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How to cite this thesis

Enhancing enterprise resource planning and manufacturing execution system efficiency with simulation-based decision support

A Dissertation Submitted in Partial Fulfilment of the Degree of

MASTERS

In

ENGINEERING MANAGEMENT

at the

FACULTY OF ENGINEERING AND THE BUILT ENVIRONMENT

of

UNIVERSITY OF JOHANNESBURG

by

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June 2016

SUPERVISOR

DR. ARNESH TELUKDARIE
Abstract

Business corporates inclusive of large, medium and small-scale entities traditionally conducts activities based on business processes. Large multinationals have adopted various automation systems at various levels of business units, in capturing essential business activities across the entity. These automation systems, inclusive of Enterprise Resource Planning (ERP), Manufacturing Execution Systems (MES) and Plant systems has been adopted by larger corporates in executing and optimizing business functions. These large multinationals are described as complex entities with complex business structures inclusive of business processes. The effect of automation, escalations and other critical variables influencing these business processes has not been effectively quantified. “Systems thinking” adds the complexity of integrating all enterprise functions but creates a framework for evaluating the limitations and synergies so as to optimize these processes. This research focuses on the development and configuration of a simulation model for modelling enterprise maturity, directing attention to process maturity relative to the turnaround time of business processes.

This research approach includes hierarchical layout and segregation of these business processes, investigated adopting business process tools, techniques, and methodologies aligned with systems thinking approach. A simulation framework is configured and tested adopting scenario impact assessments based on certain key business variables aligned with associated critical constraints conditions. Optimization framework of these business variables is adopted in presenting an integrated case. The results prove that a simulation model potentially benefits a complex organization specific to evaluating time taken to conduct business processes. The results indicate that interdependent processes can be modelled together with determining impacts of multiple variables in reducing interdependent business process time. This implies that business entities can adopt and utilize outputs of this research to serve as a navigation tool specific to business process time when optimizing shop floor together with top floor communications and vice versa.

Keywords:
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To all the above-mentioned individuals and the University of Johannesburg which gave me the platform to carry out this research, I say a very big thank you.
Dedication

This research becomes deficient without recognizing the encouragement, support and love showered on me by my parents (Chief & Mrs. Medoh), Siblings (Emeka & Uche) and fiancée (Ekaba Blessing).

In loving memory of my late sister (Medoh Nneka Nwakaego).

To this caring and loving people, this research is dedicated.
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<th>Definition</th>
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<tbody>
<tr>
<td>ABM</td>
<td>Agent Based Modelling</td>
</tr>
<tr>
<td>APC</td>
<td>Advanced Process Control</td>
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<tr>
<td>BP</td>
<td>Business Process</td>
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<tr>
<td>BU</td>
<td>Business Unit</td>
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<tr>
<td>CMMS</td>
<td>Computerised Maintenance Management System</td>
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<tr>
<td>CIM</td>
<td>Computer Integrated Manufacturing</td>
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<tr>
<td>CRM</td>
<td>Customer Relationship Management</td>
</tr>
<tr>
<td>DCS</td>
<td>Distributed Control Systems</td>
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<tr>
<td>ERP</td>
<td>Enterprise Resource Planning</td>
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<tr>
<td>HRM</td>
<td>Human Resource Management</td>
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<tr>
<td>INCOSE</td>
<td>International Council on Systems Engineering</td>
</tr>
<tr>
<td>ISA</td>
<td>Instrument Society of America</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
</tr>
<tr>
<td>KPI</td>
<td>Key Performance Indicators</td>
</tr>
<tr>
<td>LIMS</td>
<td>Laboratory Information Management System</td>
</tr>
<tr>
<td>MES</td>
<td>Manufacturing Execution System</td>
</tr>
<tr>
<td>MESA</td>
<td>Manufacturing Enterprise Solutions Association</td>
</tr>
<tr>
<td>MOMS</td>
<td>Manufacturing Operations Management Systems</td>
</tr>
<tr>
<td>MRP</td>
<td>Material Requirement Planning</td>
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<tr>
<td>MRP II</td>
<td>Manufacturing Resource Planning</td>
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<tr>
<td>NC</td>
<td>Not Critical</td>
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<tr>
<td>PDES</td>
<td>Process Development Execution System</td>
</tr>
<tr>
<td>PLC</td>
<td>Programmable Logic Controllers</td>
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<tr>
<td>PLM</td>
<td>Product Lifecycle Management</td>
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<tr>
<td>PM</td>
<td>Process Mapping</td>
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<tr>
<td>SCADA</td>
<td>Supervisory Control and Data Acquisition</td>
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<tr>
<td>SD</td>
<td>System Dynamics</td>
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<tr>
<td>SLA</td>
<td>Service Level Agreement</td>
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<tr>
<td>STD</td>
<td>Standard</td>
</tr>
<tr>
<td>TAT</td>
<td>Turnaround Time</td>
</tr>
<tr>
<td>VIF</td>
<td>Very Important Factor</td>
</tr>
<tr>
<td>VHP</td>
<td>Very High Priority</td>
</tr>
<tr>
<td>WMS</td>
<td>Warehouse Management System</td>
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Chapter one: Background context

Chapter one presents the reader with an overview of this research, introducing systems inclusive of ERP; MES; and plant control systems. Synopsis of this research objective, questions, methodology and design is also presented.

1.1 Introduction

Business Processes (BP's) forms a critical component of business units. Enterprise activities are described by (Marianne & Gregory, 2015; Paradiso & Cruickshank, 2007; and Harmon, 2007) as a collection of enterprise functions unified together, adding value to process inputs, concurrently transforming these inputs to outputs. Process age has resulted in large business entities adopting several enterprise automation systems, in optimizing business functions (Ryan, Stephen, & Lee, 2009). A system is defined as a collection of several types of machinery or elements that collaborate to yield an output (INCOSE). Enterprise systems are then described as a group of machinery or elements adapted to support the business functions of any Business Unit (BU). Typically consisting ERP, MES and Plant System. These automation systems which can work independently comprises elements presenting enterprise professionals and researchers with a myriad of benefits, and can also collaborate so as to enhance performance service level of business systems. Interdependencies or synergies of these systems offer more leverage opportunities to BU's, which might include faster Turnaround Time (TAT); improved analytic capabilities; present holistic BP view; enhance operational efficiency; prompt business decision making; etc.

Literature review reveals a dearth of research(es) in effectively quantifying BP's of these automation systems as a unit. (Gove & Uzdenski) established that no singular integrated concepts have been adopted in assessing system optimization from design deployment, development stage to the operational utilization of business systems. This research seeks to develop and configure a framework to quantifying and optimizing business activities of these automation systems as a singular integrated entity relative to TAT. (Rechtin) established that synergies between elements making up a system produce a system-level output, and adds value as a unit rather than the yield it provides as an independent entity.

This research firstly defined critical variables potentially affecting business process time, in business process optimization activities. This is followed by extensive literature survey on adopted mixed methodologies inclusive of systems thinking approach, automation systems, BP modelling tools together with techniques, and consequently, converse proposed integrated case emerging from reviewed literature. This research finally wraps up by presenting a synopsis of this research findings and conclusions.
1.2 Synopsis of ERP, MES, and Plant Systems

ERP together with MES automation systems has been adopted by quite a number of business entities to optimize business delivery (Marianne & Gregory, 2015; Meyer, et.al. 2009). These two automation systems work concurrently towards the effective merging of “top floor to shop floor” BP’s. This enables optimal utilization of enterprise functions in any BU. ISA-95 (an international standard for developing an automated interface between enterprise and control systems), described MES as having a relationship with ERP on level 4. Integration of these systems enables enterprise professionals and researchers to be proactive around guaranteeing efficient delivery of quality products and services, in a cost-effective and timeous manner. Resulting in greater agility, consequently leading to data improvement. Unification of these systems aids enterprise professionals when implementing forecasting philosophies, making and executing business decisions (Margaret, 2015).

Advocates of MES often claim ERP software is directed towards office-based tasks, such as order entry, accounting and as such is of minimal value to the manufacturing department. ERP proponents dispute this assertion, that the main reason for this argument is historic since ERP has advanced with today’s solutions. ERP automation present BU’s with other functionalities enterprise human resource require together with integration necessary for an aligned, plant-wide view of production and efficient usage of data (Kunal, 2014). ERP automation handles customer orders, financial functions, and update production orders to the factory floor. This automation system is responsible for connecting plant floor events in real-time with business activities.

MES provides comprehensive utilization and control of factory floor, also giving up to date information to ERP automation. Activities include managing business operations from when order release is requested into manufacturing, to the point of service, and product delivery into finished goods (Subramaniam, 2009). MES acts a middle interface between individual machines inclusive of ERP and automation controls in a manufacturing enterprise. This is achievable through designing a modelled Computer-Integrated Manufacturing (CIM) system (Subramaniam, 2009).

CIM is a manufacturing concept of adopting computers in controlling an entire production process (Roebuck, 2012). Integration of this automation systems allows a distinct entity to exchange data with each automated workflows. Figure 1 below presents an overview of automation systems (MES, ERP, and Plant).
Figure 1: Automation systems to plant system overview

An overview of synergies between critical business functions making up these systems in an enterprise is presented in Figure 2 below. Illustrating data Flow in ERP, MES to plant control adapted from Manufacturing Enterprise Solutions Association (MESA), international standards and models association White Paper.

Figure 2: Data flow- ERP, MES to control adapted from MESA International white paper
1.3 **Background of Enterprise Resource Planning (ERP)**

ERP automation enables BU’s use a collection of integrated applications in managing processes and automating back office functions (Yvette et al., 2014). This system automation is designed to obtain and arrange data from various levels of organizational operations, furnishing enterprise professionals with insights to key Performance Indicators (KPI’s) in real time. Automating these systems enables enterprise professionals monitor, and manage the supply chain, procurement, inventory, finance, product lifecycle, together with other mission-critical components of the entity, through a succession of interconnected executive dashboards (Margaret, 2015).

Background information on ERP is quite comprehensive and interesting. Review of literature shows its study dates back to the 1940s with initial efforts at calculating machine. ERP evolved in the early 1960s from combined inputs between manufacturers of tractors and other construction machinery, where Material Requirement Planning (MRP) software came into limelight as an initial effort for planning and scheduling materials for complex manufactured products. MRP software did not look at timing only need, which brought about the existence of Manufacturing Resource Planning II (MRP II) developed between the late 1970s and the early 1980s, to bring both demand and time phasing of demand into planning processes.

Gartner group and others first adopted the acronym ERP in the 1990s where this automation system is perceived to broaden capabilities of MRP and MRP II, as well as CIM. Without replacing these terms, ERP represents a larger whole that reflected the evolution of application integration beyond manufacturing. Not all ERP modules developed from a manufacturing point of view, ERP vendors variously began creating this system packages with accounting, maintenance, and human resource components. ERP systems experienced rapid developments during the 1990s and by mid-1990s, all core enterprise functions are addressed. From the early 2000s till date, there have been numerous developments in this automation systems.

