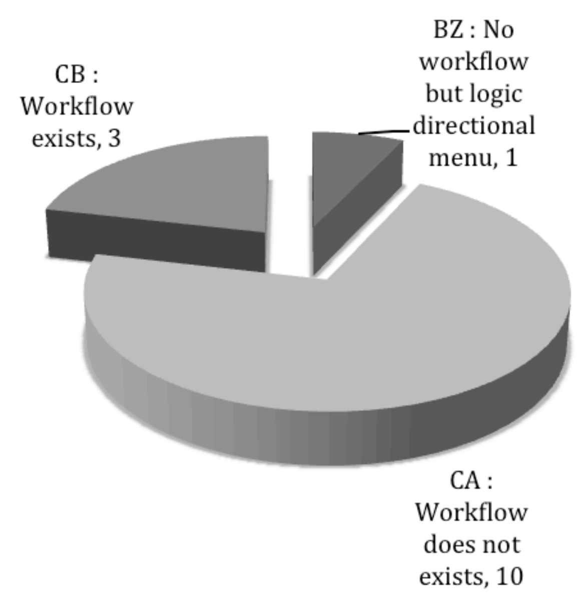
- MPUC#5: However, the workflow between the Kanban boards is not specific. Once the user select a Kanban card, the system displays in the menu ribbon a simple workflow of Start and Complete. The workflow that will be associated with the Kanban is defined in the Production control>setup>Lean Manufacturing>Production flows>Activities. A total number of actions recorded for the setup of the Kanban were one-hundred-and-seventy-two steps. The steps were recorded using the build task recorder. Configuration of the Kanban pull from the Sales Order is not simple and specific and rather a tedious process.
- MPUC#6: The workflow is complex to complete and is not indicated in the system. The user has to complete a number of unconnected forms without any indication of the workflow required.
- MPUC#8 & MPUC#9: The workflow was found to be complex and not clearly defined. The workflow spans across several modules and the user is not guided in any way e.g. through messages or info logs to know what the next step is within the workflow.
- PCUC#3: However, information that would be expected to be readily displayed such as current BOM components on hand can only be found through enquiry on Productions Details>BOM menu and will only display on-hand inventory for a single item at a time. This can be extremely cumbersome for the user to check line-by-line should there be a problem in insufficient inventory a the time or if the user needs to check the availability of the components before releasing the production order from the system. The release of the production order can

be selected and an error message displayed should the order not be scheduled for production. Typically this will result in a “not enough capacity” error.

- UC#2: The workflow to achieve integration between e.g. Excel and Dynamics AX was found to be a complex procedure with a number of configurations to be done within Dynamics AX. Within Excel the procedure requires in-depth knowledge of the tables and attributes to be able to achieve a simple update between Excel and Dynamics AX.

Workflow existing: Ten use cases were coded as *Workflow does not exists,* Three use cases were coded as *Workflow existing* and one use case as *No workflow logic directional menu* as indicated in figure 5.1.2 Y:

FIGURE 5.1.2 Y
RULE 3C: WORKFLOW EXISTING



Source: Chalil du Plessis (2014)

The majority of the use cases were coded as *Workflow does not exist*. Terms used to identify *Workflow exists* are summarized in Table 5.1.2 W:

TABLE 5.1.2 W TYPICAL TERMS USED FOR WORKFLOW EXISTS	
The user is guided somewhat by menu options which will only become active once a preceding step was completed successfully by the system e.g. Process>estimate.	The workflow for entering the production order is simple and contained within the same module. However, it is required as a pre-requisite to have a route set up with the required times in order to be able to schedule the start date.
The workflow is simple and specify for invoking the F1 function and task recorder.	
Source: Chalil du Plessis (2014)	

The following remarks were extracted for the cases coded as *Workflow does not exist*:

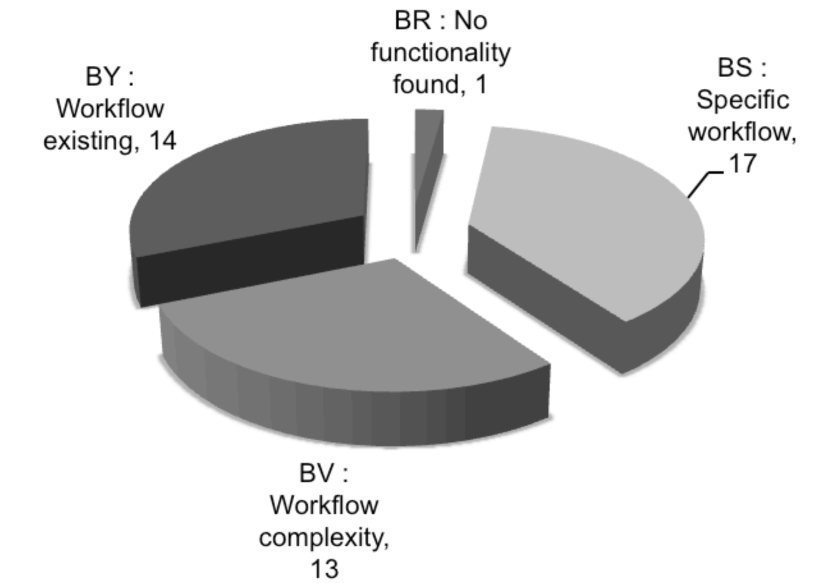
- APUC#1: There was no automated workflow found for entering an invoice for a vendor.
- ARUC#1: The user has several tab options available with some of them related to the line details and others related to the completion of the sales order.
- ARUC#1a: There is no formal workflow for adding a new customer to the database.
- FAUC#1: There was no workflow found to be associated with Fixed Assets that will guide the user through the process of adding an asset to the database.

- GLUC#1: A formal workflow was not found that was simple and specific.
- MPUC#4: The workflow is not simple and specific and there is no clear indication or guidance for the user to complete the information in a particular order or process. The Item Coverage Wizard does assist the user to complete and connect the item with the configurations to achieve lead times and inventory levels but is not complete and requires the user to prepare certain pre-requisites. If these have not been configured the wizard cannot be completed until configured in the setup.
- MPUC#6: The workflow is complex to complete and is not indicated in the system. The user has to complete a number of unconnected forms without any indication of the workflow required.
- PCUC#7-1: With no clear procedure the workflow is also unclear. The workflow was found to be scattered across several modules as well as having to alternate between modules several times to complete the procedure. There is no clear indication where the procedure should start and where the procedure will end. There is no guidance to the user to indicate if the workflow exists.
- PIUC#1: There was no workflow found to be present for adding a new product in the Product information management module. The workflow was found to be vague to the user as to where to start and when the process is complete. The user seems to be able to stop at any point within the process.
- PRUC#1: The workflow is not obvious for some of the steps in the process of preparing a purchase order. Selecting the option of “all purchase orders” does

not imply that the option of preparing a new purchase order is embedded in this option.

The metric *Workflow through the system is simple and specific* is summarized in Figure 5.1.2 Z for the total of eighteen use cases, seventeen use cases were evaluated for *Specific workflow,* thirteen use cases for *Workflow complexity*, fourteen for *Workflow existing* and one case where *No functionality* was found to evaluate.

FIGURE 5.1.2 Z
RULE 3C: WORKFLOW THROUGH THE SYSTEM IS SIMPLE AND SPECIFIC



Source: Chalil du Plessis (2014)

The following proximity matrix was calculated using the collected data from Table 4.3.2 K.

TABLE 5.1.2 X
PROXIMITY MATRIX (JACCARD COEFFICIENT) FOR RULE 3C

	BU : Workflow is specific	CB : Workflow exists	BX : Workflow is simple	BR : No functionality found	BW : Workflow is complex	BZ : No workflow but logic directional menu	BT : Workflow is not specific	CA : Workflow does not exists
BU : Workflow is specific	**1**							
CB : Workflow exists	0.600	**1**						
BX : Workflow is simple	0.571	0.286	**1**					
BR : No functionality found	0.000	0.000	0.000	**1**				
BW : Workflow is complex	0.200	0.111	0.083	0.000	**1**			
BZ : No workflow but logic directional menu	0.000	0.000	0.000	0.000	0.000	**1**		
BT : Workflow is not specific	0.133	0.071	0.200	0.000	0.462	0.083	**1**	
CA : Workflow does not exists	0.071	0.000	0.143	0.000	0.214	0.100	0.571	**1**

Source: Chalil du Plessis (2014)

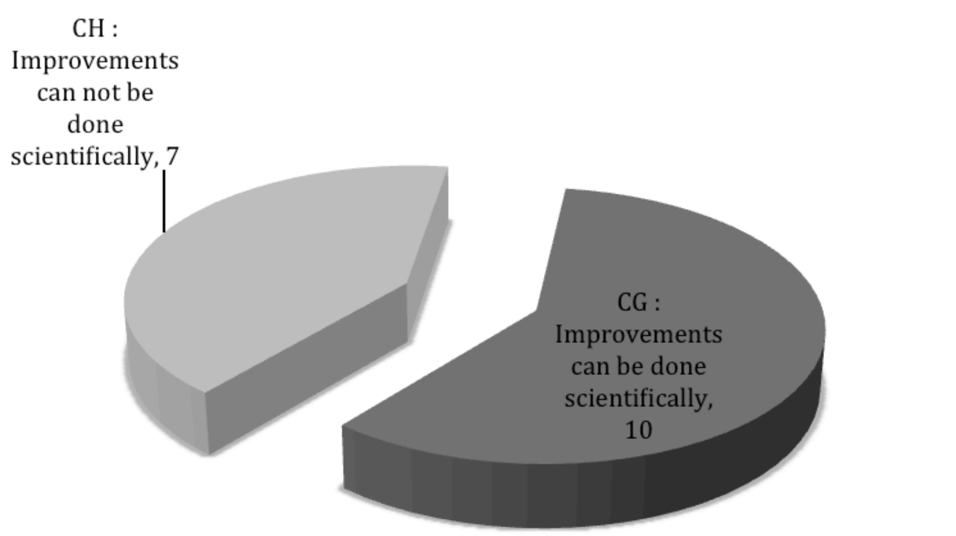
From the visual analysis as presented in Figure 5.1.2 W, Figure 5.1.2 X, Figure 5.1.2 Y, Figure 5.1.2 Z and from the Jaccard's coefficient test as presented in Table 5.1.2 X none of the categories and sub-categories were found to be similar within the set dissimilarity threshold of 0.95. Therefore one can assume that the observations for the metric of *Workflow through the system is simple and specific,* none of the sub-categories have a statistical association with each other. These categories have to be measured independently and exist independently as categories within the metric.

Rule 4: Any improvement must be made in accordance with the scientific method, under guidance of a teacher, at the lowest possible level in the organization.

Rule 4A Metric: Improvements are made scientifically and according to Rules 1- 3 for example changing the software configuration settings of the software.
Observations were done to evaluate when improvements are identified, a hypothesis should be tested with experimentation to test if changes will improve the system. The functionality that the researcher was looking for during the observations is to be able to make improvements in the software and specifically by a user. The quantitative user cases already provided the testing of these functionalities as described in the previous section 5.1.1. During the coding process in NVivo 10 software, the metric was further categorized into *User improvement*, *Scientific method* and *no functionality found* as per Table 4.3.2 O. A total number of thirty-four codings were done for the eighteen use cases. No functionality was found within the system for use case MPUC#10.

Scientific method: Ten use cases were coded as *Improvements can be done scientifically* and seven use cases as *Improvements cannot be done scientifically* as indicated in figure 5.1.2 AA:

FIGURE 5.1.2 AA
RULE 4A: SCIENTIFIC METHOD



Source: Chalil du Plessis (2014)

The majority of the use cases were found to have the functionality for improvements to be done scientifically. Terms used to identify *Improvements can be done scientifically* are summarized in Table 5 1.2 Y:

TABLE 5.1.2 Y TYPICAL TERMS USED FOR IMPROVEMENTS CAN BE DONE SCIENTIFICALLY	
Improvements can be made using the personalization option in the software and can be done with the guidance of a teacher or supervisor in order to improve the process.	Improvements can be made using the personalization function within the Dynamics AX software. These personalization are user specific and can be saved and loaded when required for testing purposes and verified by a teacher or supervisor to ensure that the process was improved.
Limited improvements can be made using the personalization option that is available to users. These can be done under supervision of another user and is applicable only for the user and not all users.	The user through the personalization function can do improvements. The personalization function is user specific and can be done with the guidance from a teacher in order to improve the process.
Improvements were made using the personalization function within the Dynamics AX 2012 system. However, these improvements can be made in accordance to a teacher student principle taking in considerations the previously mentioned principles.	Improvements were done using the personalization function. The personalization can be done per user and reviewed by a teacher or supervisor to ensure that the improvement is done in a scientific way through testing.
Changes can be mode to the input forms under the setup option for Coverage Groups and Minimum/Maximum keys and item setup. Within the wizard no changes can be done using the personalization option. This is locked for the user. Any user providing he has the necessary authorizations can do improvements or changes. The personalization changes can be done by a user in the presence of a teacher to guide the user in use a scientific method using the Save, Load and Reset options. An already tested personalization can also be retrieve from another user.	Improvements to the data entry forms can be done through the customization option as described in Use case # 1.
Improvements can be done using the personalization option hiding fields not required. The data entry can be measured before and after improvement under the guidance of a teacher to ensure that fields are not removed that will have a negative impact on the process or transaction.	The user can make changes to the data entry form using a Personalization function. This function allows the user to switch on and off visibility, skip, edit field and move the position of the field. Through using a use case analysis and measuring the time for the entry, it might be possible to use this function to improve the time that is used to process the transaction. A department head or supervisor can teach and assist with this function to ensure that users are applying changes correctly and not removing fields critical for the transaction and for the organization.
Source: Chalil du Plessis (2014)	

The following remarks were extracted for the cases coded as *Improvements cannot be done scientifically*:

- MPUC #5: The user can do changes to the configuration for the Kanban pull from the Sales Orders provided that the necessary authorization has been given to the user. It is only when setting up the production flows activities that the system allows to prepare a draft that can be activated later. This does not necessary mean that the configuration change was done as an improvement based on a scientifically based method or under the guidance of a teacher. There was no know functionality found or tested that would assist in this principle. Volkmann & Hietala (2011) explains that through duplicating a particular production flow, improvements can be made on the flow and activated once the suitable flow has been defined (Volkmann & Hietala, 2011, P. 9). Furthermore, date-effective versioning of the production flows supports continuous improvement (Volkmann & Hietala, 2011, p. 48). However, this supports tracking the changes and allowing only one version to be active. There is not any functionality to indicate or measure e.g. Improvement or that the changes are done in a scientific way such as stating a hypothesis for improvement.
- MPUC #6: The user according to the level of authorization can make Configuration changes only. The production flow within the cell can be prepared as a draft that can be activated by an authorized user once reviewed. This does not necessary mean that the configuration change was done as an

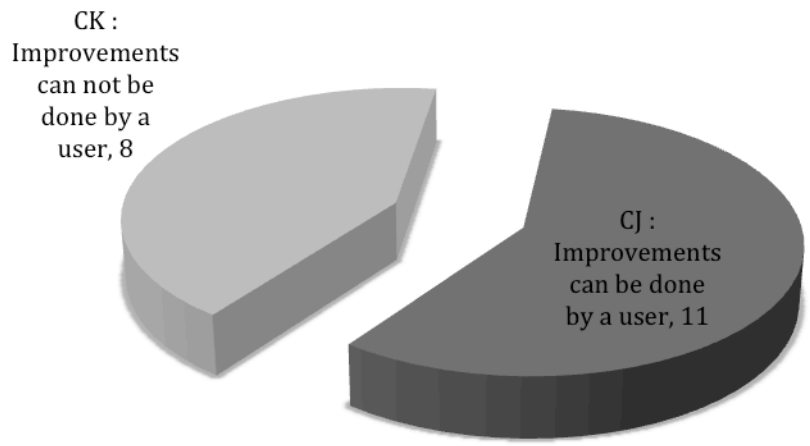
improvement based on a scientifically based method or under the guidance of a teacher. There was no know functionality found or tested that would assist in this principle.

- MPUC#8 & MPUC#9: The procedures and workflow is predefined by the software vendor and was found to have no scope for improvement to the procedures. Improvements to the data entry forms can be done through the customization option as described in Use case # 1.
- PCUC#7-1: Any user can add the configurations provided the user has the necessary authorization in the system. There are points of approval and activation for a few of the procedures such as cost category price. However, there was no procedure or workflow found provided by the vendor that could support this principle.
- PCUC#7-2: The process of scheduling and the available methods have been predefined in the system and cannot be changed.
- UC#11: The F1 function and task recorder are build in functions within the system without any options available to make improvements by users or administrators. Improvements can only be made to these systems by the vendor in the original source code.
- UC#2: The integration between Excel and Dynamics AX is a fixed procedure provided by the Dynamics AX Add-in service in Excel. The service is hard coded and cannot adapted to simplify or improve the process. The service is an out-of-the-box functionality provided by Microsoft Corporation and any changes

to be made to the coding can only be done by the vendor. There are not any configuration settings that will influence the process.

User improvements: Eleven use cases were coded as *Improvements can be done by a user* and eight use cases as *Improvements cannot be done by a user* as indicated in figure 5.1.2AB:

FIGURE 5.1.2 AB
RULE 4A: USER IMPROVEMENTS



Source: Chalil du Plessis (2014)

The majority of the use cases were coded as *Improvements can be done by a user*. Terms used to identify *Workflow exists* are summarized in Table 5.1.2 Z:

TABLE 5.1.2 Z TYPICAL TERMS USED FOR IMPROVEMENTS CAN BE DONE BY A USER	
Improvements can be made using the personalization option in the software and can be done with the guidance of a teacher or supervisor in order to improve the process.	Improvements can be made using the personalization function within the Dynamics AX software. These personalization are user specific and can be saved and loaded when required for testing purposes and verified by a teacher or supervisor to ensure that the process was improved.
Limited improvements can be made using the personalization option that is available to users. These can be done under supervision of another user and is applicable only for the user and not all users.	The user through the personalization function can do improvements. The personalization function is user specific and can be done with the guidance from a teacher in order to improve the process.
Improvements were made using the personalization function within the Dynamics AX 2012 system. However, these improvements can be made in accordance to a teacher student principle taking in considerations the previously mentioned principles.	Improvements were done using the personalization function. The personalization can be done per user and reviewed by a teacher or supervisor to ensure that the improvement is done in a scientific way through testing.
Changes can be made to the input forms under the setup option for Coverage Groups and Minimum/Maximum keys and item setup. Within the wizard no changes can be done using the personalization option. This is locked for the user. Any user providing he has the necessary authorizations can do improvements or changes. The personalization changes can be done by a user in the presence of a teacher to guide the user in use a scientific method using the Save, Load and Reset options. An already tested personalization can also be retrieve from another user.	The procedures and workflow is predefined by the software vendor and was found to have no scope for improvement to the procedures. Improvements to the data entry forms can be done through the customization option as described in Use case # 1.
Improvements can be done using the personalization option hiding fields not required. The data entry can be measured before and after improvement under the guidance of a teacher to ensure that fields are not removed that will have a negative impact on the process or transaction.	The improvement applied in this use case was through the use of an alternative process to add a new item. The process is already predefined by the vendor and cannot be changed by the user. The improvement can be supervised or guided by a teacher to indicate which process would be the most suitable.
The user can make changes to the data entry form using a Personalization function. This function allows the user to switch on and off visibility, skip, edit field and move the position of the field. Through using a use case analysis and measuring the time for the entry, it might be possible to use this function to improve the time that is used to process the transaction. A department head or supervisor can teach and assist with this function to ensure that users are applying changes correctly and not removing fields critical for the transaction and for the organization.	
Source: Chalil du Plessis (2014)	

The following remarks were extracted for the cases coded as *Improvements cannot be done by a user*:

- MPUC #5: The user can do changes to the configuration for the Kanban pull from the Sales Orders provided that the necessary authorization has been given to the user. It is only when setting up the production flows activities that the system allows to prepare a draft that can be activated later. This does not necessary mean that the configuration change was done as an improvement based on a scientifically based method or under the guidance of a teacher. There was no know functionality found or tested that would assist in this principle. Volkmann & Hietala (2011) explains that through duplicating a particular production flow, improvements can be made on the flow and activated once the suitable flow has been defined (Volkmann & Hietala, 2011, P. 9). Furthermore, date-effective versioning of the production flows supports continuous improvement (Volkmann & Hietala, 2011, p. 48). However, this supports tracking the changes and allowing only one version to be active. There is not any functionality to indicate or measure e.g. Improvement or that the changes are done in a scientific way such as stating a hypothesis for improvement.
- MPUC #6: The user according to the level of authorization can make configuration changes only. The production flow within the cell can be prepared as a draft that can be activated by an authorized user once reviewed. This does not necessary mean that the configuration change was done as an

improvement based on a scientifically based method or under the guidance of a teacher. There was no know functionality found or tested that would assist in this principle.