(Gupta) established that ERP automation gained extensive appeal in the 21st century owing to its “do it all” approach to enterprise management functions. Figure 3 summarizes historical activities as regards ERP background.
1.4 Problem statement

The advent of globalization and fierce competitions between large business corporates has resulted in business corporates changing significantly. (Al-Turki, Ayar, Yilbas, & Sahin) established that business entities are becoming very competitive, with extremely high pressure in optimizing business functions inclusive of TAT, throughput opportunities, and financial implications. These business entities have adopted numerous automation systems together with process management philosophies. These necessitates swift decision making, shorter TAT and fast transfer of information (Song & Zhu, 2011). Besides these large multinationals introducing various automation systems in executing BP’s, business corporates have segregated business functions into critical and offline business components. A framework for promoting business “best practices” and process improvement objectives is essential. Recent publications have resulted in researchers adopting different methods in quantifying the effects of change, and other impacts of BP optimization. Literature review shows almost 70 percent of BP optimization projects have failed to bring about the expected benefits (Grant, 2002; Craig, 2003). TAT forms an integral component of process optimization projects. Literature examination reveals not many publications have effectively quantified BP’s, change and impacts relative to the business state, maturity, and optimised TAT. (Siha & Saad) established that BU’s are directing efforts towards
internally enhancing BP’s continuously in several frameworks, so as to cushion the effects of global changes. Lee & Lee also affirmed this assertion by establishing that a framework for promoting business best practices and process improvement objectives is necessitated, to limit the impacts of these changes. This research seeks to develop and configure a framework for effectively quantifying these BP’s relative to TAT, adopting “systems thinking approach” aligned with different BP modelling tools, techniques, and methodologies. This research investigates BP’s making up large corporates, quantifying time spent or how long it takes in executing process steps of these automation systems. Literature review reveals huge attention is directed to ERP automation, rather than executing BP optimization actions on synergies of these automation systems as a unit, inclusive of MES and plant systems. MES process integration with other key business IT systems presents a platform for enabling business organizations to view over all facets of enterprise operations (Todd, 2009). This research seeks to enhance the way business entities approach BP improvement projects relative to optimizing TAT. There is a necessity to configure a framework for the up-front evaluation of automation systems as a unit. Together with distinct effectiveness and impacts of certain critical business variables, aligned with associated business states on process maturity. Results present a handy document and tool which can be adopted by enterprise professionals, scholars, practitioners and BU’s involved in implementation, design, enhancement or application of these automation systems for external and internal benchmarking. Numerous advantages exist in optimizing BP’s, a synopsis of these advantages as described by (Nixon, 2015) is presented below.

1.5 Advantages of enhancing business processes
- Presents an overview that investigates process in context and promotes further grasp for the procedure. In addition, presents an outlook of other functional areas in a process which helps lessens the silo effect.
- Assist in streamlining execution of business functions singularly and together as a team.
- Leads to fewer errors, delays and less duplicated effort.
- Enhance productivity, efficiency, and control together with customer satisfaction.
- Aligns operations with new business philosophies.
- Improves process communication.
- Enables business organizations gain competitive advantage.
- Increases Cost efficiency.
- Improves business agility.
- Enhances customer focus and staff satisfaction.
1.6 Research objectives

The principal objective of this research is geared towards presenting an optimised business state. Achieved by developing an integrated case together with investigating the impacts of change on process, business and system maturity. The proposed integrated case seeks to optimize communication between enterprise systems, the specific focus being BP TAT. Simchil-Levi et al.; Lee & Lee argued for BU’s to remain competitive in this era of organizational competitiveness, such business entities must strive towards shorter BP TAT. In order to accomplish the above stated main objectives, the following subordinate goals are outlined:

- To determine the core BP of a large business together with the definition of these processes relative to global standards.
- Develop a representative (80% accurate) set of BP’s and configure in a current BP tool.
- To review, select, configure and simulate two priority processes.
- To determine critical variables together with distinct essential constraints having a significant effect on BP optimization activities specific to BP TAT.
- Develop a simulation model of the selected BP’s.
- Development of an experimental framework to test scenarios, impacts, and potential benefits of the critical variables relative to optimised TAT.
- Present recommendations on optimizing BP’s relative to critical variables and business process TAT.

Examining these objectives expedites business decisions and efficiency, illustrating how these automation systems interact with each other as it relates “Top floor to Shop floor” communication and vice versa. Results of the above-enumerated objectives add to the existing body of knowledge within manufacturing and process community.

1.7 Research questions

Pertinent questions which might arise in evaluating identified gaps of this research objectives include but not limited to:

- What are the critical factors affecting a BP?
- What are the levels of importance of each of these critical factors?
- What are the essential critical variables together with associated business states having a consequential impact on these critical factors?
- What BP tools, techniques, and methodologies can be adopted in developing, testing, together with configuring an experimental model for proposed optimised business state?
Answers to research questions detailed above bring applicable insights into “systems thinking”, “modelling and process mapping”, “simulation approaches” and “process optimization”.

1.8 Research process
This research adopts the following research process in investigating above detailed objectives and questions as illustrated in Figure 4 below.

![Research Process Diagram]

Figure 4: Research Process

1.9 Research methodology and design
Enterprise professionals and scholars have adopted numerous methods in quantifying and investigating BP’s when executing optimization actions. Sharpening this edge over time becomes increasingly difficult (McDonald & Jones, 2012), except through continuous investigation and quantification carried out by aligning new methodologies into core enterprise functions. How can large corporates develop and sustain a new edge when grinding away at respective current philosophies, remaining productively competitive together with attaining productive edge. The answer lies in such BU’s being able to make quick decisions, enhanced information transfer and shorter cycles times (Simchil-Levi et al., 2000; Lee & Lee, 2009).

In fulfilling this research set objective, “Systems Thinking Approach” aligned with several BP tools, techniques and methodologies are adopted in order to discover, map out, configure, understand, together with manage the current phase of BP’s and recommend improvements for achieving set purpose. An initial step in addressing objectives of this research, a literature review of these BP’s together with respective critical variables having significant impacts on these processes is carried out.
adopting systems thinking approach. Bringing multiple processes of these automation systems together, through investigating synergies and interdependencies of this automation systems as a unit rather than as an independent entity.

In this research “Microsoft Visio” and “Simulation-Based Decision Support Approach” BP tools and techniques is adopted as part of the mixed methodologies utilised in executing this research objective. Focus is directed to “Maintenance” and “Logistics” systems which can be reasoned among the essential differentiators, for optimum process optimization operations relative to global best practices. Reasons for these choices of selection has been presented in literature review chapter of this research.

1.10 Data collection and analysis

In this research, both primary and secondary data is put into cognisance. This research collected primary data through an opinion poll from professionals and scholars across some large business entities in South Africa. This served as a framework for gathering data on critical process steps relative to logistics and maintenance systems, ensuring quality and type of data collected is plausible. Secondary data is collected from review of books, articles, journals, thesis and dissertations describing applications, challenges, and implementation of this research methodological approaches. These materials are available at the university of Johannesburg library and also through an online medium (internet search).

After collection of data, activities of these processes is modelled, simulated and analysed adopting “Microsoft Visio” and “Simulation” BP tool. Recommendations are then outlined, which if implemented would accelerate overall efficiency of these automation systems and improve organizational competitiveness.

1.11 Research report layout

This research is composed of five chapters with each chapter commencing with an introduction and concluding with a summary. Breakdown of these chapters is as illustrated in Figure 5 below.
### Chapter 1.12 Chapter summary

Chapter one presented an introduction and synopsis of ERP automation together with MES and plant systems. This research problem, objectives, questions, limitations, methodology, and design is also presented. The next chapter seeks to investigate how established literature applies to the objectives in this research.
2 Chapter two: Literature review

The previous chapter presented background context of this research. Chapter two presents the reader with a comprehensive literature review of this research, inclusive of information on what other researchers have discovered in this domain of study.

2.1 Introduction

Literature examination of this research is dependent on review of articles, dissertations, and journals. Describing the execution or implementation of systems engineering, BP tools & techniques, systems thinking, MES; ERP & plant automation systems, together with logistics and maintenance systems. These materials are available at the university of Johannesburg library and online sources (internet search). Literature review shows attention is focused on ERP automation systems, rather than executing BP optimization actions on inter-dependencies of these automation systems as a unit, inclusive of MES and plant systems. The previous chapter of this research illustrates communication between these automation systems from "top floor to shop floor" and vice versa relative to ERP, MES together with plant control. In this research, a holistic view of these automation systems is carried out adopting systems thinking approach, bringing multiple processes together as an integrated unit. Numerous BP modelling tools, techniques, and methodologies have been introduced, inclusive of Microsoft Visio, ARIS toolset, ADONIS toolset, visual paradigm toolset, Bonapart toolset, and simulation packages. As refined toolsets for system optimization activities. (Lattila) established, simulation software's comes into perspective when developing sophisticated or refined tools in decision support systems, and improving the efficiency of BP’s. Microsoft Visio tool and techniques inclusive of Process Mapping (PM) is also regarded as one of the essential resources in improving BP’s, illustrating "what BP’s are executed", "who executes the BP’s", "how these BP’s are executed" and "where distinct BP is executed". This research adopts systems thinking approach together with simulation and Microsoft Visio tool and techniques in presenting and optimizing proposed integrated case.

These tools, techniques, and methodology are brought together to develop, configure, analyse and illustrate that proposed critical variables “human resource resolution time”, “escalation rate”, “critical factor”, “system resolution time”, “system maturity index”, and “business state index” with distinctly associated business states has an impact on process TAT relative to logistics and maintenance systems. Synopsis of these mixed methodologies which include system thinking approach, Microsoft Visio tools & techniques, and simulation tool & techniques together with distinct reasons for selection is detailed in later sections of this chapter. Definition and reasons for selection of proposed critical variables potentially affecting the TAT in business process optimization are also presented.
MES has developed considerably into more advanced, integrated and efficient machinery with the advancements in global automation systems (Pellerin et. al. 2009). The distinct relationship between MES with other enterprise levels is detailed in sub-sections below.

### 2.2 MES relationship with other enterprise systems

MES has a relationship with other enterprise systems acting on different levels inclusive of ERP and plant controls. Integration with other enterprise systems simply describes how these automation systems work concurrently towards effective linking of shop-floor to top-floor activities. Synchronizing automation systems necessitate efficient utilization or management of BP’s in any BU. Aligning with the ISA-95 model, there are five different levels in an enterprise system, which includes level 4, level 3, level 2, level 1 and level 0. Illustrations presenting MES positioning in CIM context is depicted in Figure 6 while Table 1 shows enterprise levels and respective functionalities.