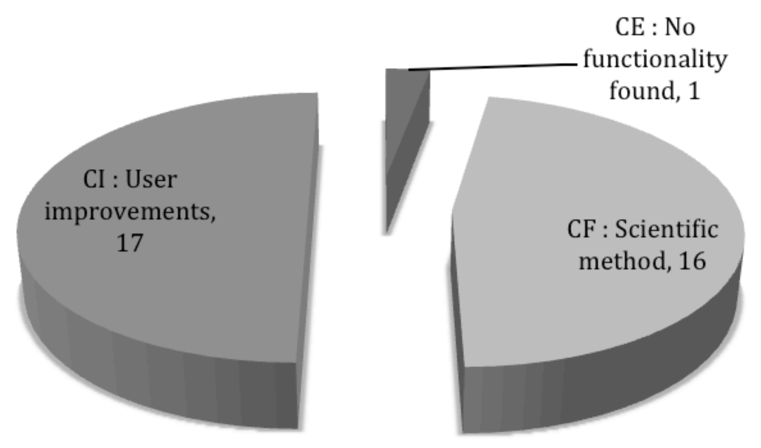
- MPUC#8 & MPUC#9: The procedures and workflow is predefined by the software vendor and was found to have no scope for improvement to the procedures. Improvements to the data entry forms can be done through the customization option as described in Use case # 1.
- PCUC#7-1: Any user can add the configurations provided the user has the necessary authorization in the system. There are points of approval and activation for a few of the procedures such as cost category price. However, there was no procedure or workflow found provided by the vendor that could support this principle.
- PCUC#7-2: The process of scheduling and the available methods have been predefined in the system and cannot be changed.
- PIUC#1: The improvement applied in this use case was through the use of an alternative process to add a new item. The process is already predefined by the vendor and cannot be changed by the user. The alternative method could be tested for improvement in data entry time for analysis. Therefore improvements can be done using a scientific method but limited to the processes available in the system. The improvement can be supervised or guided by a teacher to indicate which process would be the most suitable.
- UC#11: The F1 function and task recorder are build in functions within the system without any options available to make improvements by users or

administrators. Improvements can only be made to these systems by the vendor in the original source code.

- UC#2: The integration between Excel and Dynamics AX is a fixed procedure provided by the Dynamics AX Add-in service in Excel. The service is hard coded and cannot adapted to simplify or improve the process. The service is an out-of-the-box functionality provided by Microsoft Corporation and any changes to be made to the coding can only be done by the vendor. There are not any configuration settings that will influence the process.

The metric A*ny improvement must be made in accordance with the scientific method, under guidance of a teacher, at the lowest possible level in the organization* is summarized in Figure 5.1.2 AC for the total of eighteen use cases, sixteen use cases were evaluated for *Scientific method,* seventeen use cases for *User improvements* and one case where *No functionality* was found to evaluate.

FIGURE 5.1.2 AC
RULE 4A: ANY IMPROVEMENT MUST BE MADE IN ACCORDANCE WITH THE SCIENTIFIC METHOD, UNDER GUIDANCE OF A TEACHER, AT THE LOWEST POSSIBLE LEVEL IN THE ORGANIZATION



Source: Chalil du Plessis (2014)

The following proximity matrix was calculated using the collected data from Table 4.3.2 O:

TABLE 5.1.2 AA
PROXIMITY MATRIX (JACCARD COEFFICIENT) FOR RULE 4A

	CK : Improvements cannot be done by a user	CH : Improvements cannot be done scientifically	CE : No functionality found	CJ : Improvements can be done by a user	CG : Improvements can be done scientifically
CK : Improvements cannot be done by a user	**1**				
CH : Improvements cannot be done scientifically	0.875	**1**			
CE : No functionality found	0.000	0.000	**1**		
CJ : Improvements can be done by a user	0.118	0.059	0.000	**1**	
CG : Improvements can be done scientifically	0.059	0.063	0.000	0.909	**1**

Source: Chalil du Plessis (2014)

From the visual analysis as presented in Figure 5.1.2 AB and Figure 5.1.2 AC and from the Jaccard's coefficient test as presented in Table 5.1.2 AA none of the categories and sub-categories were found to be similar within the set dissimilarity threshold of 0.95. Therefore one can assume that the observations under the metric of *Any improvement must be made in accordance with the scientific method, under guidance of a teacher, at the lowest possible level in the organization* none of the sub-categories have a statistical association with each other. These categories have to be measured independently and exist independently as categories within the metric.

5.2 ANALYSIS

Answering the main research question as restated in the beginning of this chapter requires the findings as identified in the previous section to be tested against the main null hypothesis and the alternative hypothesis. The null hypothesis that was developed to answer the main research question is presented again as follows:

> H0: ERP systems have not been designed to support the principles of Lean operations.
>
> H1: Vendors have already designed ERP modules to support the principles of Lean operations and therefore ERP modules can be developed based on Lean principles.

In the previous Chapter Four and Section 5.1 of this chapter the research data has been presented in detail. In this section the researcher will discuss the findings as well as test the findings and accept the null hypothesis H0 or reject the stated null hypothesis in favor of the alternative hypothesis H1. The following analysis considers the relevance of the research to examine and discover the differences between the Lean principles and ERP applied principles as set out in Section 1.2. Furthermore, the following analysis will also validate the conceptual framework.

Analysis of Rule 1: All work must be highly specific as to content, sequence, timing and outcome.

Table 5.2 A summarizes the findings whether to accept or reject the null hypothesis from the results in previous section for Rule 1. For seven of the twelve categories the null hypothesis should be accepted therefore the research for Rule 1 indicates that ERP systems have not been designed to support the principles of Lean operations.

TABLE 5.2 A HYPOTHESIS RESULTS METRICS AND CATEGORIES FOR RULE 1		
Metric	Category	Accept or Reject H0
A. Information to be entered is clear and specific	Information Clarity	Reject
	Specific Information	Reject
	No functionality found	Accept
B. Procedures to perform a task are specified	Specific procedures	Accept
	User guidance	Accept
	No functionality found	Accept
C. Sequence of data entry steps are clear	Sequence	Accept
	Clarity	Accept
	No functionality found	Accept
D. The time to perform a task in the software can be measured and optimized	Time measurement	Reject
	Time optimization	Reject
	No functionality found	Reject
Source: Chalil du Plessis (2014)		

Analysis of Rule 2: Every customer-supplier connection must be direct with a yes-or-no method to send requests and receive responses.

Table 5.2 B summarizes the findings whether to accept or reject the null hypothesis from the results in previous section for Rule 2. For six of the eight categories the null hypothesis should be rejected in favor of the alternative hypothesis therefore the research for Rule 2 indicates that vendors have already designed ERP modules to support the principles of Lean operations and therefore ERP modules can be developed based on Lean principles.

TABLE 5.2 B HYPOTHESIS RESULTS METRICS AND CATEGORIES FOR RULE 2		
Metric	Category	Accept or Reject H0
A. Connecting processes or modules are direct and standardized	Connectivity	Reject
	Processes	Reject
	No functionality found	Accept
B. Information is evaluated as correct before committed to the database	Information evaluated as correct	Reject
	No functionality found	Reject
C. Time between each connecting process can be measured and optimized	Time measurement	Reject
	Time optimization	Reject
	No functionality found	Accept
Source: Chalil du Plessis (2014)		

<u>Analysis of Rule 3:</u> The pathway for every product and service must be simple and direct.

Table 5.2 C summarizes the findings whether to accept or reject the null hypothesis from the results in previous section for Rule 3. For all of the eight categories the null hypothesis should be accepted therefore the research for Rule 3 indicates that ERP systems have not been designed to support the principles of Lean operations.

TABLE 5.2 C HYPOTHESIS RESULTS METRICS AND CATEGORIES FOR RULE 3		
Metric	Category	Accept or Reject H0
A. The workflow can only change when redesigned	Workflow can be redesigned	Accept
	No functionality found	Accept
B. Workflow is specific to identify the next procedure, module and person	Workflow specify next procedure	Accept
	No functionality found	Accept
C. Workflow through the system is simple and specific	Specific Workflow	Accept
	Workflow complexity	Accept
	Workflow existing	Accept
	No functionality found	Accept
Source: Chalil du Plessis (2014)		

<u>Analysis of Rule 4:</u> Any improvement must be made in accordance with the scientific method, under guidance of a teacher, at the lowest possible level in the organization.

Table 5.2 D summarizes the findings on whether to accept or reject the null hypothesis from the results in previous section for Rule 4. For two of the three categories the null hypothesis should be rejected in favor of the alternative hypothesis therefore the research for Rule 4 indicates that vendors have already designed ERP modules to support the principles of Lean operations and therefore ERP modules can be developed based on Lean principles.

TABLE 5.2 D HYPOTHESIS RESULTS METRICS AND CATEGORIES FOR RULE 4		
Metric	Category	Accept or Reject H0
Improvements are made scientifically and according to Rules 1- 3 for example changing the software	Scientific method	Reject
	User improvements	Reject
	No functionality found	Accept
Source: Chalil du Plessis (2014)		

Table 5.2 E summarizes the findings for the four metric for Lean modules as initially set out in Chapter Three, Table 3.0 and the summarized findings as stated in the above tables:

TABLE 5.2 E LEAN PRINCIPLE OF OPERATIONS - SUMMARY OF METRICS FOR A LEAN MODULE - ACCEPT OR REJECT NULL HYPOTHESIS		
RULE 1	All work must be highly specified as to content, sequence, timing and outcome.	Accept H0
RULE 2	Every customer-supplier connection must be direct with a yes-or-no way to send requests and receive responses.	Reject H0
RULE 3	The pathway for every product and service must be simple and direct	Accept H0
RULE 4	Any improvement must be made in accordance with the scientific method, under guidance of a teacher, at the lowest possible level in the organization	Reject H0
Source: Chalil du Plessis (2014)		

The research therefore indicates for Rule 1 and Rule 3 the null hypothesis was predominantly accepted and for Rule 2 and Rule 4 the null hypothesis was predominantly rejected. If we consider all the individual categories for the total of thirty-one categories, the null hypothesis was rejected only for thirteen categories or forty-two percent of the total number of categories.

5.3 DISCUSSION

The objective of the research is to attempt answering the main research question stating to propose an ERP systems framework that will incorporate Lean principles of operations. The building blocks to determine the elements of the ERP systems framework is rooted in a research design for systems development consisting of gap analysis, requirement analysis, use cases, experimentation and observation furthermore adapting the research design as a framework to incorporate testing the Lean principles of operations as proposed by Spear & Bowen (1999). The principles of Lean Operations were included in the framework with two objectives in mind for this research. Firstly, using the four rules or principles as a metric to measure empirically the existence of these principles in a current ERP system therefore testing if vendors of of-the-shelf ERP systems have incorporated all or some of these principles either by design or simply by result of the many years of ERP systems development and secondly, refining the metrics through active research within an existing ERP system to complete the framework to measure the existence of the Lean principles of operations.

Spear and Bowen spent four years researching their article *Decoding the DNA of the Toyota Production System* (1999), carefully observing every part of the production system to finally formulate the four rules or principles of Lean Operations that was used during this research to determine the "leanness" of a typical ERP system. Powell (2012) remarked that as a result of his research there is noticeably a need and a clear trend by ERP vendors to attempt to incorporate the ERP and Lean philosophies as a competitive advantage. However Powell recognizes and suggests that this "leanness" needs to be investigated and calls for research in order to quantify the effects of this approach by ERP vendors. This research uniquely proposes a methodology to investigated and quantify the "leanness" or Lean operations in an ERP system. The following discussion of this research illustrates how the research attempted to quantify the principles of Lean operations within the Lean ERP Metrics Framework (LEMF) and the findings in terms of the null hypothesis and the research question.

In order to illustrate Rule 1, Spear & Bowen (1999) give a vivid example of how people work on the assembly lines at Toyota to install a car seat. For example the exact sequence of tightening the bolts is specified, how many turns for each bolt and the torque on each bolt is specified. Any deviation from these specifications would allow for variations and consequently mistakes, poor quality and ultimately rework resulting in waste. The research indicated that it is possible to apply the same rule as a metric to measure if the principles of lean operations exist within an ERP system. Using the proposed metrics the research indicated that the ERP system is designed to ensure that information entered to the system is clear and specific based on the results for Rule 1A. A possible explanation would be that ERP systems uses databases to store transactions and by its very nature requires information to be specific. As indicated in Table 5.1.2 AA Table 5.1.2 BB some of the methods used in software development to ensure that information is clear and specific is the use of functions such as data field labels in conjunction with lookups, drop down lists and master databases for example customer records. Although the null hypothesis is not supported for Rule 1A, there are still gaps that need to be addressed by ERP vendors such as indicating how a process will be affected if certain data fields are not completed, using of common user interface names when referencing processes and indicating measures of values as part of data field labels.

The research results for Rule 1B, Procedures to perform a task are specified, indicates acceptance of the null hypothesis. There was no statistical association found between where users are not guided through procedures and procedure not specific. The remarks from the use cases highlight several possible reasons why the null hypothesis was accepted for procedures not specific. Procedures were found to be vague, non-specific, sequence of procedures are unclear and the beginning and end of a procedure is not indicated to the user. In addition the null hypothesis was also accepted for User guidance. In twelve of sixteen cases the use cases were coded that the user is not guided thought the procedure. Cooprider et al. (2010) describe user guidance as a property of their Collaboration model of ERP use and the empirical evidence from their study confirms the findings of this research. Scholtz, Calitz, & Cilliers (2013) also reported similar results where negative results were reported on user guidance provided within another ERP system SYSPRO. Scholtz et al. (2013) also linked user guidance to learnability of an ERP system. There seems to be a lack of design in this regard by ERP vendors and therefore this functionality requires to be improved should ERP vendors want to build systems with Lean principles.

The research result for Rule 1C indicate the acceptance of the null hypothesis. For the categories that were coded namely Clarity of steps and Sequence of steps the null hypothesis was accepted for both. The proximity matrix also did not indicate a statistical association between the two categories. Fourteen out of the seventeen of the cases were coded as steps not clear in the data entry steps and fifteen out of seventeen codings were where the next steps are not indicated with two coding where more than one sequence was available. It was rather surprising that the for a renown ERP system where one of the primary functions of the system is data entry, the functionality was found to be very weak in terms of data entry sequence. In order for the ERP system to be able to support Lean principles considerable improvements have to be made in this regards by the ERP vendors.

For metric Rule 1D and Rule 2C the research results indicated the support of the alternative hypothesis therefore indicating that ERP vendors have developed systems with functionality where time can be measured and optimized. Cooprider et al. (2010) also refer to the optimization of data entry as mutual responsiveness in the proposed

Collaboration Model for ERP User-System Interaction where they propose system processes change based on the repetitive user actions and behavior for example to remove fields that are not used by the user. One of the participants in their study remarked that fields that are not used should be removed and found it is a waste of time. The quantitative research that was done during this research for the use cases illustrated that the ERP system can support this functionality and ERP systems with their current design can most likely support Lean principles in terms of reducing waste from a process.

Rule 2 as described by Spear and Bowen (1999) as a direct, unambiguous connection between customer and supplier. Translating this rule to systems require processes to be connected in the same way humans are connected in a client-supplier relationship. A request from one process as a customer and a process providing a service as a supplier would form the client-supplier relationship. The research findings for Rule 2A supports the alternative hypothesis indicating the majority of processes and modules were found to be connected directly within the ERP system in a standardized way. ERP systems have already been designed with packaged integrations and these integrations support Lean (Cottyn, Van Landeghem, Stockman, & Derammelaere, 2011; Shaw, Lengyel, & Ferre, 2004). Even though the alternative hypothesis is being supported by the outcome of the research the comments for the cases coded as Processes not connected directly does point to several areas where the provided connected processes by the ERP vendors are perhaps not as successful as expected. Not all ERP systems are successful in providing connected processes between modules and users are forced to use the modules in a decoupled mode relying on other methods such as spreadsheets, e-mail and sub-systems (Steger-Jensen & Hvolby, 2008). External supplier connected processes were not evaluated during this study and was not considered as part of the research scope, however the internal processes were evaluated and gaps were still found where connectivity between modules and processes has been done only on the basic level such as master data field population through connected master data tables from another module e.g. Customer code. Procedures were found to spread across several modules as loose standing islands in the case of PCUC#7-1. Vendors of ERP systems will have to consider redesigning integrated processes and procedures for a stronger evaluation of this metric for Lean operations.

Spear and Bowen (1999) explains an underlying requirement for Rule 2 information to be identified correctly within the customer and supplier process referring to the information contained on a Kanban card typically used in a Lean manufacturing environment. The Kanban card references the specific part number, quantities and location of the part or the supplier. The metric for the subcategory Rule 2B attempt to measure whether information is correct before it is being committed to the database as it is being passed through connected processes in a similar way than a Kanban card is passed through the production line. The research findings for Rule 2B rejects the null hypothesis in support of the alternative hypothesis. Within all of the sixteen use cases evaluated the research found that the ERP system contain the functionality to evaluate information to be correct. Four of the cases were found with additional automatic evaluation of data and one case where the system has a function that the user has an option to validate data after the transition was completed. However, the system would generate system logs that are mostly single statements logs when a problem is encountered with no explanation or direction to correct the problem. Resolving a problem without a clear guidance or reason to the user could be considered as a weakness in terms of Lean principles and potentially could be a form of waste. In some cases it was found that the user has to delete the transaction and re-enter the transaction to correct the problem. A further problem encountered was that information would be identified only at the end of the transaction or during the update process. This also could potentially be an area of waste where the complete transaction might have to be reworked or searching for the mistake within the transaction.

Rule 3 as defined by Spear and Bowen (1999) requires the pathway for every product to be simple and direct. For the purpose of the research the pathway was considered as the workflow of the selected use cases and the product effectively a transaction and its related information. The definition of a workflow for the purpose of research is the steps that the user has to select functions in the systems to complete a particular task. Spear and Bowen further mention two more requirements for rule three namely that the pathway should only change when specifically redesigned and that the goods or services do not flow to the next available person or machine but to a specific person or machine. For the purpose of measuring the Lean principles in ERP specific person or machines are referenced as procedures, modules and person.

The research findings for Rule 3A, The workflow can only change when redesigned, support the null hypothesis of ERP systems have not been designed to support the principles of Lean operations. From the eighteen use cases, seventeen of the uses cases were coded as Workflow cannot be redesigned and one use cases was coded as No functionality found. From the remarks for the use cases supporting the null hypothesis, the comments can be generalized as workflow have been predefined by the vendor and cannot be redesigned by the user. ERP vendors typically design their systems to contain best practices from their experience with numerous clients and provides a form of standardization, however best practices are not necessary a benefit to the organization if these cannot be adapted in a Lean environment. Halgeri et al. (2010) attempt to compromise between ERP and Lean on the use of best practices referring to Lean as one of the best practices however does not mention standardized workflows as a benefit for Lean.

Rule 3B attempts to measure the workflow to be specific to identify the next procedure, module and person. The research supports the null hypothesis that ERP systems have not been designed to support the principles of Lean operations. From the eighteen use cases sixteen use cases were coded as Workflow does not specify the next procedure (module and person). The only evidence found that the system has a workflow that will specify the next procedure and module is for MPUC#4. The workflow consists of an automated wizard that will assist the user in complete the data entry process to complete item coverage. Considering the research result for

Rule 1C measuring Sequence of data entry steps are clear, where the majority of use cases were found to not have clear steps, it is not surprising that Rule 3B would result as accepting the null hypothesis as the majority of the use cases do not have a workflow that is specific to specify the next procedure. A workflow as per the research definition consists of a number of steps and if the steps are not clearly defined, the workflow does not exist. The lack of a specific workflow in ERP systems have also been found in previous research by Scholtz et al. (2013) as a problem for the learnability of an ERP system and a problem in terms of usability (Cooprider et al., 2010; Kanellou & Spathis, 2013). This clearly is still a weakness in the functional design of the current ERP systems in term of the Lean principles of operations framework. It seems that an improvement in this area will not only benefit Lean operations and ERP but will also contribute to the ERP systems in terms of usability and learnability as remarked by Scholtz et al. (2013), Cooprider et al. (2010) and Kanellou & Spathis (2013).

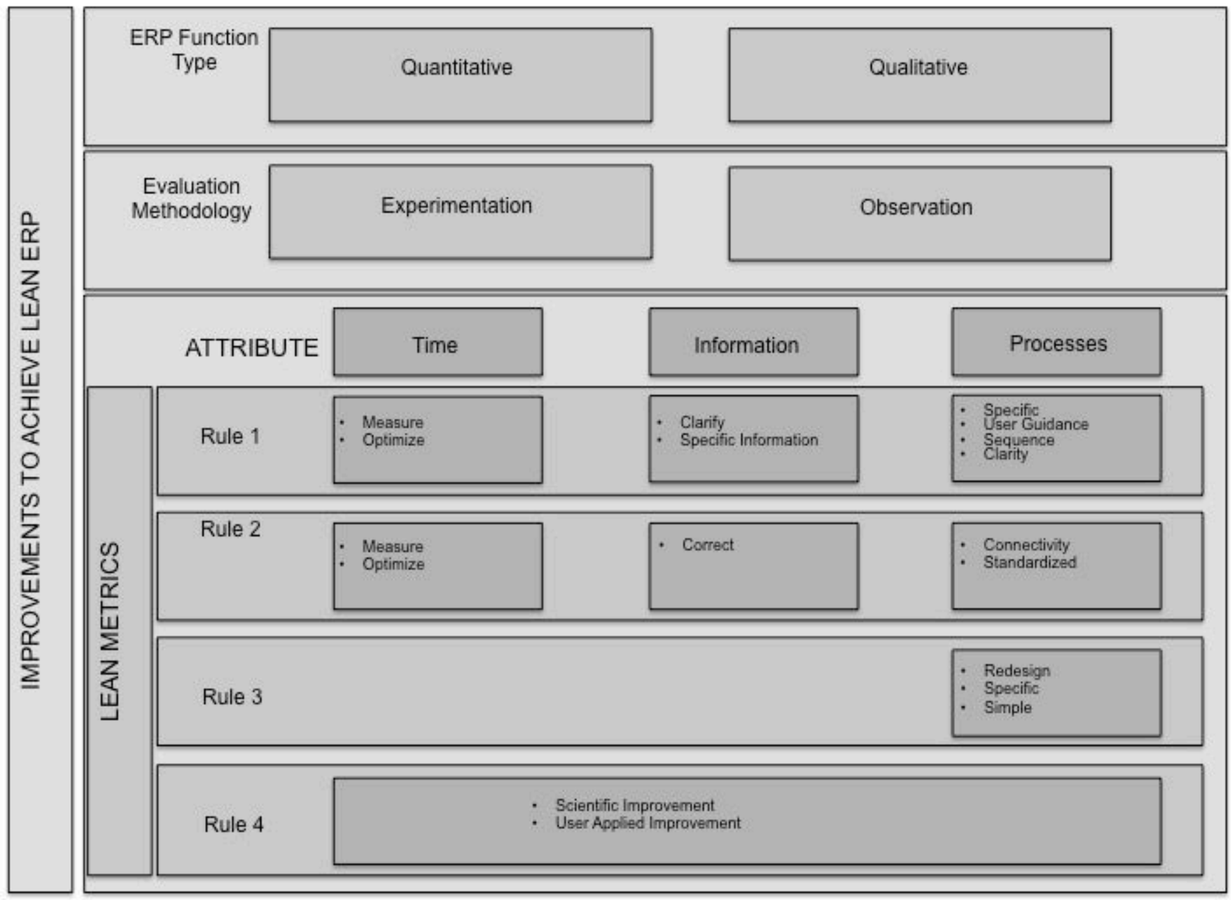
Rule 3C metric attempts to measure whether workflows through the system are designed to be simple and direct. The researcher considered the number of steps in a workflow, functions available to the user during the execution of the workflow and configuration options in the system that can simplify a workflow. The rule was evaluated in three parts as Specific workflow, Workflow complexity and if a workflow exists. The null hypothesis was accepted in all three cases concluding the acceptance of the null hypothesis for Rule 3 across all the categories for Rule 3. Rule 3C metric has a narrower scope than rules 3A and 3B evaluating the construction and the functionality within a workflow itself. Considering the research results for Rules 3B and 3C it is not surprising that for Rule 3C metric the null hypothesis should be accepted. Considering the definitions of an ERP systems as mentioned by Klaus et al. (2000) and Shanks et al. (2003), ERP systems should be containing business processes and best business practices and it is easy to make the assumption that for Rule 3C an ERP system cover the requirements. However, Spear and Bowen (1999) in their explanation of Rule 3 point out the that the rule has to be applied in such a way that the next step for person is highly specific and not only the next available e.g. machine or person. In terms of a workflow in an ERP system the next step should be clearly defined in the system for the user. The research result indicated that this area has not been developed enough to support Lean principles. The workflows were found to be specific when not spanning across modules and the workflow is contained within a specific module. ERP vendors have to design workflows to be more simple and specific in order to be compliant to Lean principles.

The research indicated the rejection of the null hypothesis in terms of Rule 4 therefore supporting the alternative hypothesis that Vendors have already designed ERP modules to support the principles of Lean operations and therefore ERP modules can be developed based on Lean principles. The research results in terms of Rule 4 are primarily based on the quantitative research that was done. Spear and Bowen (1999) explain Rule 4 as a method of improvement. However, changes for improvements should be scientifically constructed with a hypothesis in order to not simply apply changes on a trial and error basis in a production method. Besides the potential disaster from a trial and error method, the scientific method formulates the improvement with controlled and considered metric in the form of a hypothesis. This scientific method of applying improvements is not a common known method to apply improvements within ERP software. Improvements in terms of ERP would most likely consist of customization of the code of the system or more common in todays already sophisticated ERP system, changes to the configuration options of the system. Customization changes would normally being done outside of the system and applied as patches to the current system. Some methodologies would use a testing or staging area to test these customizations before applying them in the so-called production environment. Configuration changes would also be applied in the same method however for minor configuration changes with little or no impact on the production environment are often applied directly to the production environment. Besides, these changes would rarely be in the hands of the user or what Spear and Bowen calls the lowest level of the organization. These users might request these improvements but seldom participate in the improvement itself other than perhaps testing the final improvements for user acceptance. Spear and Bowen (1999) consider this as the most important rule of the four rules that they formulated and are an amalgamation of the three previous stated rules (Staats et al., 2011). Without the ability to apply the fourth rule in terms of the other three rules the Lean principles of production is not complete. The research found that for the use cases that were selected for quantitative testing, all of the use cases could be improved using a scientific method.

5.4 CONTRIBUTION TO KNOWLEDGE

The research results from the previous analysis and discussion have led to formulating the Lean ERP Metrics Framework (LEMF) as illustrated in Figure 5.4:

FIGURE 5.4
LEAN ERP METRICS FRAMEWORK (LEMF)



Source: Chalil du Plessis (2014)

The outcome of this research has practical and theoretical implications for vendors of ERP systems as well as users of ERP systems applying the Lean philosophy in production environment. The research proposed and tested a scientific framework for reconciling the principles of ERP and Lean. Other known proposed frameworks evaluate Lean tools contained within ERP systems (Powell et al., 2012) or proposes a framework for the development lifecycle of an ERP system (Carvalho, Johansson, & Manhaes, 2009; Poppendieck & Poppendieck, 2003) however they do not discuss or explain how to design or evaluate the Lean principles and philosophy embedded in an ERP system. The framework furthermore proposes a research method with quantitative and qualitative research that as per the knowledge of the researcher has not been done before in terms of ERP systems and Lean principles. The framework closes the gap between the ERP philosophy and the Lean philosophy in term of systems development providing architecture for vendors to reference the development and improving the gaps identified during the discussion. The framework also provides users of Lean systems with a scientific method to evaluate their current ERP system or new ERP systems in terms of Lean usability as well as a set of metrics that can be used for evaluation as well as continuous improvement. Finally, the framework is able to test and indicate areas of design within an ERP system that can be comparable with the philosophy of Lean operations as well as highlighting those areas that require improvement in order to align with the principles of Lean operations.

5.5 SUMMARY OF CHAPTER FIVE

After a comprehensive analysis of the research findings, the results have revealed that the quantitative and qualitative testing of the metrics, designed based on the four rules that forms the core of the Lean principles of operations as proposed by Spear and Bowen (1999), ERP systems have not been designed to support the Lean principles of operation. Although the null hypothesis was predominantly accepted for Rule 1 and Rule 3 and the null hypothesis rejected for Rule 2 and Rule 4, the null hypothesis was rejected for only thirteen of the individual categories of the total of thirty-one categories. Furthermore, during the discussion the research revealed that for a number of the metrics that indicated positive results in support of the null hypothesis, ERP systems do contain functionalities that can support the Lean principles of operations under certain conditions albeit these conditions were not intended by the ERP developers to be necessary supporting Lean principles. The research also supports the notion that the presence of Lean tools does not indicate that an ERP system design is following the Lean principles and is fully compatible with a Lean operational environment.

It is believed and to the best knowledge of the author considering a thorough investigation of the literature that the present research is the first detailed qualitative and quantitative research done to test the presence of Lean principles of operations within an existing ERP system. The resulting conceptual Lean ERP Metrics Framework not only provides a research and testing framework but also addresses the core requirements necessary to design, implement and operate an ERP system with Lean as a philosophy.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

CHAPTER SIX – CONCLUSIONS AND RECOMMENDATIONS

6.0 REVIEW

For summary purposes, the main research question is restated below:

> “What is the ERP systems framework that can be developed to incorporate Lean principles of operations, which will enable global Lean industry users to both reduce costs in their traditional ERP system while simultaneously reducing waste?”

Since Taiichi Ohno published the seven types of waste in 1988 and started the era of Lean production and Lean thinking, the controversy existed whether ERP systems could contribute to a Lean production system (Bartholomew, 1999) or that the functionality and philosophy of an ERP system differs so vastly from that of the Lean philosophy that ERP systems can not contribute to Lean (Gill, 2007). This controversy still continues more than two decades later with more recent authors such as (Bartholomew, 2012b) and (Powell et al., 2012) still actively investigating the use of ERP systems in Lean production environments. Even though there has been attempts at proposing frameworks for Lean ERP systems the research are of theoretical nature and predominantly qualitative research (Powell, 2012; Syspro, 2007). The author believes that to even begin to understand and answer the controversy, a system should contain the principles of the production philosophy that it is proposing to support. Therefore this research was inspired by the absence of research in finding support through active research for the principles of Lean operations in the design of modern ERP systems.

This research has focused on investigating the available literature on the subject of ERP systems and Lean operations philosophy and finding a suitable research methodology in terms of a mixed method methodology adapted to be able to do an in depth quantitative and qualitative study of an existing ERP system in a laboratory environment. The research results lead to a framework that support the Lean principles of operations as proposed by Spear and Bowen (1999) with sufficient metrics to measure ERP systems design and development for support of Lean principles.

6.1 THE SIGNIFICANCE BEHIND THE RESEARCH FINDINGS

Comparing the research to the existing Lean ERP literature, the significance of the findings of the present research culminates into a comprehensive Lean ERP Metric Framework. The adoption of this framework can be instrumental in the success of ERP systems within Lean operational environment assisting vendors of ERP systems as well as the users of these systems to measure the adherence to the Lean principles of operations. The present research uncovered the following main findings:

1. The set of metrics based on Spear and Bowen's (1999) rules for the principles of Lean operations can be suitably used as a metric to evaluate an ERP system's Lean functionality.

2. The sub categories of each of the four rules are not inherently related for a particular rule and most likely have to be measured as individual metrics.

3. The research is pointing to support the null hypothesis that vendors have not developed ERP systems to support lean principles.

4. The research is supporting the school of thought that ERP systems have not been developed to support Lean principles.

5. The research pointed out the areas of incompatibility between ERP and Lean principles of operations.

6. To generate a framework for Lean ERP systems metrics that will be useful for academics, vendors, implementers and users of ERP system within a Lean operations environment.

7. The generated framework indicates the functional architecture for ERP system design that can support Lean principles of operations.

It is hoped that the research findings can assist academics, vendors, implementers and users of ERP system within a Lean operations environment in the insight and understanding with regards to:

<u>Academics:</u> will be able to reference the research methodology and framework as starting point for future research concerning Lean ERP systems to expand the body of knowledge.

<u>Vendors:</u> of ERP systems will be able to use the research to give them insight into understanding the Lean concept and how to apply and measure the concept within their ERP products as well as to develop their system modules to be able to support Lean.

<u>Implementers and consultants:</u> of ERP systems within Lean environments will have a framework to configure modules to reflect Lean principles and narrow the gap between Lean and ERP to ensure the success of ERP implementations within a Lean environment.

<u>Users of Lean operations:</u> will be able to evaluate their currently implemented ERP systems and use the framework as well as the methodology to measure and improve

their systems applying a scientific method in order to narrow the gap between ERP and Lean at the same time reducing waste. The framework could also serve as a guideline for management of Lean companies in the evaluation of ERP systems during the acquisition process.

6.2 CONTRIBUTION TO LEAN ERP SYSTEMS

Lean has developed into a mature business philosophy applied throughout the world in all spheres of business with the objective of eliminating *muda* or waste. Eliminating waste increases profits and eventually benefits the stakeholders of an organization. In order to apply Lean in an organization it is critical for the success of the implementation that Lean is applied as a philosophy throughout the organization throughout all the systems and sub-systems (Hancock & Zayko, 1998).

Most organization requires an ERP however the literature indicates two points of view, one group believing that ERP and Lean should remain independent based on the premise that ERP was designed based on a manufacturing philosophy that promotes a “push” action whereas Lean is a philosophy based on a “pull” action throughout the system. The second group believes that ERP can contribute to a Lean system. ERP systems have become highly accessible to all sizes of business as off-the-shelf packages offering functionality for a few hundred dollars that a decade ago would have been extremely costly. However, the research indicated that vendors have not given priority to development of Lean ERP systems even though Lean's popularity has increased tremendously over the last decade. Furthermore, the Lean functionality that vendors of ERP systems claim are purely tools such as electronic Kanban. However, the research also indicated that the principles of Lean operations are not imbedded in the ERP systems. These findings are supported by the vigorous statistical analysis of the quantitative and qualitative data collected and analyzed during the research process.

Through the research the Lean ERP Metrics Framework (LEMF) was developed and refined. The framework closes the gap between the ERP and Lean philosophy concerning the expected functionality within an ERP system. Furthermore, LEMF can serve as a set of metrics whereby Lean and ERP practitioners, users as well as ERP systems developers can measure and continuously improve their ERP systems to bridge the gap between Lean and ERP systems reducing waste.

6.3 RESEARCH VALIDITY AND RELIABILITY

As previous mentioned in Chapter Three Section 3.3, the use of a multi-methodological method as the research approach, bring some complexity to the topic of validity and reliability in the sense that Nunamaker et al. (1991) did not discuss the reliability and validity of the research method. However they do refer to demonstration as a method of validity. Since the research consisted of quantitative and qualitative methods and did not rely only on purely demonstrations we can verify the validity and reliability of the research (Tichy, 1998). Both quantitative and qualitative research was used in combination with experimentation rather than surveys for the qualitative research. The following paragraphs will discuss how validity and reliability relate to the present research.

Validity as per Venkatesh & Brown (2013) for quantitative research is divided into three broad categories namely measurement validity, design validity and inferential validity. Validity for the research was mitigated during the research for each of the categories as follows:

Measurement validity: During the quantitative experimentations measurements were done measuring time and stops. Both of these were recorded using IOgraph software that can record the time by starting and ending the recording of the time. The time recorded were saved as files with the mouse movements as well as timestamps saved within the filenames. The accuracy of the stops presented by the size of the circles at the times of the stops was verified through a calibration test of five stops starting with one second up to five seconds with a one second increment to ensure that the software records the waiting times as a graphic with each mouse click. The calibration test is reflected in Appendix U.

Design validity: The internal validity as per Zikmund (2000, p. 271) requires that the experimental treatment can be determined as the root effect of the changes in the dependent variable. External validity on the other hand indicates the degree by which results can be applied to a larger population under study (Zikmund, 2000, p. 273). During the research the following measures were taken for the quantitative testing to ensure the internal and external validity:

Methods to ensure internal validity included:

- The same transaction data were processed before and after the treatment.
- The quantitative test were done using ten randomly generated transactions with up to five detail lines for each use case depending on the type of transaction in order to reduce the effect of a learning curve for the researcher during the testing.
- Only a single treatment was applied for each use case even though multiple treatments might be available. The objective was not to investigate the type of treatments rather than if a treatment is available in the system by design that can contribute to the Lean principles of operations.
- The virtual machine was rolled back to the instance before the treatment was applied and the transaction repeated. This was done to ensure that the first testing did not influence the second processing of the same transaction. Furthermore, within and ERP system duplication of the same transaction would be prevented e.g. use of the same document number or payment of the same invoice.

Methods to ensure external validity included:

- Based on the research by Gupta & Kohli (2006) the estimated overlap of features of the top four vendors is approximately 60-70%. The research was conducted using standard off-the-shelf software with the vendor sample data and configurations.
- Treatments were designed using only standard features available within the standard software.