<table>
<thead>
<tr>
<th>ENTERPRISE LEVEL</th>
<th>ENTERPRISE DOMAIN</th>
<th>FUNCTIONALITIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 0 (L0)</td>
<td>Actual physical process.</td>
<td>High-level aggregation of physical processes.</td>
</tr>
<tr>
<td>Level 1 (L1)</td>
<td>Intelligent device level.</td>
<td>Manipulation and sensing of physical processes occur.</td>
</tr>
<tr>
<td>Level 2 (L2)</td>
<td>Control systems level.</td>
<td>Controlling, supervising and monitoring of physical processes occurs.</td>
</tr>
<tr>
<td>Level 3 (L3)</td>
<td>Manufacturing operations level.</td>
<td>Detail scheduling and process optimization including performance and resource management. etc.</td>
</tr>
<tr>
<td>Level 4 (L4)</td>
<td>Business logistics level.</td>
<td>Demand and supply chain planning, cost accounting, human resource management. e.tc.</td>
</tr>
</tbody>
</table>

Table 1: Enterprise levels and functionalities adapted from ISA-95 model
Level 4 is generally regarded as business planning and logistic level. Activities at this level include demand planning, supply chain planning, cost accounting, human resource management, sales and distribution, material management, production planning, warehouse management, and maintenance management (Subramaniam, 2009). Systems acting on ISA-95 level 4 enterprise comprises Product Lifecycle Management (PLM), Customer Relationship Management (CRM), Human Resource Management (HRM), Enterprise Resource Planning (ERP), and Process Development Execution System (PDES). Literature review reveals that quite frequently, middleware enterprise application unification systems are adopted when exchanging interaction messages between MES and level 4 enterprise systems. Where a data definition has been defined within ISA-95 standard to link MES systems to these level 4 systems.

Level 3 is referred to as manufacturing operations level. Activities at this level include but not limited to detail scheduling, recipe management, process optimization, performance management, production execution, process analysis, resource management, production history, and quality management (Subramaniam, 2009). Accumulations of systems on ISA-95 level 3 are referred to as Manufacturing Operations Management Systems (MOMS). Examples of systems acting on level 3 enterprise systems besides MES are Laboratory Information Management System (LIMS),
Computerised Maintenance Management System (CMMS) and Warehouse Management System (WMS).

Level 0, 1, 2 are known as plant or shop floor control level. MES connects mostly with these level systems for exchange of plant floor data. Some of the activities of these level systems include real-time execution, real-time monitoring and real-time control (Subramaniam, 2009). Level 0 defines the actual physical process, level 1 is the intelligent device level where manipulation and sensing of physical processes occur, while level 2 is the control systems level where controlling, supervising, and monitoring of physical processes occurs. Connectivity between this level systems most often begins with Supervisory Control and Data Acquisition (SCADA) or Distributed Control Systems (DCS), where plant floor data is first gathered and examined for real-time supervision. Direct exchange of information between plant floor equipment data is founded by connecting to Programmable Logic Controllers (PLC). Examples of systems associated with ISA-95 level 0, 1, 2 are SCADA, DCS, PLC, and Batch Automation Systems.

2.3 Characteristics of MES and ERP

Characteristics are distinguishing qualities or peculiar attributes a component or system must possess. For effective implementation of ERP and MES within an enterprise, the following technological characteristics as described by (Exforsys, 2007) must be accommodated.

- Use or integration of relational database that functions in or almost real time without many dependencies on regular updates.
- Very flexible, as most business enterprises need to change or update distinct operations and transactions on a frequent basis. An ideal MES must be able to conform to these changes.
- Enhanced modularity, which means the module must have the ability to be separated whenever it is required to function with other system modules. Must also be proficient in supporting more than one computer framework.

2.4 Essence of MES and ERP

The Inherent nature of a system is described as its essence. Business entities interested in ERP together with MES automation systems needs to comprehend what the essence of these automation systems is before implementation. Vanarsdall and Exforsys presented a summary of this essence as presented below.

- Processes are all handled as same in MES unlike computing in traditional systems which involves singular transactions handled separately.
There are numerous data tables which accumulate information for several transactions and are not restricted, unlike traditional systems where there exists no connection between application programs adopted by different departments.

These automation systems enhance standards with respect to management obligations and internal functional productivity, by the integration of easily obtainable enterprise resources through the help of functional processes and standard information data.

Improves successful execution of management principles, by integration of MES which is built based on optimised and current business operation process. These automation systems are also capable of implementing data-sharing under a united technical platform.

Provides insights to business management concepts, and carries out the united enterprise process. Consisting all kinds of fundamental business data and develops various reports for management.

### 2.5 MES functional areas

MESA drafted out MES core business operations or functional areas during previous publications (MESA model 1997b) in terms of distinct activities into eleven (11) principal MES functions as illustrated in Figure 7 below.

![Figure 7: Overview of MES core-processes](image)
ZVEI, a German electrical and electronic manufacturing association further segregated these core processes into smaller sections, in terms of distinct connections and functions. These include operations request, operations definition, operations capability, and operations response. (Weiss, 2009) further affirmed that these sections exist in four functional areas across manufacturing operations management level which includes: production, quality, inventory, and maintenance.

2.6 ERP functional areas

Literature examination from MESA international white paper discloses the following functional areas for ERP automation, commonly grouped together and called ERP modules. Synopsis of these functional areas is illustrated in Figure 8 below.

![Figure 8: Overview of ERP core-process](image)

(Salvendy) established that activities of ERP automation system exist in two (2) functional groups which include execution and Planning activities, across manufacturing operations management level as depicted in Figure 9 below.

![Figure 9: Activities in ERP core process](image)
### 2.7 Core processes in Plant Control

Core processes at Plant/Shop Floor as illustrated in MESA international white paper is enumerated below:

- Monitoring and Sensing
- Control
- Operations

**Figure 10: Core processes of control**

### 2.8 Functional areas of a large multinational

Core processes in a large multinational as depicted by (Subramaniam, 2009) comprises:

- Human resource management
- Marketing
- Production operations
- Accounting
- Finance
- Supply Chain
- Research
- Logistics
- Security
- HSE
- Maintenance
Figure 11: Synopsis of large multinational core-processes

2.9 Advantages/benefits of MES and ERP

If ERP and MES are properly integrated into an enterprise, such business entities would attain unparalleled benefits for business competitiveness and reckoning. Advantages/benefits of MES as described by (Olhager & Selldin, 2003; and Mabert, et al., 2000) can be summarised as follows:

- Swift information response together with resolution time, improved order cycle and efficient cash management.
- Enhanced quality, data security, tracking functions, decision making, and efficiency of the business.
- Reduction in direct operating cost and inventory level.
- Strengthens interactions or communication both externally and internally across the enterprise inclusive of suppliers, customers, and organization.
- Presents to the enterprise less rigidity and more flexibility in making the business entity swift. Sales forecasting which necessitates inventory optimization and unnecessary duplication of data.
- Elicits easier evaluation of organizations profitability and faster response to any unforeseen circumstances.
2.10 Disadvantages/limitations of MES and ERP

Advantages of ERP and MES usually outweigh its disadvantages for most business entities implementing these systems (Panic, 2014). A large number of business organizations supposedly see advantages of MES and ERP automation systems without giving a chance to study some of its limitations/disadvantages. A detailed synopsis of these disadvantages is presented by (Christina, 2013) in one of her studies as follow:

- Very high cost of maintenance and implementation. ERP system comprises a high initial investment, unification, data analysis and alteration.
- Security concerns and the extent of customization is restricted or limited in most circumstances.
- Adaptation of the hardware in the enterprise. There is a necessity for employees to undergo training in the organization on the efficient and effective use of these automation systems, which requires lots of effort, time, and resources.
- There could be a scarcity of continuous technical assistance.
- Implementation and execution take quite a lot of time because of the necessity to re-engineer business operations.
- Since these are generic technologies, might result to the rigidity of the system.

2.11 Plant control system

Control systems are devices or accumulation of devices that manages, commands, regulates or directs the behavior of other devices or systems (Schreuder, 2014). These control systems are classified into two categories namely closed loop control systems referred to as feedback control system, and open loop control systems (Wilamowski & Irwin, 2011). Basic distinctions between these two categories of control systems are that output in open loop systems is developed based on inputs, meaning open loop systems do not require feedbacks and only run in pre-arranged ways. While in a closed loop, the output is required and corrections are outlined based on feedback.

Process optimization or control which may either be a closed loop control system or an open loop control system is a statistical and engineering tool adopted in an enterprise. Which deals with algorithms, mechanism, and architectures for sustaining the output of a specific process within a set range (Kurian, 2013). Major benefits of process control lie in the fact that it encourages or promotes automation in such a way that few operating personnel can operate a complicated or complex process from a control compartment. Systems such as PLC, DCS, and SCADA acting on ISA-95 level 0, 1, 2 are adopted in controlling complex and less complex process control systems. PLC is a digital computer utilised for automation in process control systems to decode sets of digital and analogue inputs, create
sets of digital and analogue outputs, and apply sets of logic statements. More complex process control systems can be controlled by a digital computer known as DCS and SCADA system.

2.12 Logic behind adopting logistics and maintenance systems

Numerous functional processes of ERP, MES, together with plant control automation systems exists as described in detail in earlier sections of this chapter. Placing time constraints into considerations, this research is unable to evaluate these core business functions in entirety. Rather an integrated case adopting two core processes of these automation systems is presented. Illustrating a framework which can be adopted for establishing this research objective. These two adopted core processes ought to be intent towards meeting this research set objective. Configured integrated case illustrates that proposed critical variables to be adopted in this research together with distinctly associated business states would have an impact on BP steps of these automation systems relative to optimised TAT.

Attention is directed to “maintenance” and “logistics” systems among numerous functional processes of these automation systems.

These core enterprise functions are reasoned to be among the essential differentiators for optimum process optimization operations in large corporates, relative to international best practices. Al-Turki, Ayar, Yilbas, & Sahin established that maintenance philosophies are a critical domain of ERP together with MES automation systems. Describing this enterprise activity as one core enterprise functions of engineering and asset management as a whole. (Evgeny & Tomohiro) affirmed the importance of this business function, by establishing that maintenance philosophies have a significant impact on the financial implications of a system, and adopting suitable maintenance policies is critical for any large corporate. Lattila asserted, logistics in totality is a major source of costs for any business entity. As detailed in earlier sections of this research, simulation BP tools and techniques are adopted as one core methodology utilised in accomplishing this research objective. Evgeny & Tomohiro established that simulation packages can be adopted when developing a maintenance flow or work orders. Simulation software’s can be utilised as a tool for analyzing and improving maintenance processes (Ivana & Branko, 2001). (Hongbo & Zhongwei) established that with logistics becoming more and more intricate, whose internal connection is becoming stronger than before, the modelling and simulation method also becomes more and more essential during the process of logistics system completion. (Hesse & Rodrigue) also affirmed that efficiency enhancements are major attributes in logistics management process, which is significantly visible in the development of cycle time demands during the last 50 years. This research adopts logistics and maintenance systems, utilised for accomplishing this research objective, presenting and illustrating an integrated case when aligned with validated
thoughts detailed above. This research seeks to model and simulate processes of these systems to at least 80% process accuracy. Synopsis of these systems is presented in sub-sections below.