Inferential validity: Inferential validity refers to the statistical interpretation and the correct application of an appropriate statistical method. Student's two-sample T-test for paired samples was found to be the most appropriate method considering the small sample size and the standard deviation being unknown. XLSTAT, a renowned statistical add-in software for Excel 2010, was used to calculate the results using a hypothesized difference (D) of 0 and a significance level of 5% for each of the calculations.

Following the classification of Venkatesh & Brown (2013) validity of qualitative research is grouped as design validity, analytical validity and inferential validity. Validity for the research was mitigated during the research for each of the categories as follows:

Design validity: consists of descriptive validity, credibility and transferability. The following mitigated these during the qualitative research:

Descriptive validity reflects the accuracy by which the researcher is reporting the observations of the test cases. Descriptive validity was mitigated using a use case document designed for the research of which the elements are described in details in Chapter Three, section 3.2. The researcher conducted the qualitative testing in order to evaluate each use case as consistently as possible. However, this could contain some bias from the researcher in his understanding of Lean principles of operations and processes and procedures in the tested ERP software. Furthermore none of the configurations settings were changed in the demonstration software to facilitate a different outcome of the qualitative tests.

Credibility requires determining whether the research can be trusted and believed through the methods applied by the researcher (Venkatesh & Brown, 2013). Some of the methods to establish credibility mentioned by Guba & Lincoln (2001) such as persistent observation, negative case analysis, continuous testing of hypothesis and preliminary categories were used during the qualitative research:

- Selection of the use cases based on a literature review and gap analysis grounded in research from scholars rather than users give more credibility to the use cases as listed in Table 3.5.
- The use of observation during the use cases.

- Documentation of the processes and procedures in the use case document during observations.
- Establishing the testing objectives for the qualitative use cases to reflect the testing hypothesis as reflected in Table 4.2.3 C.
- Coding of the quantitative data and the use of statistical analysis to determine any similarities between the coding.
- Negative case analysis for each use case and metrics tested.

Transferability indicates the degree with which the research can be generalized. The transferability of the research was negated through the use of standard off-the-shelf software without any customization configurations to fit the use cases. Use cases were established from a literature review to establish common requirements for a Lean ERP system.

<u>Analytical validity:</u> consists of theoretical validity, dependability, consistency and plausibility. The following mitigated these during the quantitative research by developing the Lean ERP Metrics Framework, through the rigorous collection of the data through the processing of transactions for different use cases and documenting the observations and description of the data collection process used during the research. The data was analyzed through tabulation of the coding results and the application of statistical analysis.

Inferential validity: is established by interpretive validity and confirmability of the research. Interpretive validity cannot be established for the research since the researcher was the only participant during the qualitative research. Confirmability was mitigated through referencing of similar research results by other researchers from literature where possible.

Reliability of the research findings was found to be consistent throughout the research findings using the chosen research methodology and framework. The research instruments were applied in different scenarios represented by the use cases indicating the results to be repeatable. Furthermore, it was possible to replicate the experiments for each of the use cases generating similar results for experiments.

6.4 FUTURE RECOMMENDATIONS

It is believed that the concept of Lean ERP systems is still immature in terms of defining the metrics to measure whether ERP systems could be designed or configured based on the principles of Lean operations. However, as the research indicates there are multiple opportunities for future research in terms of Lean ERP systems. Considering the findings of the research, the scope and the limitations of the present research, the following areas of future research are recommended:

1. Test Lean ERP Metrics Framework (LEMF) in a Lean production environment: The present research was conducted in a laboratory setting using standard ERP software. Conducting a similar research with an existing ERP system in an organization where the Lean philosophy is practiced will test the usability and transferability of the LEMF model to a real world scenario. The practicality of the framework is that the metrics could easily be expanded or reduced in the categorizations in order to test a particular area that they would like to improve for example, an organization could decide to only conduct a number of quantitative tests based on the use cases conducted during this research following the same methodology for the testing and analysis of the results. To have a more holistic view the full framework should be applied.

2. Duplicate the research across a number of existing ERP systems: The research was focused on the functionality of a single bespoke ERP system. Although ERP systems do contain similar functionality and the research attempted to stay within these similar functionalities, future research should be duplicated using other renowned ERP systems such as SAP and Oracle to validate and refining the Lean ERP Metrics Framework. This research should not only be conducted by independent researchers but it is hoped that these leading providers of ERP software and services will find the framework developed during this research useful to be able to narrow the gap between the functionality of standard ERP systems and the Lean philosophy. It is believed that such an approach could have a positive impact on the initial implementation costs of ERP systems in Lean environments through the alignment of the philosophies as well

as for the Lean users of such Lean ERP software to be able to apply Lean principles in such future ERP systems.

3. Testing of the LEMF model with a Lean ERP development project: Future research should be conducted during the system design stages of an ERP system using the LEMF model. The current research to develop the model was conducted using an already designed ERP system, however the resulting framework would be most valuable during the initial design of an ERP system in order to embed the principles of Lean operations within the software. Furthermore, the future research should include use case testing of the completed software in order to test the usability and transferability of the model throughout the complete software design life cycle. It is hoped that leading providers of ERP software and services such as SAP and Oracle will find the framework developed during this research useful to embed the Lean philosophy and therefore be able to narrow the gap between the functionality of standard ERP systems and the Lean philosophy.

4. Extend the quantitative and qualitative testing across all the possible use cases identified during the gap analysis from the literature: The gap analysis extrapolated from the literature review conducted during the gap analysis and requirement analysis phase as described in Chapter Four Section 4.2.2 yielded two-hundred-and-twenty-two results. The researcher evaluated each requirement on the merit whether a test can be devised for the requirement in Microsoft Dynamics AX 2012 R2. The criteria were based on the practicality of testing this particular requirement as well as whether testing

the requirement contributes to supporting the null hypothesis however the remaining requirements should be tested in the future in order to complete a study with a larger sample size. The gap analysis should also be evaluated continuously and extended with requirements from new literature that might become available from time to time.

5. Validation of the LEMF model by implementers and users familiar with Lean and ERP implementations: The use of the LEMF model within an implementation of an ERP system in a Lean environment should be tested and in particular in term of the qualitative testing. The current research is based on the observations of the researcher however these could be bias towards the research findings. Furthermore, the LEMF should be tested in case studies across a variety of industries.

6.5 SUMMARY OF CHAPTER SIX

Considering all aspects of the present research, the contribution to the field of study of Lean ERP systems is notable in specifically investigating and explaining the concept of the application of Lean principles of operations in terms of ERP systems development. Furthermore, the present research contributes to the Lean and Enterprise Systems discipline by propose a set of metrics to measure the presence of the principles of Lean operations within Lean ERP systems.

In conclusion the research has made the following critical observations concerning Lean ERP systems:

1. Contemporary ERP systems have not been developed sufficiently in terms of design and functionality to support the Lean principles of operations.

2. It is critical for future research to utilize mixed method research methodology during research to expand and strengthen the quantitative and qualitative research literature in the discipline of Lean ERP systems.

3. The developed LEMF model will contribute to future research and ERP development projects by providing a foundation from where results can be evaluated in terms of Lean ERP discipline of research.

Keeping in the mind the above findings and conclusions, it is hoped that the field of Lean ERP systems will further develop as a unique domain of study in academia and practice.

APPENDICES

APPENDIX A: USE CASE ANALYSIS TEMPLATE (SLOAN 2005)

Use Case ID:
Module Description:
Use Case Name *Give a short descriptive name for the use case to serve as a unique identifier. Consider goal-driven use case name.*
Goal *The goal briefly describes what the user intends to achieve with this use case.*
Location *Describe the location the evaluation is taking place, e.g. station number.*
Primary Actor *The person that interacts with the system that initiates the sequence of activities for the evaluation.*
Actors *List actors, people or things outside the system that either acts on the system (primary actors) or is acted on by the system (secondary actors). Primary actors are ones that invoke the use case and benefit from the result. Identify sensors, models, portals and relevant data resources. Identify the primary actor and briefly describe role.*
Analysis Description *A general description of the interaction with the information system.*
Information System Description *A description of the software that the primary actor interacts with such as ERP, module and version.*
Equipment or Peripherals used

List the equipment or peripherals that is used in the activities under evaluation such as barcode scanner etc. Equipment and peripherals also have to be taken in account for the evaluation for process improvement.

Time measured

Time measured at the end of each activity.

All work must be highly specified as to content, sequence, timing and outcome:

- *Sequence of data entry steps are clear*
- *Information to be entered are clear and specific*
- *Procedures to perform a task are specified*
- *The time to perform a task in the software can be measured and optimized*

Every customer-supplier connection must be direct with a yes-or-no way to send requests and receive responses:

- *Information is evaluated as correct before committed to the database*
- *Connecting processes or modules are direct and standarized*
- *Time between each connecting process can be measured and optimized*

The pathway for every product and service must be simple and direct:

- *Workflow through the system is simple and specific*
- *The workflow can only change when redesigned*
- *Workflow is specific to identify the next procedure, module and person*

Any improvement must be made in accordance with the scientific method, under guidance of a teacher, at the lowest possible level in the organization:

- *Improvements are made scientifically and according to Rules 1- 3 for example changing the software configuration settings of the software.*

Notes and Improvement Opportunities

Any observations such as data input/output, movement of the actor, file import/exports etc or suggestions from the actor.

Preconditions *Here we state any assumptions about the state of the system that must be met for the trigger (below) to initiate the use case. Any assumptions about other systems can also be stated here, for example, weather conditions. List all preconditions.*
Triggers *Here we describe in detail the event or events that brings about the execution of this use case. Triggers can be external, temporal, or internal. They can be single events or when a set of conditions is met, List all triggers and relationships.*
Basic Flow *Often referred to as the primary scenario or course of events. In the basic flow we describe the flow that would be followed if the use case where to follow its main plot from start to end. Error states or alternate states that might be highlighted are not included here. This gives any browser of the document a quick view of how the system will work. Here the flow can be documented as a list, a conversation or as a story.(as much as required)* 1) 2) 3)
Alternate Flow *Here we give any alternate flows that might occur. May include flows that involve error conditions. Or flows that fall outside of the basic flow.* 1) 2) 3)
Post Conditions *Here we give any conditions that will be true of the state of the system after the use case has been completed.*
Activity Diagram *Here a diagram is given to show the flow of events that surrounds the use case. It might be that text is a more useful way of describing the use case. However often a picture speaks a 1000 words.*
Notes *There is always some piece of information that is required that has no other place to go. This is the place for that information.*

APPENDIX B: GAP ANALYSIS FROM LITERATURE WITH ITEMS FOR EVALUATION

APPENDIX B GAP ANALYSIS FROM LITERATURE			
Use Case	Description	Reference	Qualitative/ Quantitative
UC#1: APUC#1/APUC#1a/ARUC#1/ARUC#1a/GLUC#1/FAUC#1/PRUC#1/PIUC#1	The ERP system should have functions to remove unnecessary mouse clicks, reduce navigation time and waiting time for the user to complete his/her task in the ERP system. Net throughput time of a transaction should be used as a metric to measure if waste has been reduced.	Krause (2007)	Quantitative
UC#2	Lean strives to minimize the information and transaction flow. A Lean ERP system should be able to share electronic information and transaction with other systems in an organization and globally. ERP systems need to offer facilities that simplify the integration of external and internal systems.	Miller (2004), Halgeri et al. (2010)	Qualitative
UC#3: PCUC#3	The ERP system should support once off production orders.	Miller (2004)	Qualitative
UC#4: MPUC#4	The ERP system is required to fully support and continuously improve the pull production system by providing the functionality to be able to measure and record information pertaining to the production performance and use this information to optimize production lead times and inventory levels.	Krause (2007), Powell et al. (2012)	Qualitative
UC#5: MPUC#5	The ERP system is required to support Flow Scheduling. The ERP system should support flow manufacturing without the use of work orders. Typically use a system of bar-coded Kanban cards to indicate completion of a finished product and to trigger to backflushing of the materials used.	Miller (2004), Halgeri et al. (2010)	Quantitative
UC#6	An ERP system is required to support cellular manufacturing	Miller (2004)	Qualitative

APPENDIX B
GAP ANALYSIS FROM LITERATURE

Use Case	Description	Reference	Qualitative/ Quantitative
UC#7	The ERP system should be able to define production routing, map items to production lines and cells, measure production output, calculate schedules backwards for production from delivery due dates, define the points to capture transactions and cost data.	Dixon (2004)	Qualitative
UC#8	Often Lean manufacturing is disconnected from the rest of the ERP to operate as a manual system utilizing Lean tools such as Kanban and visual methods. Purchases for Kanbans are processed manually into the ERP to complete the purchasing process. The purchasing systems need to have the capability to simultaneously process purchases for demand as well as a Kanban driven purchases. ERP system should have an auto procurement system using typical Lean terminology. The ERP system requires the ability to identify the primary vendor for automated purchasing and calculate the reorder quantity and price.	Krause (2007)	Qualitative
UC#9	The pull concept must be supported throughout the ERP system by pulling orders through the supply chain from supplier to customer. Furthermore, JIT concept should be applied where the frequency of purchases increases dramatically and with smaller quantities per order without the need of a purchase orders.	Nakashima (2000), Halgeri et al. (2010)	Quantitative
UC#10	Engineering change orders impacts directly on the flow of production. The ERP system requires communication technology such as workflow systems in order to alert the production line instantly of such changes.	Nakashima (2000), Halgeri et al. (2010)	Qualitative
UC#11	The ERP requires to have simple operations and supported by use of process mapping, help and training	Miller (2004)	Qualitative

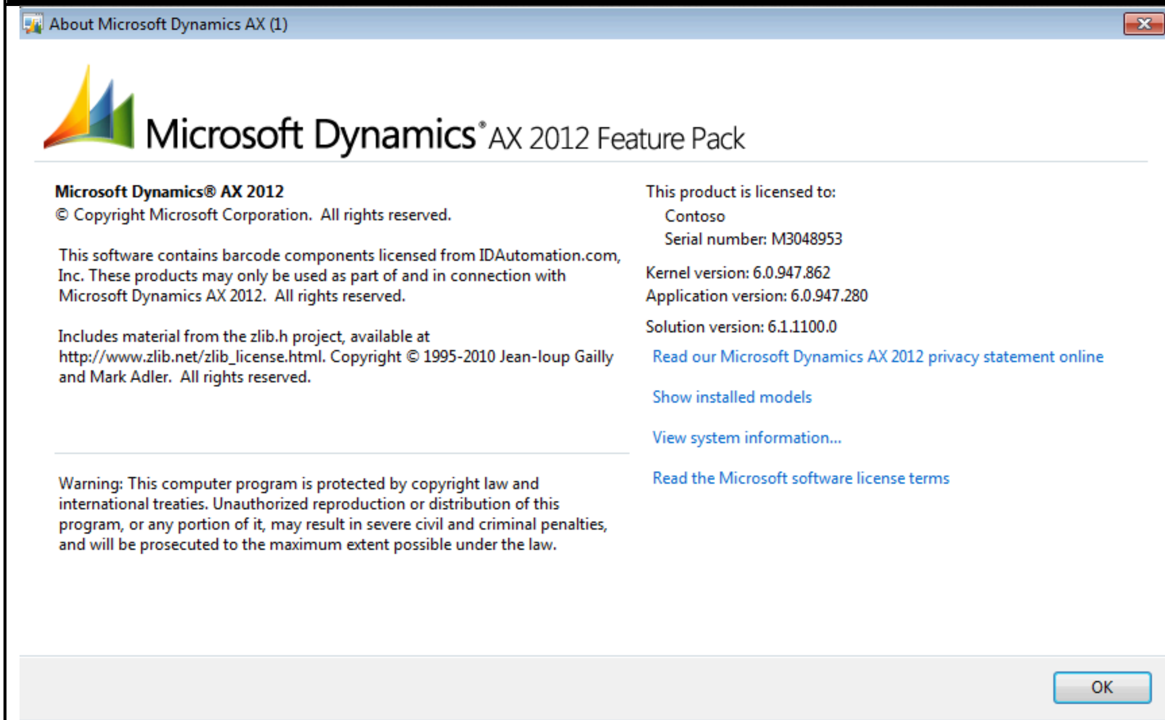
APPENDIX C: EXCEL RANDOM TRANSACTION GENERATOR

Test #	Number of line items	Random Vendor Code	line #	Random Item Code	Random Item Description	Random Qty	Observed Time
1	2	3113	1	D20	Lock repair	337	
			2	D16	Office Professional 2010	919	
			3	6017	Packaging inserts, preformed/5.1 HTS	871	
			4	5006	Wiring harness - center channel speaker	948	
			5	7021	Enclosure back - mahogany/14X36 inches	716	
2	5	2101	1	CSS_AMP2	AMP2	839	
			2	1001	LCD Television Model 01	981	
			3	2002	Speaker enclosure - ash/14 inches	725	
			4	1299	Assembled Home Theater System	523	
			5	CSS_FCB	Front cover Blue	589	
3	2	7013	1	7029	Enclosure top/bottom - oak/15X16 inches	845	
			2	8006	Sealer	331	
			3	CSS_SS1B	Speaker set 1 Blue	425	
			4	6011	Packaging inserts, preformed/14"	142	
			5	7022	Enclosure back - mahogany/16X38 inches	905	
4	3	7008	1	8010	Stain - front speaker mount	316	
			2	Work-Shirt	Work-Shirt	711	
			3	9004	Chair, Executive, Leather, Black	727	
			4	1000	LCD Television 42" HD Black	180	
			5	6015	Packaging inserts, preformed/center channel	557	
5	3	2002	1	21001	HTS Light	148	
			2	SCPS_UPSCR	Un Painted Speaker covers Right	609	
			3	7011	Enclosure sides - mahogany/16X40 inches	663	
			4	CSS_SKR2	Speaker kit Rear 2	445	
			5	1163	Satellite Speaker Model 03 / 600 watts	540	
6	1	3004	1	7018	Enclosure back - oak/16X38 inches	737	
			2	Painting	Painting	521	

Test #	Number of line items	Random Vendor Code	line #	Random Item Code	Random Item Description	Random Qty	Observed Time
			3	CSS_SKR2RG	Speaker kit Rear 2 Right green	626	
			4	9009	Chair, Reception, Blue, Arms	283	
			5	CSS_RCX	Rear cover Black	411	
7	3	9003	1	D9	OneNote 2010	122	
			2	5020	Power Cable	611	
			3	D14	Office Home and Business 2010	847	
			4	CSS_SKF2RX	Speaker kit Front 2 Right black	924	
			5	CSS_SKR1RG	Speaker kit Rear 1 Right green	696	
8	2	3107	1	21001	HTS Light	448	
			2	7030	Enclosure top/bottom - oak/17X18 inches	323	
			3	1003	Plasma Television Model 01	582	
			4	CSS_SS2G	Speaker set 2 green	586	
			5	1601	Standard Digital Video Recorder Model 01	214	
9	5	9003	1	1003	Plasma Television Model 01	712	
			2	2011	Speaker enclosure - oak/16 inches/2 woofer	794	
			3	7034	Enclosure front speaker mount 14X36 in	590	
			4	CSS_SKR1RB	Speaker kit Rear 1 Right blue	383	
			5	7044	Injection molded speaker housing 8" model 02	892	
10	3	3114	1	1163	Satellite Speaker Model 03 / 600 watts	213	
			2	CSS_RCY	Rear cover Gray	866	
			3	SCPS_PSCL	Painted Speaker covers Left	226	
			4	2007	Speaker enclosure - mahog/12 inches	350	
			5	9022	Office Supplies	379	