### 2.12.1 Logistics management

Canadian association of logistics management defined Logistics as the succession of functions, which comprises harmonizing materials and information flow across a supply chain. Logistics process involves organizing, implementing, executing and controlling efficient cost effective flow together with storage of raw materials, in-process inventory, finished goods and information from the source of origin to source of consumption. Logistics is an essential business and functional activity for any business BU appraising strategic business assets of ERP together with MES automation and technology, ensuring customer requirements are met. In executing effective logistics management concepts, large corporates must draft out logistic management goals and objectives for the business enterprise. The overall goal together with the objective of logistics management is to have a framework that supports production order types, facility or location material handling, operations and organization philosophies, information systems investment management, planning and control performance measures, cost reduction, capital reduction, service improvement etc. presenting information for containerization, automatically guiding vehicles for picking, presenting best inventory plans for customers and suppliers, sending alert signals for exceptions discovered on the system and put-away, monitoring and handling large scale movements and accounting in the reverse direction etc.

Aligning with logistics best practices, this research logistics maturity model is segmented into three key enablement management actions which include logistics strategies; logistics execution and logistics control. Logistics execution is further segregated into inbound logistics; in-process logistics; and outbound logistics. A Visio depiction illustrating comprehensive logistics maturing model is presented in later sections and appendix of this research.

### 2.12.2 Maintenance management

Maintenance is described as a critical functional area of MES together with ERP in any business domain. This enterprise activity has an effect on every other functional area associated with these automation systems. In its narrow meaning, comprises a sequence of processes related to maintaining a certain level of availability and reliability of a system together with distinct components and ability to operate at standard levels of quality. This ensures manufacturing plants are continually operational or keeps running (Al-Turki et al., 2014). Modern maintenance management doesn't necessarily involve repairing broken machinery, rather comprises activities carried out towards keeping the system...
functional or running at optimal capacity (Bisina, 2008). Thus, producing quality outputs or products at minimal cost possible. Marquez also described this enterprise activity as the combination of all managerial, technical, and administrative tasks throughout the life cycle of a component, designed to keep it in or return it to a condition in which it can execute expected functions.

In accomplishing a productive maintenance management concept, a business enterprise should outline distinct organization strategic goals and objectives. The overall goal of maintenance management is to discover and analyze improvement areas with a view of reducing cumulative total repair time and enhancing customer value, thereby improving maintenance services. Other goals and objectives as enumerated by (Subramanyam, 2009) include but not limited to compliance, safety & risk management; automation and scheduling; training, support, predictive maintenance & parts management; plant and line efficiency; and preventing breakdown or failures through eliminating downtime events or reducing downtime durations .etc.

Aligning with maintenance best practices, this research maintenance maturity model is segmented into two key maintenance enablement philosophies which include planned maintenance (proactive) and unplanned maintenance (reactive). These philosophies are further segregated into several process steps which include Preventive, Corrective, Predictive maintenance .etc. relative to each distinct process level, adapted from established publications by (Dhillon & Liu, 2006). Preventive maintenance is often regarded as planned maintenance and executed regularly or after an inspection in order to keep equipment or machinery in working condition. Corrective maintenance is carried out to return equipment or machinery to working condition after a breakdown or after perceived deficiencies. Predictive maintenance adopts technology in diagnosing item(s) or equipment(s) condition during operation. This type of maintenance involves the process of gathering information about the state of machinery which is then adopted in planning and scheduling maintenance activities. These three types of maintenance process can be categorised as planned maintenance operations. There exist a maintenance task known as run to failure maintenance, which can be categorised as unplanned maintenance process, further subdivided into emergency and breakdown maintenance. A Visio depiction illustrating comprehensive maintenance maturing model is presented in later sections and appendix of this research.

BP modelling tools and techniques are adopted in laying out these systems relative to maintenance and logistics process steps. The next section presents a synopsis of these methodologies.

2.13 Business process model/flow

Modelling involves discovering optimality and consistency from a problem to its solution adopting a risk-free platform, permitting the modeller to commit errors, undo mistakes, return in time, and begin
the process all over (Grigoryev, 2015). European association of BP management defined BP model as the systematic approach of depicting tasks. These BP’s might include measuring, capturing, documenting, execution, monitoring and controlling automated and non-automated processes. These processes are illustrated in an enterprise so as to attain specific goals, either for the current process to be analysed or enhanced.

BP model adopts flow tools when describing sets of steps or activities developed in order to achieve specific business functions. These steps may include BP’s for finance, security, human resources, shipping activities, maintenance, logistics, or simply the overall transformation of an input into a desirable output (Rosenberg, 2010). BP flows may be adopted in differentiating or examining several forms of data that a simple flow would not easily identify, sometimes viewed as an essential tool or asset because of its peculiar characteristics. These attributes include the ability to be clear, succinct, complete and decisive in depicting an entire process from start to finish. BP flow presents inputs, route, actions, decision points and completion for any business entity.

2.13.1 Background of business process model

Historical background of BP model is quite extensive and interesting. An overview of the background is summarised as follows:

BP model background dates back to the 20th century when techniques adopted in modelling BP’s such as Gantt chart, flow chart, control flow diagram, functional flow block diagram, PERT diagram, and IDEF developed. The terminology BP modelling was coined in the late 1960s in the field of system engineering by (Williams) during his 1967 article “Business Process Modelling Improves Administrative Control”. His thought is that techniques for developing a more appealing comprehension of physical control systems could be adopted in the same way for business functions. However, the term didn’t prevail until the 1990s when “processes” as a terminology became a new productivity model. Business entities are inspired to think “processes” instead of “functions” and “procedures”. These thoughts results to the designing of traditional modelling tools adopted in illustrating time and cost, which necessitated a redesign of modern tools with the aim of focussing on cross-functional activities. During the early 1990s, all existing and new modelling methodologies adopted in illustrating BP's is merged as “BP modelling languages”. BP modelling became a platform for new technologies and around 1995, the first visually oriented tools for BP execution and modelling is presented.
2.13.2 Attributes of business process model/flow

BP flow document inputs or requests for information, products or any other deliverables and routine steps in accomplishing such request and output or deliverables that is developed by the input. Components of a BP may include but not restricted to:

- Data required in accomplishing an enterprise objective.
- Tasks that generates or alters data.
- Decisions that develops or change data.
- Control points for statutory obligations.
- Error correction activities.
- Department who performs tasks.
- Owners of the task or functions.

There are six levels of BP flow as great care and analysis need to be given during breakdown of processes, sub-processes, and functions. Synopsis of these level types is described by (Rosenberg, 2010) and presented below as follows:

- **Level 1**: Regarded as business area level depicting a function which is a high-level aggregation of an enterprise presenting mainly logical Flows (core support functionalities depending on the framework of the process to be examined). At this level flow, too much information is not added, as it necessitates complexities to this level illustrations. Level 1 illustrations must, therefore, be proportionately simple displaying only major Processes. Attributes of level 1 function include:
  - Level 1 illustrations present an optimal level of a Process Flow.
  - Consists of multiple Processes.
  - Usually Cross-Functional.

- **Level 2**: Known as process group level comprising activities and functions within a business enterprise belonging to the same domain of responsibility for its functional area. Characteristics of level 2 functions include:
  - Usually, Cross-Functional which are the primary tasks within a Function.
  - Includes tasks which have a beginning and an end, generally transform data and ought to have a higher level of detail than Functions.
  - Level 2 illustrations can be broken down into other functions or Sub-Processes.

- **Level 3**: Considered as BP level which often times comprises of sub-processes. This level flows consist of sub-processes usually relating to procedures, aggregating business oriented functions or steps to a unit that is meaningful and comprehensive, in the sense that steps or functions incorporated are essential in fulfilling a business mission related task. Sub-Processes are described as specific tasks which transform data that cannot be further split, but based on the
size of an enterprise and range of distinct activities, the number of Sub-Processes may not be the same.

- **Level 4:** Regarded as BP variant level. This level flow is often times adopted for further subdivisions of subprocess fulfilling same business-critical mission but in a different approach or with a different application compared to BP’s explained in level 3. In this level flow, input and output are more or less same but the route to reach output is different. It is unsuitable to use level 4 flow as a catch-all or due to insufficient planning, but perfectly justified when adopted in showing singular information or for unusually complex or complicated processes.

- Level 5: Described as process step or level comprising activities that are correlated to exactly one object, typically executed by one person and documented adopting a suitable representation of the object. From a user interaction point of view, this level flow is regarded as a single work task in a casual workflow without role change, usually identified by the fact that process task owners have got all necessary obligations in implementing such task.

- Level 6: Viewed as activity level. This level flow are considered as the lowest level for BP modelling and illustrates all single actions a user or system carry out in fulfilling a given process step.

<table>
<thead>
<tr>
<th>BUSINESS PROCESS FLOW</th>
<th>BUSINESS LEVEL DOMAIN</th>
<th>FUNCTIONALITIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1 (L1)</td>
<td>Business Area</td>
<td>High-level aggregation of an enterprise presenting mainly logical flows.</td>
</tr>
<tr>
<td>Level 2 (L2)</td>
<td>Process Group</td>
<td>BP’s within an entity belonging to the same domain of responsibility.</td>
</tr>
<tr>
<td>Level 3 (L3)</td>
<td>Business Process</td>
<td>Consists of sub-processes aggregating business oriented steps to a unit.</td>
</tr>
<tr>
<td>Level 4 (L4)</td>
<td>Process Variant</td>
<td>Adopted for further subdivisions of the sub-processes fulfilling same business-critical mission but in a different approach.</td>
</tr>
<tr>
<td>Level 5 (L5)</td>
<td>Process Step</td>
<td>Level comprising activities that are correlated to exactly one object, typically executed by one person.</td>
</tr>
<tr>
<td>Level 6 (L6)</td>
<td>Activity Level</td>
<td>The lowest level for BP modelling depicting all single actions a user or system carry out in fulfilling a given process step.</td>
</tr>
</tbody>
</table>

Table 2: Business process flow levels adapted from (Rosenberg, 2010)
This research adopts “Microsoft Visio” and “Simulation” BP tools, techniques, and methodologies aligned with “systems thinking” approach in developing together with configuring a BP model. Description of this approach and methodologies is presented in sections below.

2.14 Synopsis of systems thinking approach

The International Council on Systems Engineering (INCOSE) defined systems engineering as an interdisciplinary methodology, inclusive of technical and business approaches, which necessitates the integration and accomplishment of successful business technologies. Systems thinking approach is an integral part of this technical and business approaches. Earlier sections of this research review in detail “Top floor to Plant floor” automation systems, inclusive of ERP, MES together with plant systems, and why these technologies can be considered as an innovative and flexible computerised system. “System thinking approach” seeks to investigate how BP steps of these automation systems can be integrated or collaborated effectively, resulting to an enhanced business enterprise.

Bahill, & Gissing established seven (7) systems thinking steps. This research adopts these steps which include “stating the problem”, “investigating feasible alternatives”, “modelling the system”, “integrating the system”, “launching the system”, “assessing system performance” and “re-evaluating the system”, in examining this research objective. Synopsis of these steps is presented below.

**Stating the problem**: This system thinking phase should present a description of “what”, together with “how” this research intends to investigate and resolve stated objectives.