APPENDIX D: MICROSOFT DYNAMICS AX 2012 R2 VERSION

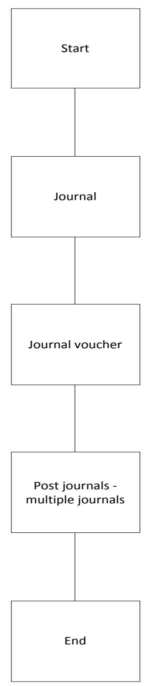
APPENDIX D:
MICROSOFT DYNAMICS AX 2012 R2 VERSION



APPENDIX E: APUC#1 ENTER AP INVOICE

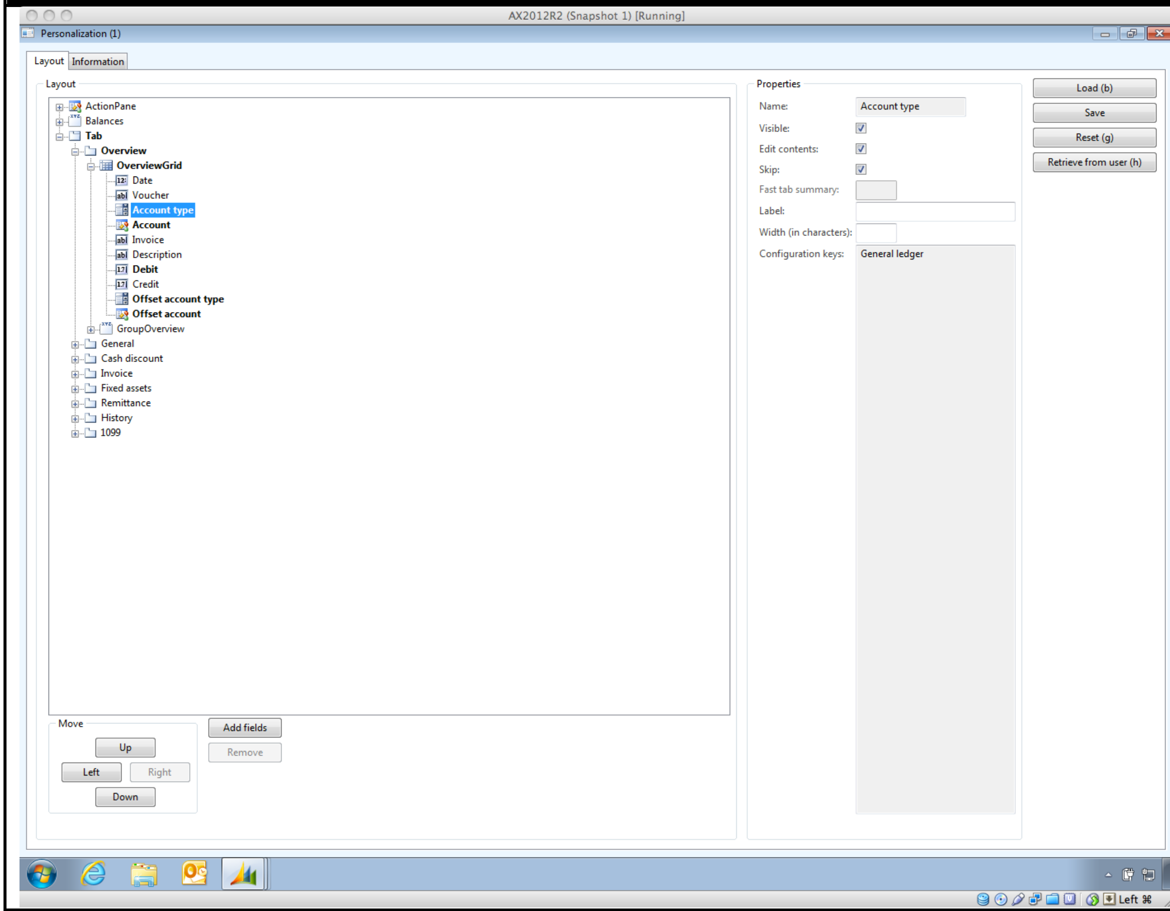
APPENDIX E:
APUC#1 ENTER AP INVOICE

Client: Microsoft Dynamics AX customer	Page 1 of 1	Prepared by: Admin	Date: 7/2/2014
Process: APUC#1 Enter AP Invoice		Approved by: Admin	Date: 7/2/2014



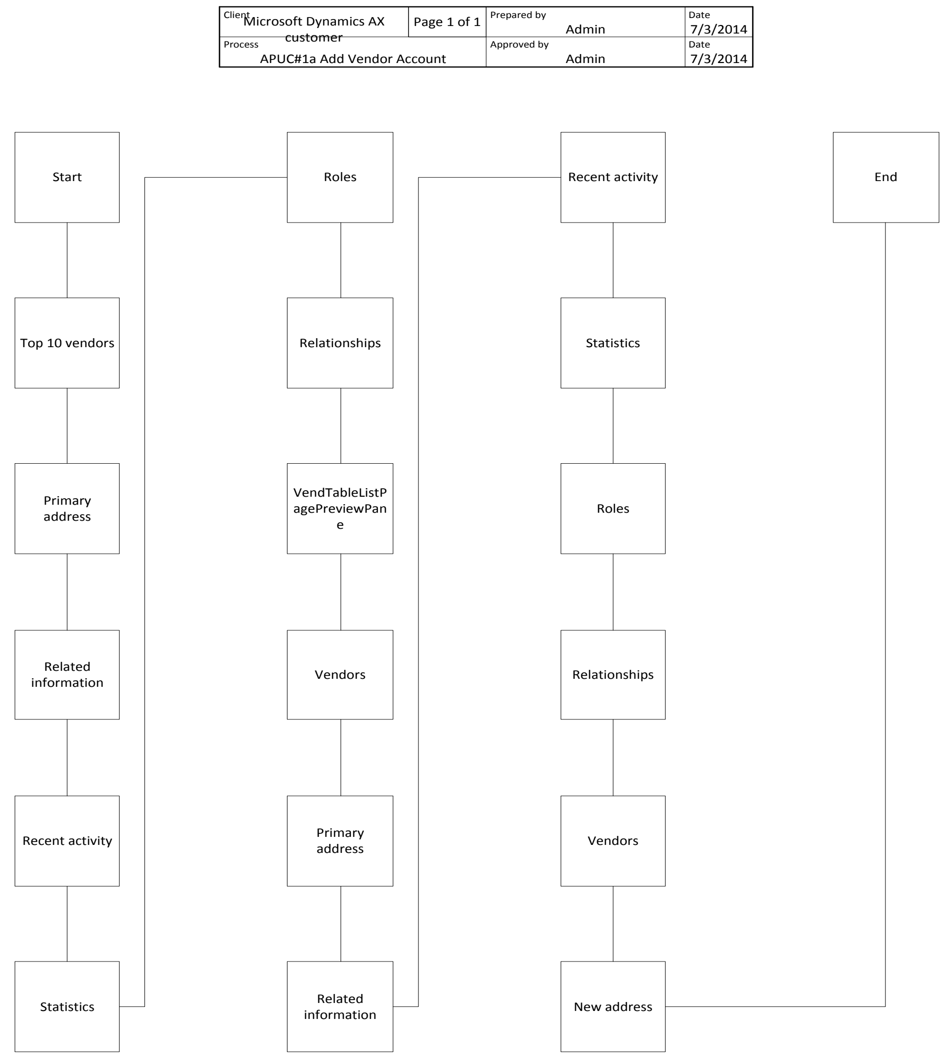
APPENDIX F: SCREENSHOT PERSONALIZATION APUC#1 IMPROVEMENT

APPENDIX F:
SCREENSHOT PERSONALIZATION APUC#1 IMPROVEMENT



APPENDIX G: APUC#1a ADD VENDOR ACCOUNT

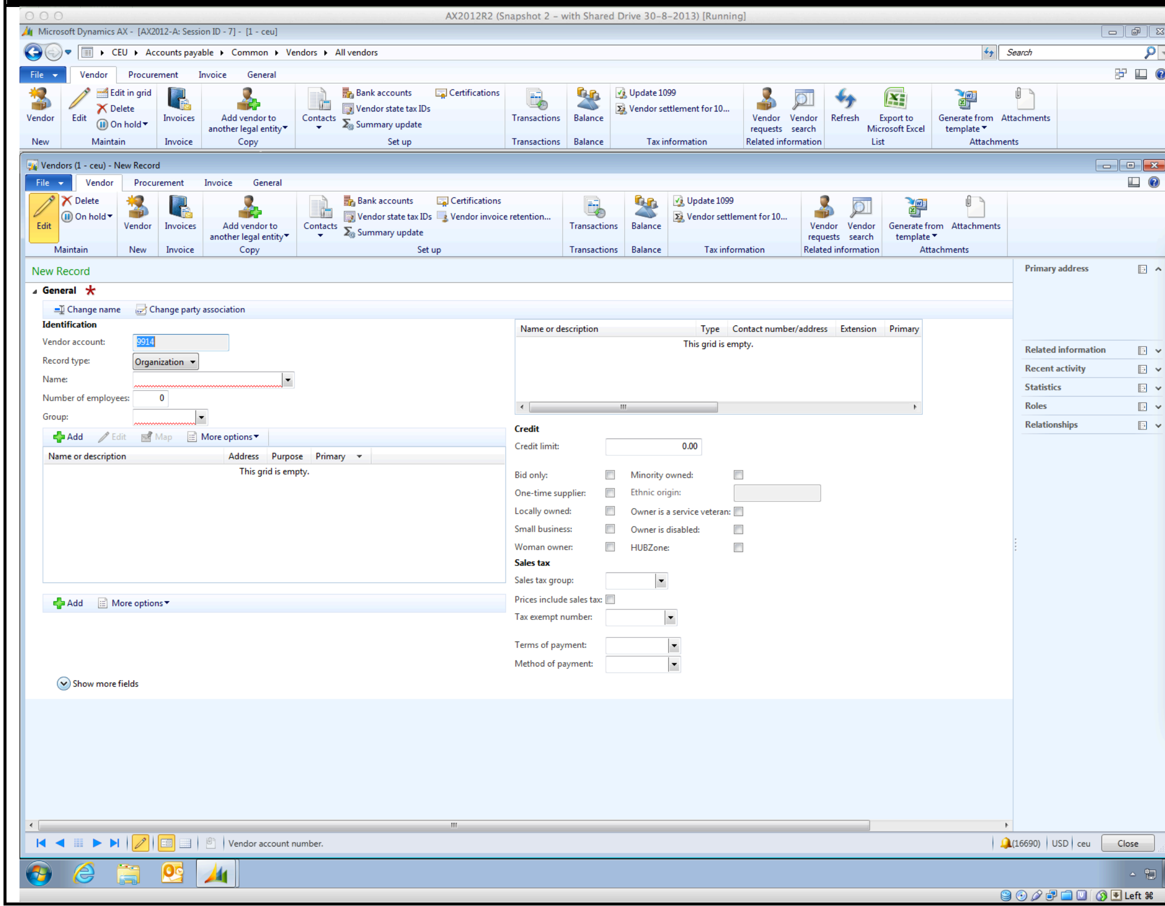
APPENDIX G:
APUC#1a ADD VENDOR ACCOUNT



Mr. Chalil du Plessis, B.Acc., M.Prof.
Final Submission To The Dissertation Committee
UGSM-Monarch Business School Switzerland
31 December 2014

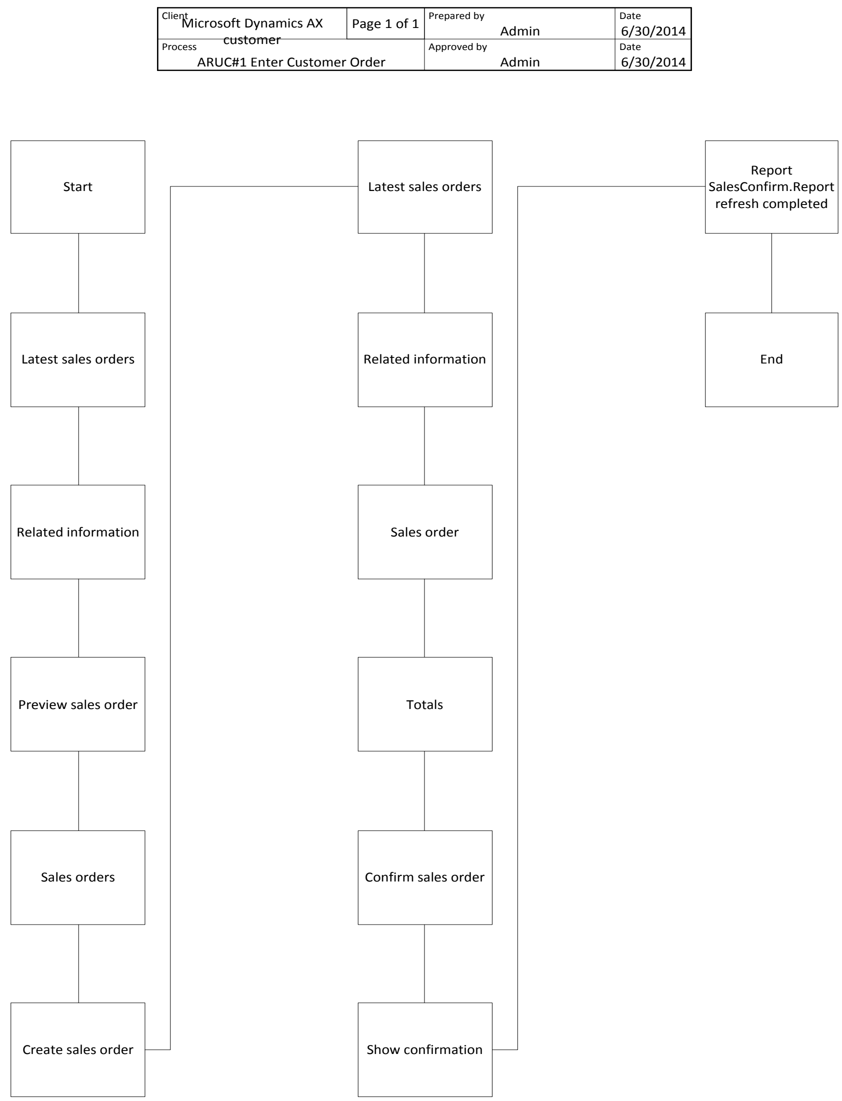
APPENDIX H: APUC1a SCREENSHOT DATA ENTRY AFTER CUSTOMIZATION

APPENDIX H:
APUC1a SCREENSHOT DATA ENTRY AFTER CUSTOMIZATION



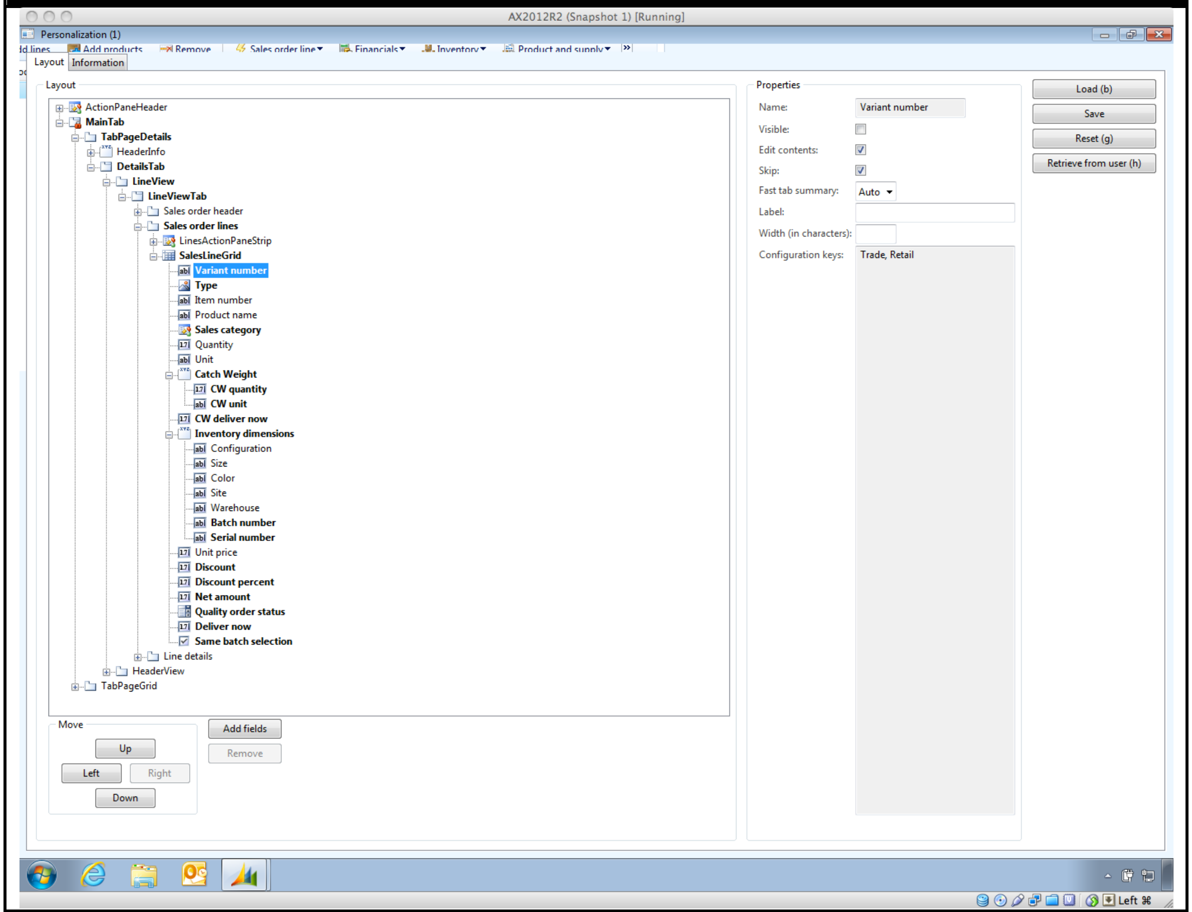
APPENDIX I: ARUC#1 ENTERING CUSTOMER ORDER

APPENDIX I:
ARUC#1 ENTERING CUSTOMER ORDER



APPENDIX J: SCREENSHOT ARUC#1 ORDER ENTRY PERSONALIZATION

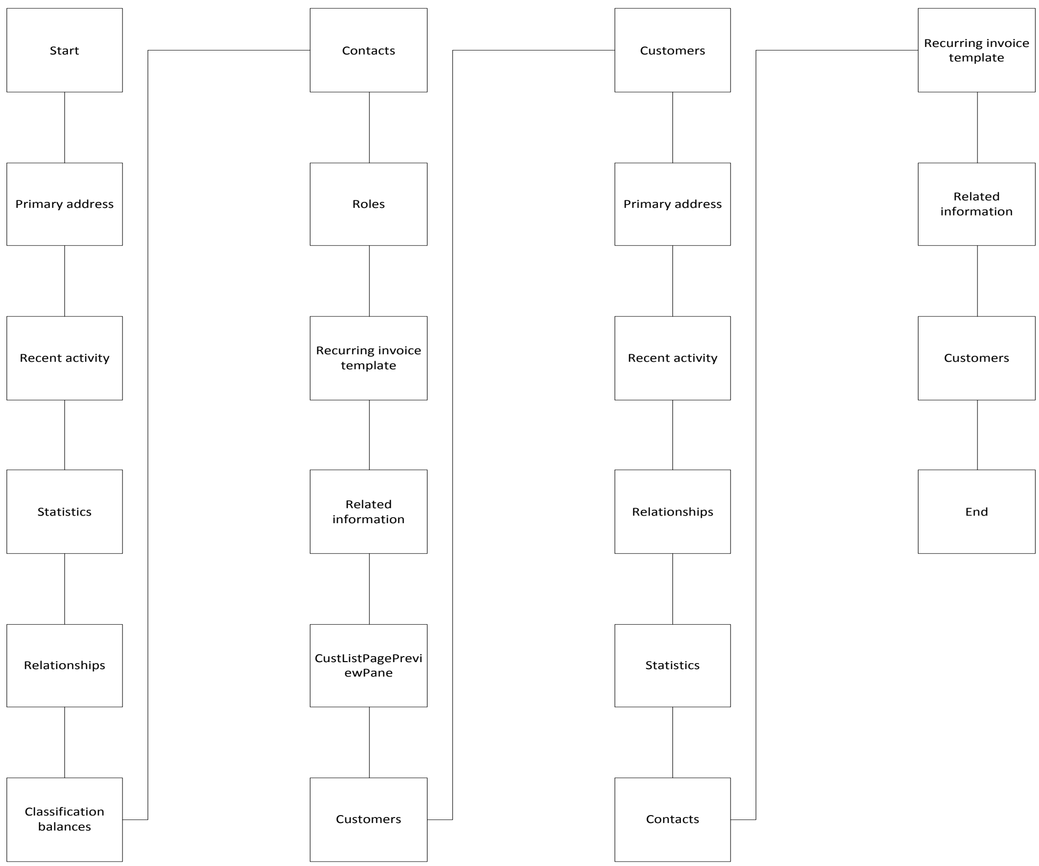
APPENDIX J:
SCREENSHOT ARUC#1 ORDER ENTRY PERSONALIZATION



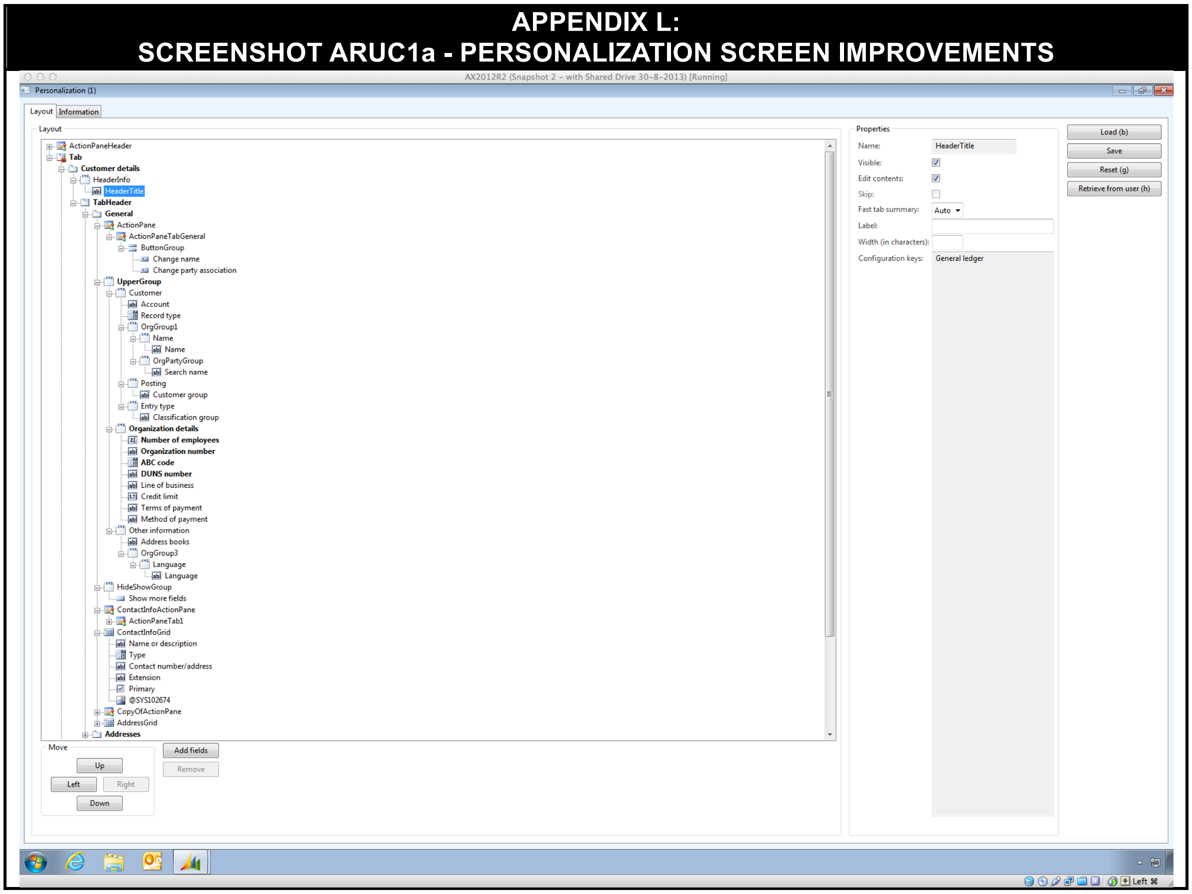
APPENDIX K: ARUC#1a ADDING CUSTOMER MASTER DATA

APPENDIX K:
ARUC#1a ADDING CUSTOMER MASTER DATA

Client		Prepared by	Date
Microsoft Dynamics AX customer	Page 1 of 1	Admin	7/1/2014
Process		Approved by	Date
ARUC#1a Adding Customer Master Data		Admin	7/1/2014



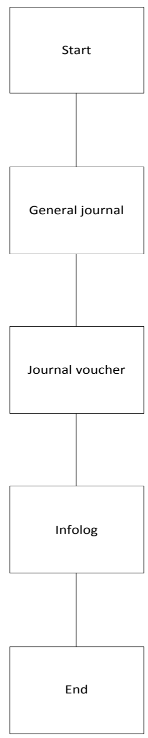
APPENDIX L: SCREENSHOT ARUC1a - PERSONALIZATION SCREEN IMPROVEMENTS



APPENDIX M: GLUC#1 GENERAL LEDGER JOURNAL

APPENDIX M:
GLUC#1 GENERAL LEDGER JOURNAL

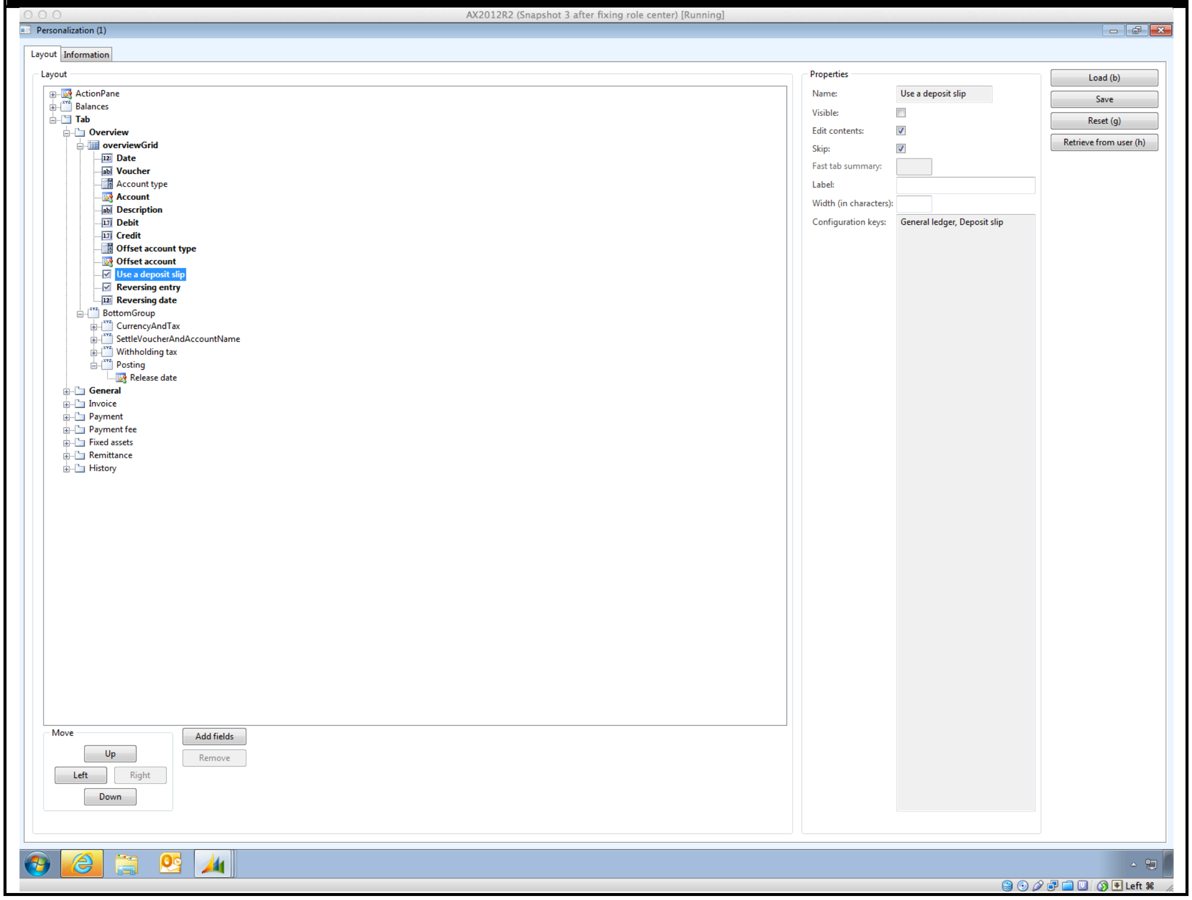
Client: Microsoft Dynamics AX customer	Page 1 of 1	Prepared by: Admin	Date: 7/5/2014
Process: GLUC#1 Post General Journal		Approved by: Admin	Date: 7/5/2014



Mr. Chalil du Plessis, B.Acc., M.Prof.
Final Submission To The Dissertation Committee
UGSM-Monarch Business School Switzerland
31 December 2014

APPENDIX N: SCREENSHOT CUSTOMIZATION SCREEN FOR GLUC#1

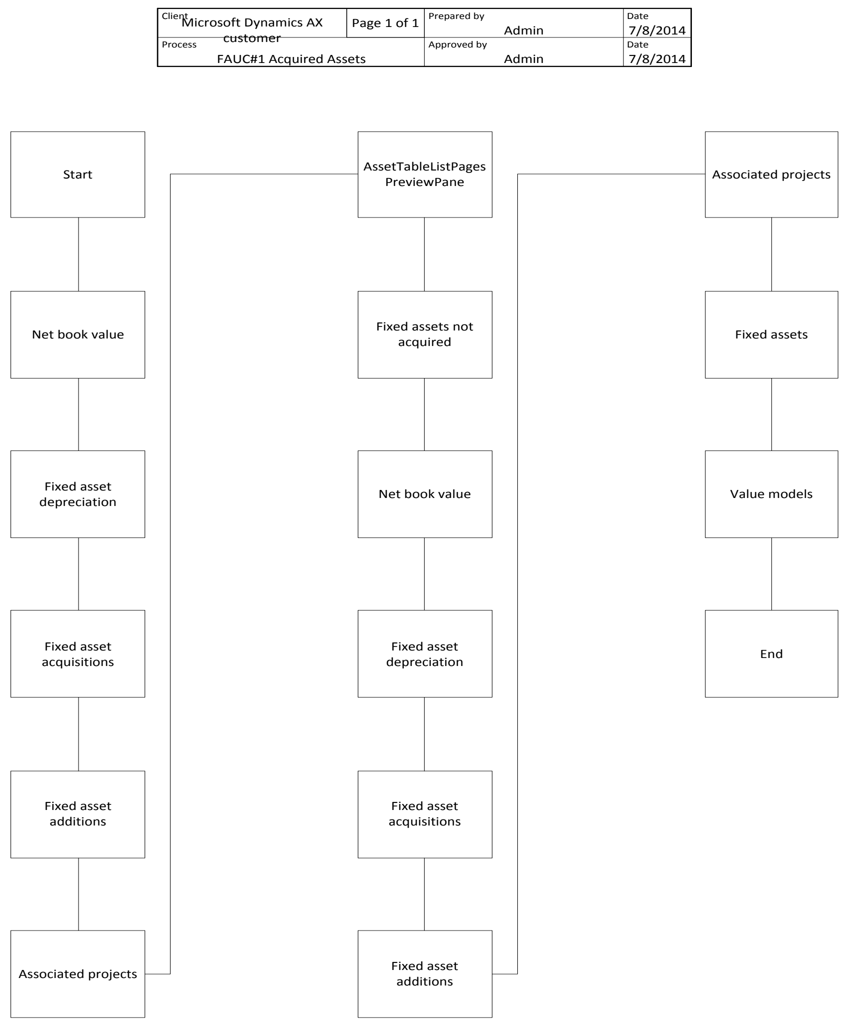
APPENDIX N:
SCREENSHOT CUSTOMIZATION SCREEN FOR GLUC#1



Mr. Chalil du Plessis, B.Acc., M.Prof.
Final Submission To The Dissertation Committee
UGSM-Monarch Business School Switzerland
31 December 2014