**Investigating feasible alternatives**: Involves examining alternative approaches to illustrate a clearer picture of this research stated objectives.

**Modelling the system**: A business state model of this research methodologies should be developed and configured.

**Integrating the system**: Methodological approaches to this research should be validated with earlier established research(es).

**Launching the system**: Launching the system means allowing configured business model illustrate distinctly intended objectives.

**Assessing system performance**: Involves exploring multiple iteration or standard conditions in assessing for system performance.

**Re-evaluating the system**: This step describes the significance of constantly re-evaluating developed and configured business model.
2.15 Synopsis of simulation business process tool and techniques

The dynamics inherent of manufacturing systems are most often times too complex and complicated to be dealt with from an analytical perspective. Especially when manufacturing functions have attributes like high variety and low quantity production, unexpected events, a large number of planning decisions, routing flexibility, etc. Simulation BP modelling tool and techniques avail itself as a powerful and important tool for performance examination, analysis and efficiency improvement (Ingalls et al., 2004). This tool together with techniques is adopted for implementing or executing modelling scenarios, and usable in numerous fields besides engineering. Tuncer defined this methodology as the process of conducting experiments with a model, for the purpose of observing together with understanding the behaviour of the system modelled under selected framework. This tool and techniques can also be adopted when evaluating various processes for the operation of a system, within the constraints set by developmental or operational standards.

Simulation modelling involves succession of steps, these steps enumerated by (Ingalls et al., 2004) are listed below:

- Conceptual problem formulation and analysis: The decision maker and examiner must be in harmony on a good problem articulation from the very beginning of the study.
- Data and Information Collection: This is an essential aspect among simulation steps. This research intends to achieve this step through literature search and PM. However, data collection occurs throughout the whole simulation process as the model must be refined and adjusted in several instances, so as to attain perfection towards promoting better outputs.
- Model building: When data has been gathered, the information collected is adopted in designing a conceptual model.
- Verification and validation: it is paramount to ensure the designed model corresponds to the real system in order to carry out the experiment and propose changes. Verification simply refers to the model performing required task while validation ascribes to the model illustrating the system as a whole (Banks et al., 2004).
- Experiment design: Experimental design involves selecting the alternatives to be simulated which is more or less an iterative process in conjunction with the analysis phase. These alternatives refer to different policies relating to the system. The experimental design may alter only some operational outlook of the system (required safety stock), modify capacity (including a new machine), or even change the whole operational rules (e.g. production philosophy change from make-to-stock to make-to-order). A large number of other items need to be chosen as well (such as the initialization period, the length of simulation runs, and the number of replications), and
after that the results are analyzed. The analyst then decides whether more runs are required or not (Banks et al., 2005, Sterman 2000).

- Experiment execution and result analysis: Putting into effect data obtained from experimental design analysis.
- Refinement of experiment design: Process carried out towards improving the design experiment.
- Final result analysis: Activities involved in examining the result obtained.
- Process documentation: Putting into record evidence of results obtained from experimental design.

The purpose of simulation methodologies is to enhance a system by developing computer imitations of the real system (Robinson, 2004). Usually designed so as to ideate how systems conduct themselves over time and to make a comparison with distinct performances under different scenarios (Mansour, 2012). Grigoryev; Banks et al.; and Ingalls et al., presented other purpose and advantages of this very important methodology summarised below:

- Simulation presents a framework for training together with studying interactions of a complex system. Resulting in performance improvement, since a simulation framework naturally describes a systems structure.
- Different alterations such as inventory reduction, creativity fostering.etc. can be simulated and distinct effects on the system observed.
- Divergent inputs can generate information about the most sensitive variables. This methodology allows researchers analyze systems and obtain solutions where procedures such as linear programming and analytical concepts or calculations fail.
- Use of a model to forecast and foresee future behaviour, i.e. the effects produced by an alteration in the system or by new operations method.
- Study of capacity usage, inventory levels, control logic, integration, sequencing/scheduling, bottle-necks, search for better layouts and maturation process is standardised, resizable and incremental.

Despite numerous advantages of this very essential methodology, simulation is not a process tool without its limitations or disadvantages. These disadvantages is enumerated by (Robinson, 2004) and are summarised below:

- This approach is highly intense and very time-consuming.
- It is an expensive software.
- Data – hungry.
- Needs special training and expertise.
- Overconfidence.
2.15.1 Selecting simulation software

There are numerous simulation software’s available as a decision support tool for use in the market. Three simulation software’s deemed appropriate when aligned with this research objective and questions are examined below:

- **FlexSim**: This software is mostly adopted when modelling small processes, and can effectively model discrete-time system. Logistics and maintenance process are discrete-time systems, this simulation software is an ideal model when planning a simulation for these functional processes (Xiangguo et al., 2011).

- **Anylogic**: This multi-approach decision support simulation software supports all three modelling methods. Anylogic is the most functional software in the market which allows users create hybrid models. GIS mapping is one major attribute of this software, which makes its abilities beyond expectations, and in addition supports programming within the model allowing for more unified results (Anylogic, 2015).

- **Insight Maker**: A web-based, multi-user simulation software that supports casual loop diagrams, dialogue mapping, rich pictures, mind mapping, as well as Stock and Flow simulation models (Insight Maker 2015).

Selecting the best simulation software for this research is essential, towards achieving accurate outputs. Gupta *et al.* established that choice of correct simulation software must gratify certain criteria, and key criteria’s as enumerated by him during selection are summarised below:

- **Affordability**: Is the simulation software to be adopted by the students very affordable?
- **Accessibility**: Is the software easily assessable by the student?
- **User-Support**: Does the software provide user support to the students’ in terms of online videos, tutorial documentations .etc.
- **Visual Aspects**: Includes all types and the quality of graphical objects provided by the software.
- **Input/Output**: How easy can the students input data and also present data to the audience?
- **General Features**: Is the software user-friendly in terms of ease of learning, usage and user friendliness.
- **Modelling Assistance**: Are online help available to the students.

In choosing best simulation software for this research aligning with above-enlisted criteria, this research selects Anylogic simulation software. Besides the software possessing above detailed criteria’s and attributes, this software is capable of modelling a wide range of logistics and maintenance networks for any given business entity (Anylogic 2015). Synopsis of Anylogic simulation
resources together with distinct definitions adopted in the development and configuration of this research simulation framework is presented below.

- **Agents**: Are regarded as a model's building block which is adopted in modelling all kinds of real world objects inclusive of companies, retailers, physical objects, resources .etc. Each type of agent represents and distinct a model logical segments, allowing simulators break down models into several stages of details. Agent(s) behaviour in this research is defined utilizing parameters, collections, variables, and functions .etc. simulation blocks.

- **Resources**: Resources are objects deployed to execute a specific action utilizing model agents. An agent obtains a resource, implement necessary actions, and release the resource. Examples of resources include workers, wheelchairs, containers, forklifts, vehicles .etc. Resources can be categorised into static, moving or portable, dependent on distinct ability to be moved by agents, bound to a specific location and cannot move or be moved, moved by moving resources, move independently .etc. Resource pool block works concurrently with resource block adopted for defining each pool or sets of resource units.

- **Variables**: Variables represent a model state, and may change during simulation runs. Are generally adopted in storing outputs of a simulation process. Variables can also function as a tool for modelling object attributes and data units changing over specified time limits. In this research, the variable block is adopted in evaluating time variance taken by each process step, overall time in the system, system maturity index time and business state index time.

- **Parameters**: Parameters are commonly adopted when describing objects statically. Perceived as constants in a single simulation run, changed only when there is a need to adjust model behaviour. Most often adopted when describing attributes of modelled objects possessing same behaviour in a collection or class but differ in all or some parameter values.

- **Service**: Process modelling block responsible for delaying agents, seizing and releasing specified number of resource units. The service block is adopted in this research when defining each process step.

- **Source**: Responsible for generating model agents, and is most often times the block adopted as a starting point of a process flow chart. This process modelling block can also be utilised when creating agents with custom animation or specific attributes, configuring custom agent type and specifying agent name in the “new agent” property of the block.

- **Sink**: Adopted for disposing of incoming agents in a process flowchart. Sink functions as the block responsible for removing agents from the model.

- **Time Measure Start and Time Measure End**: These simulation blocks are a pair of process modelling blocks adapted for measuring variance in time, inclusive of “time agents spend
between them”; “time in system”; “length of stay”, specifying given points in the process flow chart.

- **Slider**: Model block which allows modellers graphically choose numeric data within a bounded interval by sliding a knob. Adopted for varying or modifying parameters and numeric variables of the model during runtime.

- **Charts**: Process modelling block designed for efficiently visualizing and presenting simulated outputs and simulation runtime data.

### 2.15.2 Selecting simulation method

All simulation type assumes an abstraction, details which are believed to be essential are included in the configuration process while those considered less important are omitted. This makes simulated models less complicated or complex when compared with the original system (Grigoryev, 2015). Selecting the best simulation type or a combination of two or more types in any modelling process is very essential. If wrongly chosen the simulation model might have inaccurate design or structure which in turn leads to misleading outputs, which may further aggravate as the modeler may assume that presented simulation model provides the most useful results available even though the whole model is based on a poorly chosen simulation methodology. (Banks et al., 2005) stresses the fact that choosing the most suitable simulation methodology is an important task in any simulation study. There are numerous types of simulation method available for use by modelers. The most widely adopted modern approaches in business manufacturing sectors are Discrete-Event Simulation, System Dynamics (SD), Agent-Based Modelling (ABM) and Hybrid Simulations (Jahangirian et al., 2010). Each of these methods presents a specific range of abstraction phases. A synopsis of these different types of simulation methods is presented below:

- **System Dynamics Model**: Defined as a method adopted in understanding the nonlinear characteristics of intricate systems over time adopting stocks and flows, internal feedback loops and time delays. System dynamic modelling provides an insight into the dynamic behaviour of a system over time (Victor, & Samudra, 2001).

- **Agent Based Model**: Agent-based models are composed of independent and reciprocating agents. Defined as computational models for simulating the activities and interactions of autonomous agents (both individual and collective entities such as organizations or groups) of intricate and complicated adaptive systems, with an objective to assessing distinct effects on the system as a whole (Macal, 2010).

- **Discrete Event model**: Generally known as process-centric based models. The discrete event model is defined as the process of depicting the behaviour of a complicated system, as a sequence
of well-defined and ordered events. Karnon described discrete events models as performing well in almost any process where there is variability, constrained, or limited resources or complex systems interactions, presenting a sensitive and non-rigid approach to representing intricate systems.

- **Hybrid Simulations:** Individual simulation approaches have distinct weaknesses. Hybridization simply entails combining two or more simulation types so as to improve the quality of the models. This enables adopting a different method to overcome the weakness of one method (Lattila, 2012).