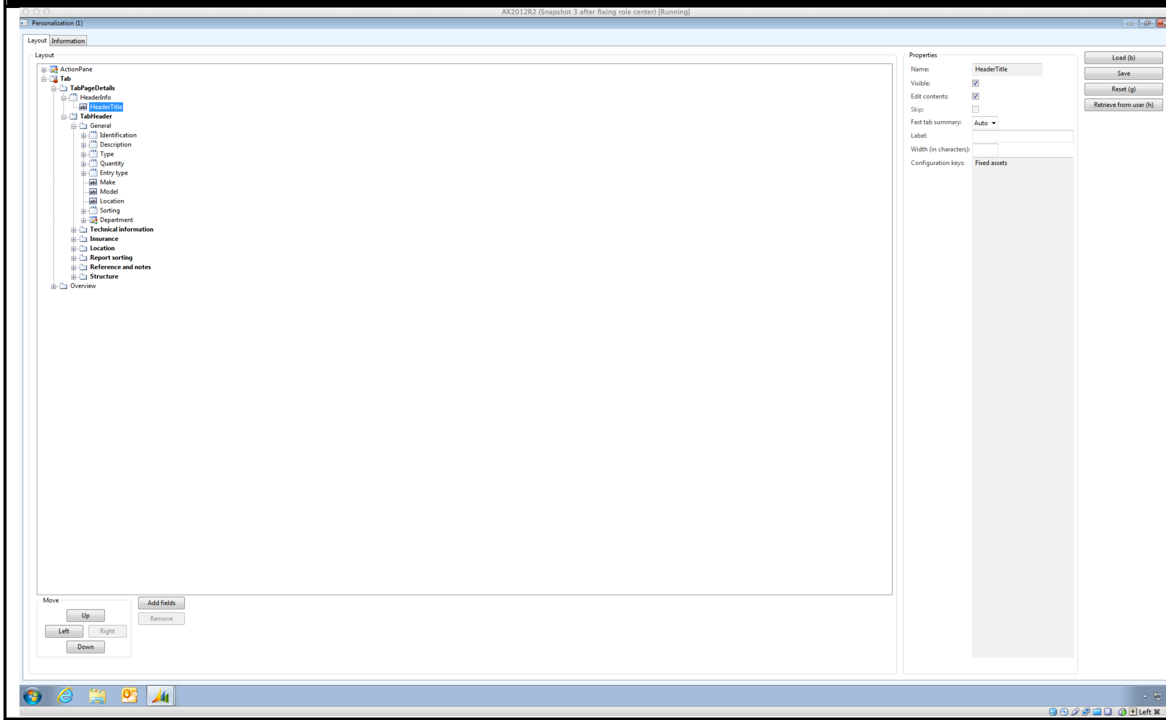
APPENDIX O: FAUC#1 ACQUIRED ASSETS

APPENDIX O:
FAUC#1 ACQUIRED ASSETS



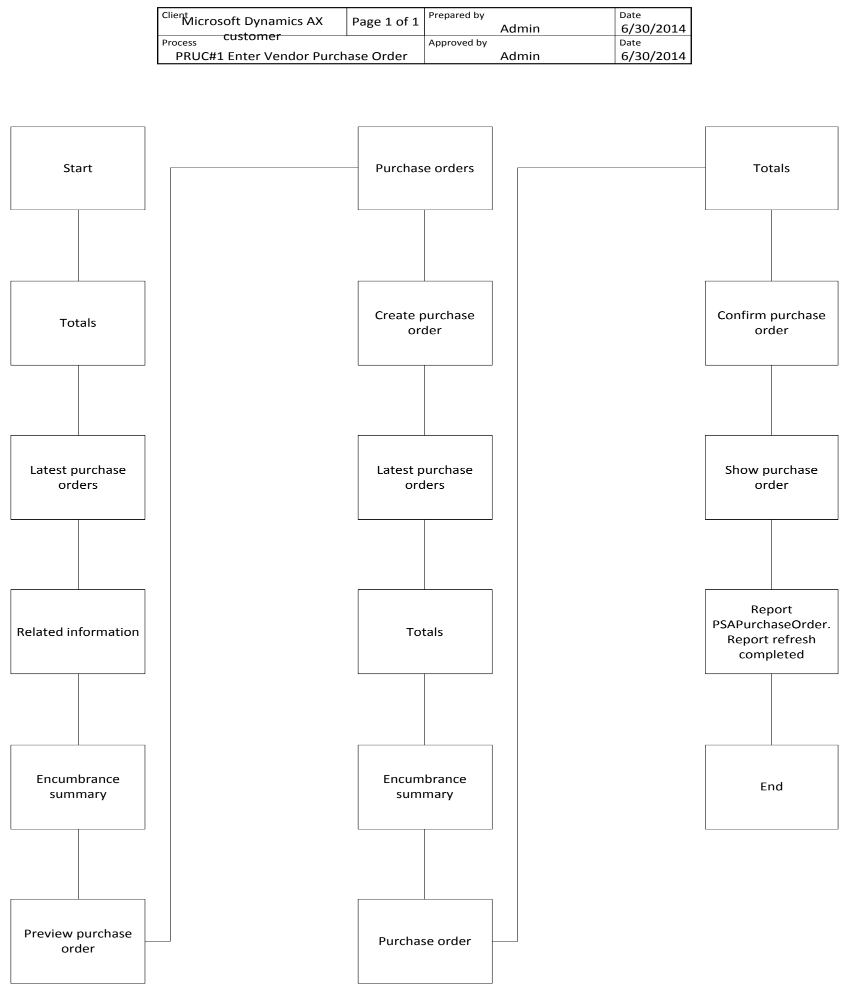
APPENDIX P: SCREEN SHOT CUSTOMIZATION SCREEN FOR FAUC#1

APPENDIX P:
SCREEN SHOT CUSTOMIZATION SCREEN FOR FAUC#1



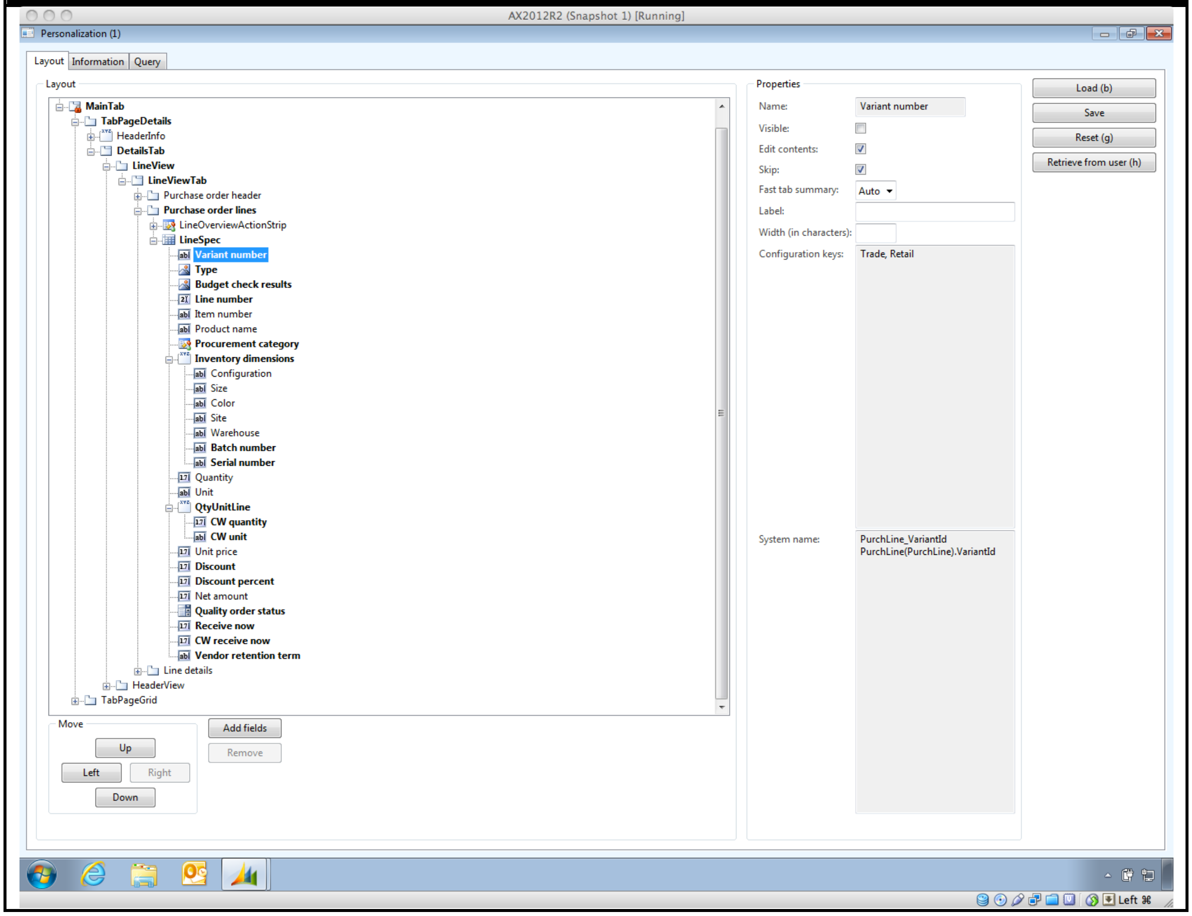
APPENDIX Q: PRUC#1 ENTER VENDOR PURCHASE ORDER

**APPENDIX Q:
PRUC#1 ENTER VENDOR PURCHASE ORDER**



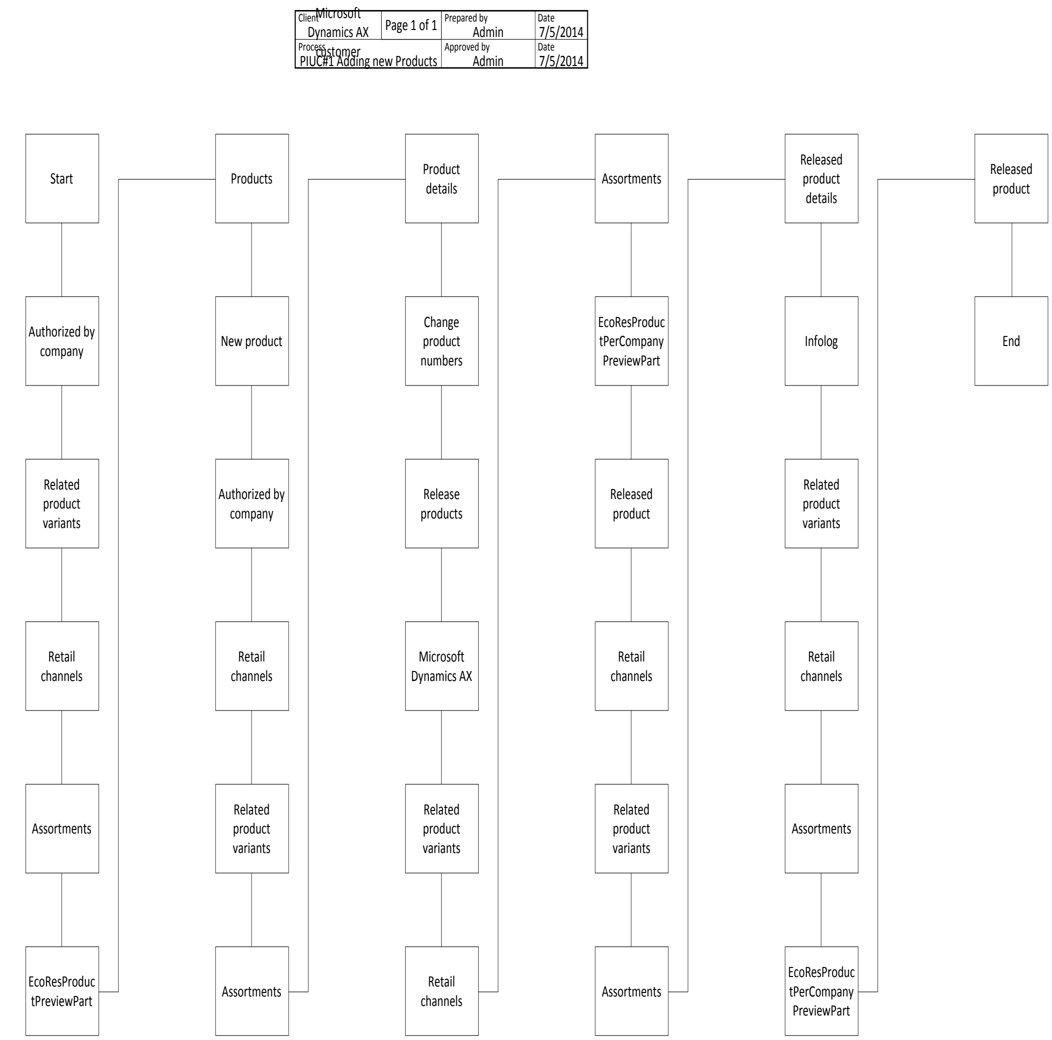
APPENDIX R: PERSONALIZATION - PRUC#1 IMPROVEMENT

**APPENDIX R:
PERSONALIZATION - PRUC#1 IMPROVEMENT**



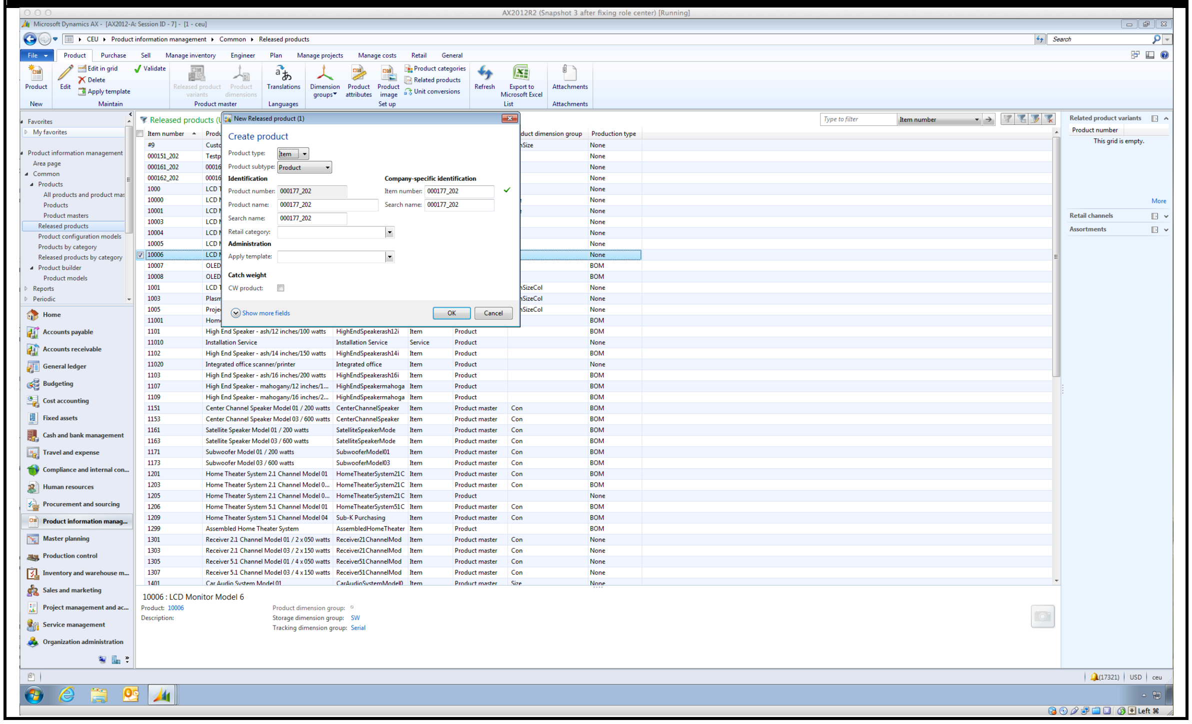
APPENDIX S: PIUC#1 ADDING NEW PRODUCTS

APPENDIX S:
PIUC#1 ADDING NEW PRODUCTS



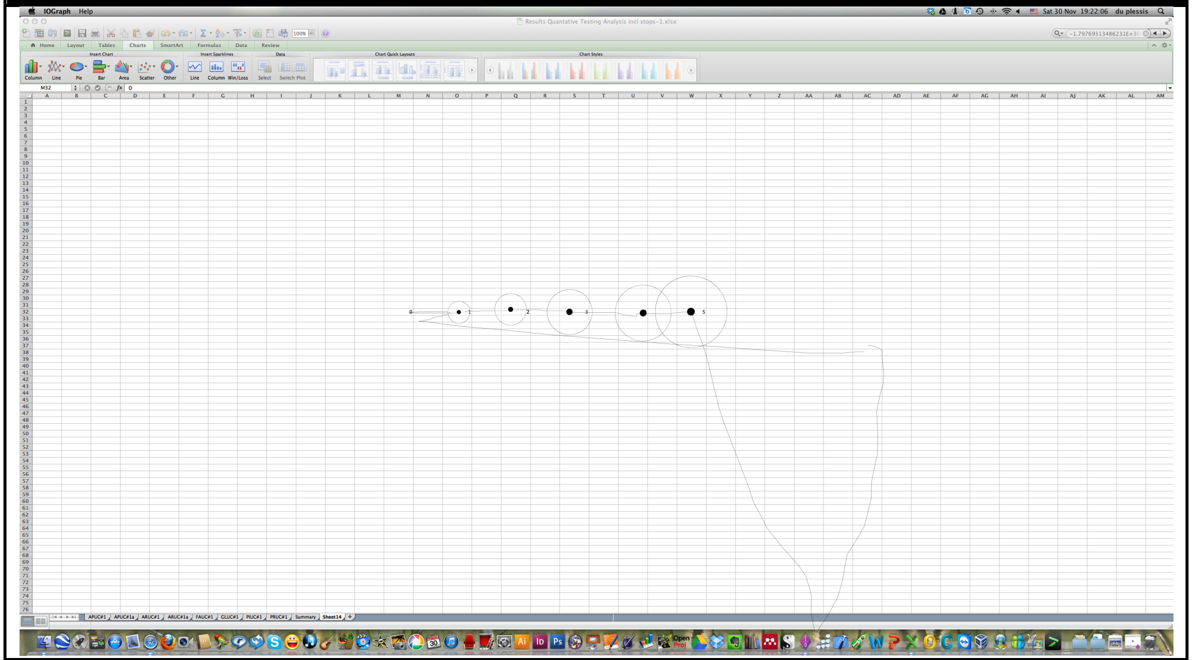
APPENDIX T: SCREENSHOT PIUC#1 ADDING NEW PRODUCTS

APPENDIX T:
SCREENSHOT PIUC#1 ADDING NEW PRODUCTS



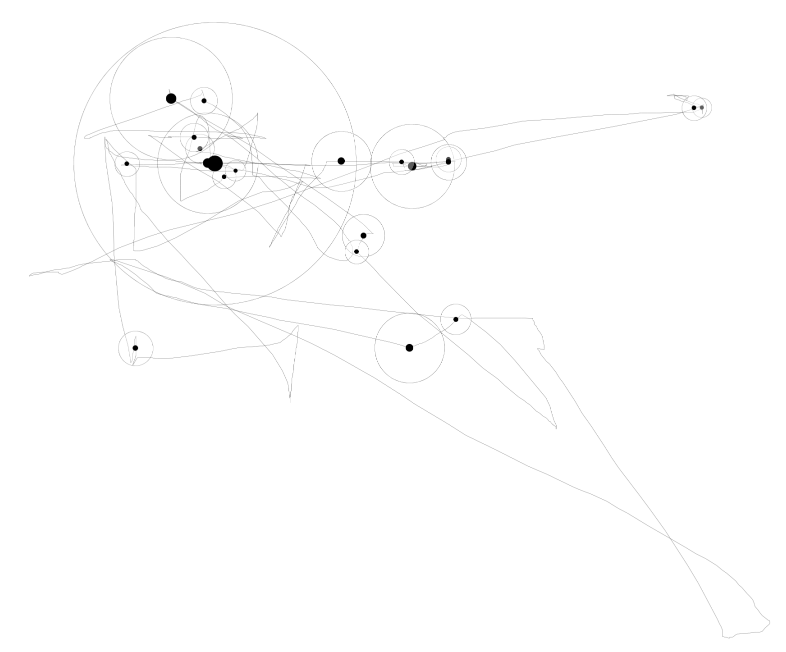
APPENDIX U: CALIBRATION TEST

**APPENDIX U:
CALIBRATION TEST**



APPENDIX V: IOGRAPHICS SPAGHETTI DIAGRAM SAMPLE

APPENDIX V:
IOGRAPHICS SPAGHETTI DIAGRAM SAMPLE



BIBLIOGRAPHY

1. Akkermans, H. A., Bogerd, P., Yücesan, E., & Van Wassenhove, L. N. (2003). The impact of ERP on supply chain management: Exploratory findings from a European Delphi study. *European Journal of Operational Research*, *146*(2), 284–301. doi:10.1016/S0377-2217(02)00550-7

2. Aslan, B., Stevenson, M., & Hendry, L. C. (2012). Enterprise Resource Planning systems: An assessment of applicability to Make-To-Order companies. *Computers in Industry*, *63*(7), 692–705. doi:10.1016/j.compind.2012.05.003

3. Bakht, A. (2003). Get ready for ERP, Part II. *Tribuneindia.com*. Retrieved May 18, 2011, from http://www.tribuneindia.com/2003/20031201/login/guest.htm

4. Bakry, A. H., & Bakry, S. H. (2005). Enterprise resource planning: a review and a STOPE view. *International Journal of Network Management*, *15*(5), 363–370.

5. Bartholomew, D. (1999). Lean vs. ERP. *Industry Week*, *248*(14), 24–30.

6. Bartholomew, D. (2012a). Can Lean and ERP Work Together? *Industry Week*, (4), 4.

7. Bartholomew, D. (2012b). Can Lean and ERP Work Together? *Industry Week*, *261*(4), 4.

8. Basili, V. R. (1996). The role of experimentation in software engineering: past, current, and future. In *Proceedings of the 18th international conference on Software engineering* (pp. 442–449). IEEE Comput. Soc. Press. doi:10.1109/ICSE.1996.493439

9. Bayraktar, E., Jothishankar, M. C., Tatoglu, E., & Wu, T. (2007). Evolution of operations management: past, present and future. *Management Research News*, *30*(11), 843–871. doi:10.1108/01409170710832278

10. Bell, S. (2006). *Lean Enterprise Systems: Using IT for Continuous Improvement*. (A. P. Sage, Ed.) (Vol. 33, p. 443). Hoboken, New Jersey: John Wiley & Sons, Inc.

11. Bell, S. C., & Orzen, M. A. (2011). *Lean IT: Enabling and Sustaining Your Lean Transformation* (p. 349). New York, New York: CRC Press.

12. Bhasin, S., & Burcher, P. (2006). Lean viewed as a philosophy. *Journal of Manufacturing Technology Management*, *17*(1), 56–72.

13. Biennier, F., & Legait, A. (2008). A Service Oriented Architecture to Support Industrial Information Systems. In T. Koch (Ed.), *Lean Business Systems and Beyond* (IFIP – The., Vol. 257, pp. 93–100). Springer US. doi:10.1007/978-0-387-77249-3_10

14. Bond, B., Genovese, Y., Miklovic, D., Wood, N., Zrimsek, B., & Rayner, N. (2000). ERP is dead–Long live ERP II. *Gartner Group Research Notes*, (4 October 2000).

15. Booch, G., Rumbaugh, J., & Jacobson, I. (1999). *The Unified Modeling Language User Guide*. (C. J. Shanklin, Ed.) (First Edit., p. 512). Reading, Massachusetts: Addison Wesley Longman, Inc.

16. Bradford, M., Mayfield, T., & Toney, C. (2001). Does ERP fit in a lean world? *Strategic Finance*, *82*(11), 28–34.

17. Carr, N. G. (2003). IT doesn't matter. *Harvard Business Review*, (May), 5–12.

18. Carvalho, R. A. de, Johansson, B., & Manhaes, R. S. (2009). Mapping Agile Methods to ERP : Directions and Limitations Agile Methods and ERP Development. *Business*.

19. Chen, I. (2001). Planning for ERP systems: analysis and future trend. *Business Process Management Journal*, *7*(5), 374–386.

20. Cockburn, A. (2001). *Writing effective use cases* (p. 204). Addison Wesley Longman, Inc.

21. Coleman, D. (1998). A Use Case Template : draft for discussion. *Fusion Newsletter*, (June), 1–6.

22. Cooprider, J., Topi, H., Xu, J., Dias, M., Babaian, T., & Lucas, W. (2010). A Collaboration Model for ERP User-System Interaction. In *2010 43rd Hawaii International Conference on System Sciences* (pp. 1–9). Ieee. doi:10.1109/HICSS.2010.5

23. Cottyn, J., Van Landeghem, H., Stockman, K., & Derammelaere, S. (2011). A Method to Align a Manufacturing Execution System with Lean Objectives. *… Journal of Production …*.

24. Davenport, T. H. (1998). Putting the enterprise into the enterprise system. *Harvard Business Review*, *76*(4), 121–31.

25. Davenport, T. H. (2000). *Mission critical: realizing the promise of enterprise systems* (p. 339). Boston, Massachusetts: Harvard Business School Press.

26. Davenport, T. H., & Short, J. E. (1990). The New Industrial Engineering: Information Technology and Business Process Redesign. *Sloan Management Review*, *31*(4), 31.