Hongbo & Zhongwei established that Logistics system is a kind of complicated discrete event system. When examining and observing the sequence of processes in logistics and maintenance daily business operations, this research distinct them into discrete subdivisions in order to make the analysis approach less complicated. (Gopakumar et al.) affirmed that configuring a discrete event simulation model within processes, presents a platform towards decreasing TAT. Karnon also described discrete events models as performing well in almost any process where there is variability, constrained, or limited resources or complex systems interactions, presenting a sensitive and non-rigid approach to representing intricate systems. This research selects the discrete event simulation methodology in developing and configuring logistics and maintenance process steps. Established literature described above validates the adoption of this methodology for this research.

### 2.16 Synopsis of Microsoft Visio tool and techniques

Microsoft Visio tool is adopted in laying out of logistics and maintenance BP steps that seek for a standardised or almost standardised logistics and maintenance framework. Ensuring inter-dependencies and networking of these BP steps are placed into perspectives. Configuring BP's with Microsoft Visio tool presents this research with a holistic view of logistics and maintenance process steps when checking for optimality relative to TAT. One essential attribute of Microsoft Visio tool is PM techniques, which utilize flowcharts inclusive of swim lane flowchart in illustrating a detailed BP steps information of logistics together with maintenance systems. PM acts as a baseline in gathering data for simulating a model and has gained more significance of late, owing to the intricacies of processes together with the necessity to capture and envisage knowledge that dwells with enterprise human resource who execute these various business functions (Hussain, 2015).

(Mcintyre) defined PM as a tool that aids in understanding and defining a process. Presenting a visualization of the path that sequence of activities must follow in producing an output. Macal; Banks et al.; and Sterman argued the necessity to develop comprehensive objectives and design an extensive framework before commencing any modelling and simulation design. Microsoft Visio tool comes into
perspective in this scenario, hence adopted in this research as one of the tools utilised in meeting this research set objective. Numerous advantages exist when PM is adopted to describe enterprise activities. These advantages are presented by (Steven, 2012) and summarised below:

- Presents a platform for enterprise human resource or researchers to agree on the order and steps at which a process occurs.
- Visualise duplicated efforts and non-value added procedures that may be lurking in a process, thus adopted for investigating existing process or planning new ones.
- Presents clearer explanation on the working relationships between business organizations and people.
- Identify and aim at specific steps for improvement in the process .i.e. assist people in focussing on the whole process instead of becoming lost in details.
- Very useful in analysing and measuring phases of lean Six Sigma methodology.

When illustrating process maps, the following guidelines as detailed by (Marianne & Gregory, 2015) can be adopted.
- A process designer or researcher must have a clear objective for mapping out any business activity.
- The scope of the business functions should be labelled at the beginning of the process map.
- Roles of each process step must be clearly determined and defined. Swim lane technique is adopted in meeting this criterion.
- Label process block decisions that are in the form of questions .i.e. each flow line branching out can be labelled with a yes or no outcomes.

In analyzing process maps, the following steps as detailed by David Thompson health region in one of its publications can be adopted.

- Challenge the necessity of each process step .i.e. is the process step unnecessarily repetitive, is value added to the product or service .etc. after which the process developer eliminates steps that are redundant in achieving quality yields.
- Investigate for delays or delay symbols or time-lags in the process steps.
- Pay attention to specialised work areas and multiple handoffs.
- Investigate decision points .i.e. key inputs and outputs.
- Observe for quality control points and rework loops.
- Investigate overall BP or comprehensiveness of the map .i.e. for logical flow, process order, and repetition .etc.
- Examine cost of executing this business tasks.
2.16.1 Flowcharts/swim lane techniques

PM Flowchart is one major toolset adopted for PM. When creating the flow of this research process steps prior to improving it, three (3) different types of flowcharts which can be adopted in PM are investigated. What is common to these three types of flowcharts is the "process-oriented technique", which defines the process first; describes the customers or clients of the process; clarify and polish the demands for all process clients/customers; indicate the steps required in accomplishing the process and specifies the sequence of steps. A brief outline of the several types of flowcharts including step-by-step guides on creating them is presented below.

- **Top-down flowcharts:** This is the simplest type of flowchart in PM adopted for describing what the major groups of tasks are, i.e. the essential ones among the total process. Top-down flow charts illustrate what the business tasks would look like without the sequences that have piled up over time to shore up a faulty or inefficient process. When designing a top-down flowchart, the designer must limit itself to no more than five or six sub-steps for each major step. Presenting only the useful work that goes into the process. Some steps that can be adopted in designing a top-down flowchart is listed below:
  - Make a list of the most basic steps of the process.
  - Write the core steps across the top of a flip chart, board or piece of paper in the order of occurrence during the process.
  - Under each core step, enumerate the sub-steps that make up that element of the process, listing them in distinct order of occurrence.

- **Deployment flowchart:** This type of flowchart might involve just core steps, sub-steps or/and sub-sub-steps. The difference between the top-down flowchart and deployment flowchart is while the former tells what, the latter explains both who and what. Investigating how the people involved in the process aligns together, operates at each step, who is involved in the process and also record track of what each individual or enterprise is supposed to do. Steps that can be adopted in depicting a deployment flowchart is listed below:
  - Enumerate core steps in a process flow in the order of occurrence.
  - Make a list of the names of the individuals or business organizations involved in the process.
  - Under the name of the individuals or organizations responsible for the first step in the process, draw a box and write that step in the box. If more than one person or group is responsible for a step, extend the box so it is also under the name of that person or group.
  - If any other individual or groups assist or advise the ones with the core functions for that process step, draw an oval under the names of those individuals or groups.
  - Make a connection between the ovals to the box with the process step in it.
On completion of the first step, align the second step under the individuals responsible for it.

Establish a connection between the first steps to the second step, and then add ovals for any advisors or helpers in the second process step.

Keep going this way with all the steps in the process.

**Detailed flowchart:** This kind of flowchart is a powerful tool for investigating a process that has built up needless complexity. Though the two types of flowcharts explained above is enough to investigate a process, but most often process designers need more details to visualize where issues are occurring. The detailed type of flowchart though very time consuming comes into perspective in this scenario, illustrating what actually takes place at each step in the process in detail. This type of flowchart presents what happens when non-standard events occur and in addition graphically display processes so process designers can easily visualize wasted efforts or redundancies. In configuring a detailed flowchart several symbols can be adopted in illustrating the process steps. Each symbol represents only one action or yes-no decision, presenting this technique with necessary details. Steps that can be adopted in depicting a detailed flowchart is listed below:

- Draw the first symbol, and then write a description of the process step inside the symbol.
- Draw the second symbol. Write the description and make a connection between the two symbols with an arrow showing the direction of flow.
- Continue in this manner until the process is completed or part of the process side-lined for investigation.

The detailed flowchart concept is utilised concurrently with the swim lane methodology in this research, as a result of respective distinct attributes in presenting details to process flows. Swimlane diagram is adopted when creating cross-functional flow process within a business entity i.e. comprises more than one functional department. This methodology assists enterprise human resource to organise, distinguish and illustrate process and sub-processes in a BU into separate functional responsibilities.

### 2.17 Selecting variables

The big question lies in discovering and defining critical variables affecting BP efficiency and state of the business. Together with demonstrating impacts of these critical variables aligned with associated business states on TAT in BP optimization activities, adopting a simulation-based decision support approach. Review of literature presents a large number of variables which can be investigated in measuring the success of any BU system. This research has simplified the complexities by limiting the variables to "Human resource resolution time", "Escalation rate", "Critical factor", "System resolution"
time”, “System maturity index” and “Business state index”. These proposed six (6) critical variables are adopted and utilised in presenting an integrated case for this research. Description of these proposed critical variables which includes clearly defining the roles of each proposed critical variable together with reasons for the distinct choice of selection is presented below.

**Human resource resolution time**: Hui & Qian described this critical variable as the total time between when a human resource initiate and resolves a specific business task. This research proposes the necessity for BU’s to shift attention from enterprise “response time” (time between receiving the first contact and starting to work on the business activity), to enterprise “resolution time” (time between initiating and resolving the business task). Human resource resolution time is an essential variable as it has consequential impacts on overall business productivity hence adopted as one of the proposed critical variables utilised in executing this research objective.

In this research, human resource resolution time is defined in Six (6) states so as to define different resolution time metrics. Proposed time matrixes are the “Executive human resource resolution time”, “Administrator human resource resolution time”, “Manager human resource resolution time”, “Supervisor human resource resolution time”, “Operations human resource resolution time”, and “Manual human resource resolution time”. These six (6) states are utilised as resource pool objects with different job specifications and resolution time during development and configuration of this research simulation framework.

**Figure 12: Human resource resolution time states**

**Escalation rate**: “Escalation” is defined as a methodology that refers to the fast lining of BP’s which has not been attended to or could not be resolved, and is transferred to another resource line (Mori,
Escalation rate is thus, the delay time a process step encounters before been passed to a senior or another resource personnel. This critical variable defines the potential to escalate a non-response, and an essential variable having significant impacts on business functions (Mori, 2007). Hence, escalation rate is adopted as one of the proposed critical variables utilised in executing this research objective. Escalation rate necessitates a framework in eliminating unnecessary business delay time. "Manual tier 1 escalation", "Auto-tier 1 escalation", "Manual tier 2 escalation" and "Auto-tier 2 escalation" are the four (4) states proposed in this research for illustrating several escalation rates. The logic behind separating these states is that the entirety of business activities is executed either in a manual or automated framework, and implementation of these BP's is dependant on time factors. A business enterprise with Auto-escalation option is likely to have shorter TAT relative to BP steps.

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**Figure 13: Escalation rate states**

**Critical factor:** Critical factor describes a business terminology adopted in defining a process at which one or more enterprise functions of a BU must undergo during the execution phase, so as to achieve its set targets. This critical variable aligned with escalation potential illustrates critical core areas where process steps must be differentiated in order of hierarchy and importance, for efficient enterprise management (Koutsikouri et al., 2006). This critical variable is also described as a significant enterprise activity having a consequential impact on business success, thus proposed as one of the critical variables utilised in achieving this research objective.

Process theory concepts adapted from (Markus & Tanis, 2000) is adopted in classifying this critical variable into five (5) critical factor states. This concept places attention on the succession of process steps directed towards process execution completion. These states includes:

- **Very High Priority (VHP):** Task in process steps having major impact requiring high escalation rates together with urgent attention by a top management team.
Very Important Factor (VIF): Process steps requiring prompt attention with medium escalation value.

Standard (STD): Business functions requiring urgent attention with minimal escalation rate.

Not Critical (NC): These are process steps which a BU should attend to but not a compelling task, describing business activities for which there is no urgent time necessity in resolving them.

BASIC: Described as a regular business function in a BU referring to BP’s that happens normally. Critical factor variable is investigated aligned simultaneously with escalation rate variable in examining impacts of adopted variables on response time.

**System resolution time:** This critical variable refers to the total time taken by a system to initiate and resolve specific input to output (Subramanyam, 2012). System resolution time describes the total time taken by a system to complete a task and a very critical variable having consequential impacts on business activities. The system resolution time is dependent on the status of maturity of the system in question (MES/ERP). System resolution time is adopted as one of the proposed critical variables utilised in executing this research objective, and differentiated into eight (8) system states relative to either a manual or an automated process. These states include “Fully enabled ERP”, “Module specific ERP”, “Manual ERP”, “Fully enabled MES”, “Module specific MES”, “Manual MES”, “Connected Plant Control”, and “Manual Plant Control”.