27. Dittrich, Y., Rönkkö, K., Eriksson, J., Hansson, C., & Lindeberg, O. (2007). Cooperative Method Development. *Empirical Software Engineering*, *13*(3), 231–260. doi:10.1007/s10664-007-9057-1

28. Dixon, D. (2004). The truce between lean and IT: Technology can help enable the elimination of waste. *Industrial Engineer*, *36*(6), 42–45.

29. Duque, D., & Cadavid, L. R. (2007). Lean manufacturing measurement: the relationship between Lean activities and Lean metrics. *Estudios Gerenciales*, *23*(105), 69–83.

30. Eckartz, S., Daneva, M., Wieringa, R., & van Hillegersberg, J. (2009). Cross-organizational ERP Management: How to Create a Successful Business Case? In *Proceedings of the 2009 ACM Symposium on Applied Computing* (pp. 1599–1604). New York, NY, USA: ACM. doi:10.1145/1529282.1529641

31. Escobar, D., & Revilla, E. (2005). The Customer Service Process: The Lean Thinking Perspective. *Instituto de Empresa Business School Working Paper No. WP05-13*.

32. Everitt, B. . (2006). *The Cambridge dictionary of statistics third edition* (Third.). New York: Cambridge University Press.

33. Ferran, C., & Salim, R. (2011). IAC Accounting Data Model: A Better Data Structure For Computerized Accounting Systems. *Review of Business Information Systems (RBIS)*, *8*(4), 109–120.

34. George, M. L. (2003). *Lean Six Sigma for service: how to use lean speed and Six Sigma quality to improve services and transactions* (p. 386). New York, NY: McGraw-Hill Professional.

35. Gill, R. (2007). Lean Manufacturing and ERP Systems: Different by Design. *Ceramic Industry*, *157*(8), 11–14.

36. Goddard, R. W. (2003). The role of information technology in the lean enterprise. *IE 780S–Lean Manufacturing*.

37. Goeke, R., & Faley, R. (2009). Finding the business value after successful ERP implementation: Making the case for gross margin. *Decision Sciences*, 1451–1456.

38. Golafshani, N. (2003). Understanding reliability and validity in qualitative research. *The Qualitative Report*, *8*(4), 597–606.

39. Gregor, S., & Jones, D. (2007). The anatomy of a design theory. *Journal of the Association for Information Systems*, *8*(5), 312–335.

40. Guba, E. G., & Lincoln, Y. S. (2001). GUIDELINES AND CHECKLIST FOR CONSTRUCTIVIST (a . k . a . FOURTH GENERATION) EVALUATION. *Evaluation Checklists Project*, (November), 1–15.

41. Gupta, M., & Kohli, A. (2006). Enterprise resource planning systems and its implications for operations function. *Technovation*, *26*(5-6), 687–696. doi:10.1016/j.technovation.2004.10.005

42. Halgeri, P., McHaney, R., & Pei, Z. J. (2010). ERP Systems Supporting Lean Manufacturing in SMEs. In *Enterprise Information Systems for Business Integration in SMEs By Maria Manuela Cruz-Cunha* (pp. 56–75). IGI Global. doi:10.4018/978-1-60566-892-5.ch005

43. Hancock, W. M., & Zayko, M. J. (1998). Lean Production: Implementation Problems. *IIE Solutions*, (JUN), 38–42.

44. Hawking, P. (2007). Implementing ERP systems globally: Challenges and lessons learned for Asian countries. *Journal of Business Systems, Governance and Ethics*, *2*(1), 21–32.

45. Herrmann, J. W. (2005). A history of decision-making tools for production scheduling. In *Multidisciplinary Conference on Scheduling: Theory and Applications* (pp. 380–389).

46. Hessman, T. (2012). Bringing ERP into the New Era Customization and Responsibility. *Industry Week*, *6*(June), 2.

47. Hestermann, C., Pang, C., & Montgomery, N. (2012). Magic Quadrant for Single-Instance ERP for Product-Centric Midmarket Companies. *Gartner Research*, (June), 1–23.

48. Hirano, H. (1990). *JIT Implementation Manual: The Complete Guide to Just-in-time* (Second Edi., p. 2865). Boca Raton, Florida: CRC Press.

49. Holweg, M. (2007). The genealogy of lean production. *Journal of Operations Management*, *25*(2), 420–437.

50. Houy, T. (2005). ICT and lean management: Will they ever get along? *Communications & Strategies*, *59*(Quarter 2005), 53–75.

51. Jacobs, R. F., & Weston, T. F. C. J. (2007). Enterprise resource planning (ERP)—A brief history. *Journal of Operations Management*, *25*(2), 357–363. doi:10.1016/j.jom.2006.11.005

52. Johnson, H. T. (2007). Lean dilemma: Choose system principles or management accounting controls—Not both. In *Lean Accounting: Best Practices for Sustainable Integration* (pp. 3–16). Hoboken, NJ: John Wiley & Sons, Inc.

53. Juristo, N., & Omar, S. G. (2012). Replication of software engineering experiments. *Empirical Software Engineering and Verification*, 60–88.

54. Kanellou, A., & Spathis, C. (2013). Accounting benefits and satisfaction in an ERP environment. *International Journal of Accounting Information …*, (July), 11–12.

55. Kass, R. (2008). Tests and Experiments: Similarities and Differences. *The ITEA Journal of Test and Evaluation*, *29*, 294–300.

56. Katz, M. J. (2009). *From Research to Manuscript* (Second Edi., p. 205). Springer Science + Business Media B.V.

57. Khadem, M., Ali, S., & Seifodinni, H. (2008). Efficacy of Lean Metrics in Evaluating the Performance of Manufacturing Systems. *International Journal of Industrial Engineering*, *15*(2), 176–184.

58. Klappich, C. D., Aimi, G., Taylor, J., & Mcneill, W. (2011). Predicts 2011 : Global Logistics Leadership a Strategic Imperative. *Gartner Research*, 1–10.

59. Klaus, H., Rosemann, M., & Gable, G. G. (2000). What is ERP? *Information Systems Frontiers*, *2*(2), 141–162.

60. Krause, R. W. F. I. (2007, November). Wanted: Lean ERP and what to do about it. *Access Your Biz*. Retrieved August 25, 2011, from http://www.lean-manufacturing-inventory.com/erpwanted.aspx

61. Lean Advisors. (2011). Assessing IT's role in lean environments - Lean Case Study. Retrieved August 30, 2011, from http://www.leanadvisors.com/kila-resources/assessing_its_role_in_lean_environments/

62. Liker, J., & Burr, K. (1999). Advanced Planning Systems as an Enabler of Lean Manufacturing. *Automotive Manufacturing & Production*, *111*(2), 29–31.

63. Liker, J. K. (2004). *The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer*. New York, NY: McGraw Hill.

64. Lõrincz, P. (2005). ERP System and Beyond. *Proceedings-3rd International Conference on Management, Enterprise and Benchmarking (MEB 2005)*.

65. Maffett, G. A., Kwon, O., & O'Gorman, D. (2002). Complex adaptive systems design for lean manufacturing. In *Academy of Information and Management Sciences* (Vol. 21, pp. 33–39). Nashville, Tennessee: Allied Academies International Conference.

66. Mahmood, Z. (2007). Service oriented architecture: tools and technologies. *Benefits*, *6*, 7.

67. Mauch, J., & Park, N. (2003). *Guide to the successful thesis and dissertation: A handbook for students and faculty* (Fifth Edit.). New York, NY: Marcel Dekker, Inc.

68. McLeod, L., MacDonell, S. G., & Doolin, B. (2011). Qualitative research on software development: a longitudinal case study methodology. *Empirical Software Engineering*, *16*(4), 430–459. doi:10.1007/s10664-010-9153-5

69. Microsoft White Paper. (2012). *Lean manufacturing : Production flows and activities*. *Production*.

70. Miller, G. (2004). Lean and ERP: Can They Co-Exist? *Technical Papers-Society of Manufacturing Engineers-All Series*, (158), ALL.

71. Møller, C. (2005). ERP II: a conceptual framework for next-generation enterprise systems? *Journal of Enterprise Information Management*, *18*(4), 483–497.

72. Molnár, B. (2011). The Country-specific Organizational and Information Architecture of ERP Systems at Globalised Enterprises. *Business Systems Research*, *2*(2), 39–50.

73. Molnár, B., Szabó, G., & Benczúr, A. (2013). Selection Process of ERP Systems. *Business Systems Research*, *4*(1), 36–48. doi:10.2478/bsrj-2013-0004

74. Monk, E. F., & Wagner, B. J. (2009). *Concepts in enterprise resource planning*. (A. Von Rosenberg, Ed.) (Third Edit.). Boston, Massachusetts: Course Technology Cengage Learning.

75. Nakashima, B. (2000, September). Lean and ERP: friend or foe? *Advanced Manufacturing Magazine*, 1–6.

76. Naseem, R., Maqbool, O., & Muhammad, S. (2010). An Improved Similarity Measure for Binary Features in Software Clustering. *2010 Second International Conference on Computational Intelligence, Modelling and Simulation*, 111–116. doi:10.1109/CIMSiM.2010.34

77. Naslund, D. (2008). Lean, six sigma and lean sigma: fads or real process improvement methods? *Business Process Management Journal*, *14*(3), 269–287.

78. Nauhria, Y., Wadhwa, S., & Pandey, S. (2009). ERP Enabled Lean Six Sigma : A Holistic Approach for Competitive Manufacturing. *Global Journal of Flexible Systems Management*, *10*(3), 35–43.

79. Nunamaker, J. F. J., Chen, M., & Purdin, T. D. M. (1991). Systems development in information systems research. *Journal of Management Information Systems / Winter 1990-91*, *7*(3), 89–106.

80. Ohno, T. (1988). *Toyota production system: beyond large-scale production* (p. 182). New York, New York: Productivity Press.

81. Paul, L. (2005). What's Holding Back Lean? *Managing Automation*, (October 2005), 31–34. doi:10.1007/s10549-010-0925-9

82. Plikynas, D. (2008). Multiagent Based Global Enterprise Resource Planning: Conceptual View. *WSEAS Transactions on Business and Economics*, *5*(6), 372–382.

83. Plikynas, D. (2010). Networking Conception for E-Manufacturing Systems. In *6th International Scientific Conference May 13–14, 2010, Vilnius, Lithuania*.

84. Pollock, N., & Williams, R. (2008). Software and organisations. In D. Preece (Ed.), *Software and organisations: The biography of the enterprise-wide system or how SAP conquered the world* (First Edit., p. 342). London and New York: Routledge.

85. Poppendieck, M. (2002). Principles of lean thinking. *OOPSLA Onward*.

86. Poppendieck, M., & Poppendieck, T. (2003). *Lean software development: an agile toolkit*. Upper Saddle River, NJ: Wesley, Addison.

87. Powell, D. (2012). *Investigating ERP Support for Lean Production*. Norwegian University of Science and Technology.

88. Powell, D., Riezebos, J., & Strandhagen, J. O. (2012). Lean production and ERP systems in SMEs: ERP support for pull production. *International Journal of Production Research*, *1*(15).

89. Quiescenti, M., Bruccoleri, M., La Commare, U., Noto La Diega, S., & Perrone, G. (2006). Business Process Oriented Design of ERP Systems for Small and Medium Enterprises. *International Journal of Production Research*, *19*, 3797–3811.

90. Ramnath, B. (2010). Application of Kanban system for implementing lean manufacturing (a case study). *Journal of Engineering Research and Studies*, *I*(I).

91. Rashid, M. A., Hossain, L., & Patrick, J. D. (2002). The evolution of ERP Systems: A historical perspective. *Enterprise Resource Planning: Global Opportunities & Challenges*, 1–16.

92. Rich, N., Bateman, N., Esain, A., Massey, L., & Samual, D. (2006). *Lean evolution: lessons from the workplace* (p. 211). New York, New York: Cambridge University Press.

93. Saeed, I., Juell-Skielse, G., & Uppström, E. (2012). Cloud enterprise resource planning adoption: Motives & barriers. *Advances in Enterprise Information Systems II*, 24.

94. Saeed, M., Maqbool, O., Babri, H. A., Hassan, S. Z., & Sarwar, S. M. (2003). Software clustering techniques and the use of combined algorithm. *Software Maintenance and Reengineering, 2003. Proceedings. Seventh European Conference on*.

95. Saira, K., Zariyawati, M. A., & Annuar, M. N. (2010). Information System and Firms. *International Business Research*, *3*(4), P28.

96. Scholtz, B., Calitz, A., & Cilliers, C. (2013). Usability Evaluation of a Medium-sized ERP System in Higher Education. *Electronic Journal of Information Systems …*, *16*(2), 148–161.

97. Schonberger, R. (2007). Japanese production management: An evolution—With mixed success. *Journal of Operations Management*, *25*(2), 403–419. doi:10.1016/j.jom.2006.04.003

98. Seidel, G., & Back, A. (2009). Success factor validation for global ERP programmes. In *17th European Conference on Information Systems* (pp. 1–13).

99. Seidel, G., & Back, A. (2011). Critical Success Factors of Global Enterprise Resource Planning Programmes: An Empirical Model Based on Expert Interviews. *European Conference on Information Systems*.

100. Senn, J. A. (1978). Essential principles of information systems development. *MIS Quarterly*, *2*(2), 17–26. doi:10.2307/248938

101. Shah, V., & Mehta, K. (2011). Using Enterprise Resource Planning To Gain A Global Competitive Advantage. *Review of Accounting Information Systems*, *3*(3), 27–32.

102. Shanks, G., Seddon, P. B., & Willcocks, L. (2003). *Second-wave enterprise resource planning systems: Implementing for effectiveness*. *Erasmus*. Cambridge Univ Pr.

103. Shaw, T. E., Lengyel, A., & Ferre, G. (2004). An assessment of the degree of implementation of the lean aerospace initiative principles and practices within the US aerospace and defense industry.

104. Shehab, E., Sharp, M., Supramaniam, L., & Spedding, T. A. (2004). Enterprise Resource Planning: An integrative review. *Business Process Management Journal*, *10*(4), 359–386.

105. Shtub, A., & Karni, R. (2009). *ERP: the dynamics of supply chain and process management* (Second.). Springer Verlag.

106. Sloan, P. (2005). Use-Case Analysis. *Unknown*, (October).

107. Snyder, R., & Hamdan, B. (2010). ERP and Success Factors. *ASBBS Anual Conference - Las Vegas*, *17*(1), 828–832.

108. Spear, S., & Bowen, H. H. K. (1999). Decoding the DNA of the Toyota Production System. *Harvard Business Review*, *77*, 96–108.

109. Staats, B. R., Brunner, D. J., & Upton, D. M. (2011). Lean principles, learning, and knowledge work: Evidence from a software services provider. *Journal of Operations Management*, *29*(5), 376–390. doi:10.1016/j.jom.2010.11.005

110. Steger-Jensen, K., & Hvolby, H. H. (2008). Review of an ERP System Supporting Lean Manufacturing. *Lean Business Systems and Beyond*, *257*, 67–74.

111. Stone, K. B. (2012). Four decades of lean: a systematic literature review. *International Journal of Lean Six Sigma*, *3*(2), 112–132. doi:10.1108/20401461211243702

112. Subramoniam, S., Nizar, H. M., Krishnankutty, K. V., & Gopalakrishnan, N. K. (2009). ERP II: Next generation ERP. *Riyadh Community College*.

113. Sugimori, Y., & Kusunoki, K. (1977). Toyota production system and kanban system materialization of just-in-time and respect-for-human system. *International Journal of Production Research*, *15*(6), 553–564.

114. Sye, G. L., & Jones, M. (2011). *Lean Six Sigma Acronyms, Terms and Definitions: Speaking the Language of Lean Six Sigma* (p. 35). Soarent Publishing.

115. Syspro. (2007). The When, Why and How of ERP support for LEAN. *Syspro White Paper*.

116. Tan, T. (2010). Going global - What should you expect from your ERP system? *Industry Week*.

117. Tichy, W. F. (1998). Should computer scientists experiment more? *IEEE*, *31*(5), 32–40. doi:10.1109/2.675631

118. Veague, R. (2011). How to Achieve Global ERP. *www.cio.com*. Retrieved June 06, 2013, from http://www.cio.com/article/694303/How_to_Achieve_Global_ERP

119. Venkatesh, V., & Brown, S. A. (2013). Bridging the qualitative – quantitative divide: guidelines for conducting mixed methods. *MIS Quarterly*, *10*(10), 1–34.

120. Volkmann, C. (2011). Microsoft Dynamics AX 2012 Lean Manufacturing : Kanban and Pull Based Manufacturing. *Microsoft White Paper*, (July 2011).

121. Volkmann, C., & Hietala, F. (2011). Microsoft Dynamics AX 2012 Lean manufacturing : Production flows and activities. *Microsoft White Paper*, 49.

122. Wallace, T. F., & Kremzar, M. H. (2001). *ERP: Making it happen*. *New York* (p. 372). New York, NY: John Wiley & Sons, Inc.

123. Wan, Y., & Clegg, B. (2011). Managing ERP, Interoperability Strategy and Dynamic Change in Enterprises. In *POMS 22nd Annual Conference: Operations Management: The Enabling Link*. Reno, Nevada, U.S.A.

124. Warfield, D. (2010). IS/IT research: a research methodologies review. *Journal of Theoretical and Applied Information Technology*, 28–35.

125. Wells, A. (2010). The ERP Umbrella. *TechTrends*, (May 2010), 2–4.

126. Wieder, B., Booth, P., Matolcsy, Z. P., & Ossimitz, M. L. (2006). The impact of ERP systems on firm and business process performance. *Journal of Enterprise Information Management*, *19*(1), 13–29. doi:10.1108/17410390610636850

127. Wiinberg, A. (2010). *Benefit realisation from Lean: a case study approach to seizing the benefits*. Luleå tekniska universitet.

128. Womack, J. P., & Jones, D. T. (2003). *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*. Simon and Schuster.

129. Womack, J. P., Jones, D. T., & Roos, D. (1990). *The Machine that Changed the World*. *Transition*. Macmillan Publishing Company.

130. Wood, B. (2007). SAP, ERP III, SOA — Learning Organizations through Social Media Collaboration. *R3now.com*. Retrieved from http://www.r3now.com/sap-erp-iii-soa-learning-organizations-through-social-media-collaboration/

131. Wood, B. (2010). ERP vs . ERP II vs . ERP III Future Enterprise Applications. *R3now.com*. Retrieved May 16, 2013, from http://www.r3now.com/erp-vs-erp-ii-vs-erp-iii-future-enterprise-applications/

132. Xu, L. Da. (2011). Enterprise systems: state-of-the-art and future trends. *IEEE Transactions on Industrial Informatics*, *7*(4), 630–640.

133. Xu, L., Wang, C., Luo, X., & Shi, Z. (2006). Integrating knowledge management and ERP in enterprise information systems. *Systems Research and Behavioral Science*, *23*(2), 147–156.

134. Yousefi, A. (2011). *Analysis of ERP Efficiency in Real Time Monitoring System in the Context of Value and Performance*. Northcentral University, Prescott Valley, Arizona.

135. Yue-xiao, L., Song, H., & Hui-you, C. (2008). Research on component-based ERP system. *Journal of Communication and Computer*, *5*(10), 6–12.

136. Zikmund, W. G. (2000). *Business Research Methods*. Thomson South - Western.

137. Zylstra, K. (1999). Lean Manufacturing and ERP - Conflict or Coexist? *Deloitte and Touche*, 1–6.