**Figure 14:** Critical factor states

**Figure 15:** System resolution time states
ERP, MES together with plant systems are the technologies under focus in evaluating this critical variable. A detailed description of these automation systems has been presented in earlier sections of this research.

**System maturity index:** Gove & Uzdzinski defined system maturity index as objective states adopted for facilitating system technology maturity optimization. This critical variable formally defines terms of any BU service contract, which includes TAT it takes an enterprise system to complete a business request, specifically a system incident. Evaluating system maturity index is very critical in assuring enterprise continuity which includes short and long-term business goals (Paschke & Schnappinger, 2006). The system maturity critical variable is therefore adopted as one of the proposed critical variables utilised in executing this research objective. This research proposes four (4) system maturity index states in utilizing this critical variable, which includes "Full-Service Level Agreement (SLA) Less Than 2hrs", Full SLA Less Than 4hrs", "Partial SLA Less Than 6hrs", and "Partial SLA Less Than 8hrs". The logic behind adopted states is that this research proposes a business entity must evaluate its system maturity index at a specific time cycle. SLA is an important state in investigating this critical variable, as it assists business entities set expectations and boundaries. A business entity with Full SLA less than 2hrs option is likely to have a shorter response relative to BP steps. While an enterprise with Partial SLA less than 8hrs is most likely to have a larger response time. Appraising an enterprise system maturity level, abreast such BU’s with information about distinct standpoint in terms of strength, weakness and status in the global maturity framework (Ibbs & Kwak, 2000). Other numerous benefits exist, synopsis of some of these benefits as adapted from (Subramanyam, 2012; Garimella, & Williams, 2008; and Paschke, & Schnappinger, 2006) include:

- Enterprise human resource can effectively manage and control BP’s resulting in swift decision taking together with gradual and overall enhancement of service quality.
- Business entities can adapt to changes and challenges swiftly through identifying bottlenecks and loopholes within enterprise activities so as to create a framework for improvement actions.
- Develops a framework for identifying enterprise customers and user actions that configure incidents, consequently improving those aspects.
- Large corporates can easily align enterprise resources and objectives to BP’s as such enhance and configure a structure for specifying response and resolution time criteria that must be met.
- Assures enterprise continuity, client satisfaction, and customer trust.
Business state index: Business state index is defined as a measure of the development stage of any BU, determining if the business entity is achieving a minimum set improvement target. This critical variable helps to reflect an entity present and future business goals, by presenting a framework which can be adopted for performing regular business analytics. Through identifying a BU essential success factors and implement calculated metrics without difficulty (Paschke & Schnappinger, 2006). Aligning with established literature detailed above, this critical variable is adopted as one of the proposed critical variables utilised in executing this research objective. Three (3) business index states are proposed in this research when utilizing this critical variable, which includes “Greater Than 2yrs Last Changed”, “Less Than 2yrs Last Changed”, and “Less Than 1yr Last Changed”. A BU with greater than 2yr last change state is more likely to have shorter response time relative to BP steps. As an enterprise, human resource is likely to have adapted fully to the effect of change. Same benefits of evaluating system maturity index detailed above can also be applicable and aligned with investigating business state index. The logic behind adopted states for business state index is that this research proposes that a business corporate must allow sufficient time for enterprise human resource to adapt to the effect of change or modification.
2.18 Chapter Summary

Chapter two reviews essential literature specific to this research. The chapter examined MES relationship with other enterprise systems. A synopsis of logistics and maintenance functional processes together with distinct sub-activities is also presented. In addition, an overview of systems thinking approach aligned with business modelling tools, techniques, and methodologies is also discussed in this chapter. The chapter wrapped up with a description of this research proposed critical variables. The next chapter analyses extensively, the methodological framework adopted in accomplishing this research objective.
3 Chapter three: Research method

The previous chapter presented comprehensive background context and support literature specific to this research. Chapter three focuses on presenting detailed methodology of process models, systems theory, together with BP modelling tools and techniques, inclusive of empirically detailed steps adopted in executing methodological approach. An extensive list of adopted business states associated with all proposed critical variables is also illustrated.

3.1 Introduction

This research presents an integrated case that focused on optimizing TAT relative to automation systems, adopting BP tools, techniques, and methodologies. Directing attention to investigating these enterprise automation systems inclusive of ERP, MES and Plant systems as a unit. Examining synergies together with inter-dependencies between core BP’s of these automation systems relative to logistics and maintenance systems. Mori established that the more standardised business system a BU possess, the more effective and stronger the business capabilities become. This research adopts systems thinking approach together with simulation and Microsoft Visio tools and techniques in presenting an integrated case. These tools, techniques, and methodologies are brought together to develop, configure, analyse and illustrate that proposed critical variables “human resource resolution time”, “escalation rate”, “critical factor”, “system resolution time”, “system maturity index”, and “business state index” with distinctly associated business states has an impact on process TAT relative to logistics and maintenance systems. Reasons for choice of selection of logistics and maintenance systems, together with adopted methodologies and critical variables has been detailed in earlier chapters of this research. Logistics and maintenance business activities form an integral component of automation systems relative to global best practices. While adopted tools and techniques ought to be very effective and efficient in developing together with configuring this research set objective.

These tools, techniques, and methodologies are developed so as to provide agility, by expediting configuration together with execution of a detailed and standardised BP oriented process steps, thereby meeting enterprise demands and standards. Developing these tools necessitates a framework in illustrating how certain critical variables aligned with distinctly associated business states ought to have an impact on process TAT in any BU. These illustrations present how automation systems interact with each other as it relates “Top floor to Shop floor” optimization and vice versa. The methods commenced with an international best practice literature review specific to defining proposed critical variables aligned with associated business states, automation systems, BP modelling tools and
techniques, systems thinking approach and BP steps relative to logistics together with maintenance systems.

BP steps encompass several functional departments within and sometimes across an entity. These BP steps are mapped out adopting Microsoft Visio tool, after which Anylogic simulation decision support toolset is utilised for setting up proposed critical variables together with modelling, and iteration purposes. Reasons for the adoption of Anylogic simulation software has been presented in the literature review chapter of this research. Mixed methodologies detailed in earlier sections of this research are adopted in configuring, developing and optimizing BP’s of these automation systems relative to logistics and maintenance systems, validating to at least 80% process accuracy.

3.2 **Systems thinking**

“Systems thinking” involves studying and depicting BP’s holistically, observing how changes in one or more critical variables affect other critical variables or the entire system. System thinking presents a framework for visualizing inter-dependencies or interrelationships of processes, rather than static activities of these processes (Senge, 2006). System thinking is defined as an approach which utilizes tools in identifying and understanding leverage points of interdependent structures that bring about desired outcomes of dynamic systems (Souvairan, 2014). Adopting system thinking concepts in any BU, develops a practical approach platform, in managing international best practice development projects or activities in the era of complexity, balancing BP’s in terms of delays, limits and behaviour over time (Richmond, 2004).

System thinking approach is adopted in this research for bringing together all business functions but creates an opportunity to evaluate the synergies and limitations in optimizing business operations. Enabling this research to take a holistic view of enterprise processes as a system, to fully understand components and interdependencies of these BP steps relative to logistics and maintenance system. This research seeks to investigate “leverage points of logistics and maintenance process steps” and “time behaviour of these BP steps” relative to TAT. (Bahill & Gissing) established seven systems thinking steps which include “stating the problem”, “investigating feasible alternatives”, “modelling the system”, “integrating the system”, “launching the system”, “assessing system performance” and “re-evaluating the system”. This research adopts these steps in utilizing this core research methodology. Detailed description of these seven steps has been presented in the literature review chapter of this research. Synopsis of how this research utilised these steps in studying the complexities and interactions of these automation systems relative to TAT is presented below:

**Stating the problem:** The step commenced with an international best practice extensive literature review specific to automation systems, BP modelling tools & techniques, systems thinking approach,
critical enterprise process variables aligned with associated business states and BP steps relative to logistics together with maintenance systems. A description of “what”, together with “how” this research intends to investigate and resolve its objectives is presented after literature search.

Investigating feasible alternatives: This research investigated alternative approaches (automation systems synergies) to illustrate a clearer picture of proposed objectives. Accomplished by iterating and assessing the impact of adopted critical variables with distinctly associated business states on logistics and maintenance systems relative to optimised TAT, at different conditions set.

Modelling the system: Results of this research investigations are tested and adopted in developing and configuring together with presenting an integrated case model (simulation-based decision support state) for enterprise scholars and professionals.

Integrating the system: This research investigated and quantified these automation systems as a unit. This research aligned and validated outputs of this research with earlier established studies, where enterprise automation systems have been investigated and quantified. Results presented a new framework for investigating and quantifying these automation systems relative to TAT.

Launching the system: This research on completion of the integrated case model, ran different simulation scenarios or iterations, thus producing simulation outputs to test its objectives. Launching the system means allowing the integrated case illustrate set objectives.

Assessing system performance: Different states, metrics or multiple conditions is explored in assessing for system performance of each critical variable with distinctly associated business states.

Re-evaluating the system: As illustrated in Figure 18 of this research, a framework for constantly re-evaluating configured integrated case must be developed, so as to necessitate for continuously improved service performance and monitoring of the system.

![Figure 18: Systems thinking steps](image-url)
3.3 Microsoft Visio tool and techniques

Visio representation of BP’s provides an in-depth information and observations on how BU’s executes business functions. Microsoft Visio is described as a tool adopted for BP modelling projects globally, and utilised for a variety of business functions within the context of distinct set targets (Sargeant, 2013). This tool is a software adopted when developing a framework of BP’s “as is” processes” before actual modelling and simulation actions occur “to be” process redesign” (Marianne & Gregory, 2015). Microsoft Visio tool is adopted in this research so as to view BP’s in respective “hierarchy”, “network” and “interdependencies”, acting as a baseline in gathering data for simulation activities validating to at least 80% process accuracy. As detailed in the literature review chapter of this research, PM which is one core integral concept of Microsoft Visio tool (Hussain T. Abubakker), utilizes flowcharts and swim lane techniques in visualizing distinct functions. Illustrating a process and communicating “what” and “where” activities are been executed.

![Visio Business Process Tool](image)

**Figure 19: Visio modelling approach**

From a simulation perspective, BP flowchart entails modelling and graphical depiction of an operative system, base system, and to a minute degree modelling planning system, together with controlling and observation activities of a system (Mansour, 2012). Swimlane diagram is utilised when creating cross-functional flow process within a BU .i.e. comprises more than one functional department. This technique assists enterprise scholars to organize, distinguish and illustrate process and sub-processes in a BU into separate functional responsibilities. (Halseth) described PM as one of the essential resources in improving BP’s, illustrating “what BP’s are executed”, ”who executes the BP’s”, “how these BP’s are executed” and “where distinct BP is executed”. Marianne & Gregory also affirmed that PM enables enterprise human resource to acquire indebt knowledge of its present BP’s together with distinct functionalities, resulting in a framework for implementing future process redesigns. Process maps visually explain critical details of an enterprise process, by illustrating BP’s with arrows and process shapes inclusive of boxes, rather than written procedures. Standard symbols utilised in this research for configuring or visualizing BP steps as adapted from (Bradford, 2015) are detailed in Table 3 below. Figure 20 presents a sample flow chart.
diagram illustrating few steps in maintenance business philosophies adopting these symbols, while Figure 21 illustrates how business functions can be separated into several levels and steps adopting swim lane techniques.

<table>
<thead>
<tr>
<th>PROCESS BLOCK</th>
<th>NAME</th>
<th>FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start/End</td>
<td>Start/Stop</td>
<td>Start and End symbols are adopted to signify the beginning and termination points in this research process map.</td>
</tr>
<tr>
<td>Process Step</td>
<td>Activity</td>
<td>A rectangular box is utilised in depicting process steps.</td>
</tr>
<tr>
<td>Subprocess Step</td>
<td>Sub-activity</td>
<td>The Sub-process rectangular box is adopted in indicating a sub-process step when developing the process map.</td>
</tr>
<tr>
<td>Document</td>
<td>Document</td>
<td>Illustrates documents in this research process map.</td>
</tr>
<tr>
<td>Decision</td>
<td>YES</td>
<td>The diamond-like shape shown is adopted for representing decisions. This PM block usually appears with two branches, one branch indicates a no response while the other branch is for a yes answer.</td>
</tr>
<tr>
<td>Decision</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>Process flow line</td>
<td></td>
<td>Connectors are adopted in this research to link process blocks together and in addition depict direction of process tasks.</td>
</tr>
</tbody>
</table>

Table 3: Process map symbols
MAINTENANCE PHILOSOPHIES

Define Maintenance Strategy Philosophy

Initiating research on Global best Practice (MES)

Plant and Equipment Design (MES)

Research Global Standard/Legislation (MES)

Document Maintenance Strategy (ERP)

Reviewed and Approved

YES

Adoption and implementation (MES)

NO

LOGISTICS STRATEGIES

LEVEL 1 (Business Area)

LEVEL 2 (Process Group)

LEVEL 3 (Business Process)

STEP 1

STEP 2

Figure 20: Sample detailed flowchart diagram

Figure 21: Swimlane diagram
Figure 22 presented below illustrates both flow charts and swim lane techniques integrated together, adopting process map symbols described above.

**Figure 22: Sample process map diagram**

### 3.4 Simulation-based decision supports approach

Evgeny & Tomohiro established that simulation BP tool is one most globally adopted operations research techniques utilised for process optimization, allowing for any arbitrary model complexity and circumvents analytically intractable models. Simulation approach has the ability to recognize or envisage logics behind a BP, challenges, and upgrade of a business entity, exploring process traits for different BP steps or parameter values (Ivana & Branko, 2001). This consequently configures a framework for identifying BP steps deficiencies. Simulation BP tool comes into perspective when developing sophisticated or refined tools in decision support systems and optimizing the efficiency of BP's (Lattila, 2012). Grigoryev also validated this knowledge, by establishing that simulation and modelling presents a base in developing a framework that makes use of mathematical languages or rules in representing real-world systems for process optimization. Simulation actions produced iterated scenarios of input together with output variables, and basic components of the simulated
These are all achieved through extensive observations and in-depth statistics of the simulation operation process.

An overview of different types of simulation software and methodologies is well accounted for in earlier chapters of this research. As detailed in an earlier chapter of this research, Anylogic simulation software and discrete event simulation methodology is adopted for accomplishing this research set objective. Reasons for these choices of selection is well accounted for.

![Simulation Approach - Discrete Event Paradigm - Simulated Scenarios](image)

**Figure 23: Simulation-based approach**

This technique is adopted in selecting and viewing holistically, how proposed critical variables ought to impact on business maturity relative to TAT. Also making explicit how this evaluation toolset forms a critical component of BP improvements projects. The problem is approached by configuring a simulation-based decision support model that seeks for a standardised or almost optimum logistics and maintenance framework, by generating different logistics and maintenance scenarios for the business model in a bid to optimize TAT of these BP steps. The scenarios are iterated adopting different business states constraints aligned with distinct critical variables. Output(s) of each iteration generated is then compared to check for optimality of TAT. The next section presents detailed steps adopted when developing and configuring this research simulation framework.

### 3.4.1 Simulation steps adopted

A detailed description of Anylogic simulation resources adopted when developing and configuring this research simulation framework has been presented in earlier chapters of this research. Step by step approach adopted when developing and configuring this research iteration integrated case is enumerated below.

- **Conceptual problem formulation and analysis**: This research ensured good problem articulation is presented, presenting enough literature to back up this research objective and questions. This research also ensured that methodological approaches to be adopted in solving this research objective and questions are clearly defined.
- **Data and Information Collection**: This research accomplishes this step through comprehensive literature examination on systems engineering, simulation concepts, Visio modelling inclusive of PM together with swim lane techniques, and Systems thinking approach. This research ensured that each iteration run is done severally before recording output to ensure accuracy and perfection of simulation results.

- **Model building**: Data gathered from earlier step is adopted in configuring and designing a conceptual case for modelling and simulation actions in this research.

- **Verification and Validation**: Verification simply refers to the configured model executing required task, while validation ascribes to the designed model illustrating the system as a whole (Banks *et al.* 2004). This research ensured during model configuration activities, the designed model corresponds to real system BP’s of logistics and maintenance BP steps to at least 80 percent process accuracy before executing simulation runs and interpret outputs.

- **Experiment Design**: This research proposed several critical variables aligned with associated business states in performing an iterative process on logistics and maintenance BP steps.

- **Experiment execution together with result analysis**: This research collected outputs of distinct iteration through charts and variables which are readily available in Anylogic simulation software.

- **Refinement of experiment design**: This research interpreted outputs from charts together with variables obtained from the previous step.

- **Final result analysis**: After interpretation actions of outputs obtained in the previous step, this research critically examined simulation results and seeks ways in which logistics and maintenance BP steps can be optimised relative to TAT.

- **Process documentation**: This research ensured detailed documentation of simulation results is recorded and an integrated case which can be adopted by enterprise human resource is presented.
3.4.2 Simulation phases

A discrete event modelling paradigm is adopted when configuring proposed simulation framework. This simulation technique is adopted in this research to illustrate logistics and maintenance BP steps as a sequence of events. Discrete Event Modelling method is often times referred to as process-centric modelling technique, adopted when assessing successive real-world processes with non-sequential events (Anylogic 2015). This research utilizes tools available in the process modelling library pallet of Anylogic simulation software to execute the discrete event simulation paradigm. A detailed description of these tools and reasons for selection of this simulation methodology have been presented in the earlier chapter of this research. Step by step phases adopted in configuring and modelling this framework is presented below.

**Phase 1: Identifying and creating different agent type.**

Agents are the principal design blocks in this research simulation ascribed with a behaviour, timing, memory (history), contacts etc. The agents configured in this research where logistics process agent, maintenance process agent, and main agent. Logistics process agent acts as an agent type comprising all logistics process steps, while maintenance process agent functions as the agent responsible for depicting all maintenance process steps. The main agent is responsible for aligning all agent types and serves a graphical platform adopted for viewing simulation outputs, simulation data sets, and charts.

**Phase 2: Configure different parameter values.**

Parameter values configured in this research simulation model comprises all declared critical variables aligned with associated business states. These critical variables include human resource resolution time, escalation rate, critical factor, system resolution time, system maturity index and business state index.

**Phase 3: Configure process flow chart.**

Logistics and maintenance process steps are illustrated and integrated adopting service blocks available at the process modelling library pallet.

**Phase 4: Configure Variables.**

Different variables are configured for measuring variance in time and total time in the system. Each process steps is assigned a critical variable, inclusive of total time in the system, business state index, and system maturity index. Variables are one of the process modelling library block adopted in this research for collecting outputs of simulation runs.

**Phase 5: Build charts to visualize design outputs.**

Chart available in the Anylogic simulation software is adopted for visualizing outputs of different iteration runs.
Phase 6: Collect and analyze outputs.

Output(s) from business states aligned with distinct variables is collected from the variable block and analysed.

![Simulation phases diagram]

**Figure 25: Simulation phases**

3.5 **Conceptual methodology and model**

This research objective is geared towards presenting an optimised business state. Achieved by developing an integrated case together with investigating the impacts of change on process, business and system maturity. The proposed integrated case seeks to optimize communication between enterprise systems, directing attention to BP TAT. As detailed in earlier sections of this research, proposed tools, techniques, methodologies, variables together with logistics and maintenance process, as illustrated in envisioned integrated case (Figure 27) below, is adopted as a mixed methodology for this research. These mixed methodologies ought to provide agility, by expediting configuration together with execution of a detailed and standardised BP oriented process steps. Thus, meeting enterprise demands and standards. Six (6) critical variables integrated with the associated business state is proposed for investigation purposes. Reasons for selection of these approaches, tools, techniques and variables have been presented in literature review chapter of this research. This section present graphical illustration of conceptualised methodology (Figure 26) and integrated case (Figure 27).
Proposed integrated case develops an experimental and optimised framework to test scenarios, impacts, and potential benefits of mixed methodologies together with adopted critical business variables. As it relates optimizing TAT of process steps making up these integrated automation systems (ERP, MES & plant system).
3.6 Variable Constraints and Parameters

This research suggests the direct impacts of proposed critical variables on BP’s in expediting business decision and efficiency, aligning conceptual model described above with international best practices. These Six (6) proposed critical variables is examined critically so as to better optimize TAT of BP steps relative to logistics together with maintenance systems and also present a business state framework for enterprise scholars.

![Diagram of Proposed Variables]

Figure 28: Proposed critical variables

This section discusses constraints, parameters and outputs framework for these critical variables, inclusive of how distinct business states and parameters are generated. Robinson established that simulation toolset is not capable of optimizing the solution of a problem independently, rather these modelling tool simply run the model based on specifications, adopting logical or mathematical computations in calculating and presenting the final output. In this research, the impact of human resource resolution time, escalation rate, critical factor, system resolution time, system maturity index and business state index on process TAT is investigated. This research proposes that these critical variables ought to have a significant impact on process TAT .i.e. time spent between BP steps.
This research evaluates time distributions of each critical variable aligned with distinct business states (Cmax, Normal, and Cmin). During simulation runs, this research data refers to (Normal), the addition of a (+0.1) factor to (Normal) refers to (Cmax), while subtraction of a (-0.1) factor to (Normal) refers to (Cmin). Numerous intermediate options exist when evaluating for an infinitesimal response time difference between these critical variables. This research has simplified the complexities by limiting these intermediate options to (+0.1) and (-0.1) range of constraints. These determined metrics ought to be best appropriate and limit complexities in meeting this research objective. Achieved after investigating several intermediate options adopting simulation-based decision support approach (reliability testing). Proposed critical variable constraints and parameters framework adopted in this research is illustrated in Tables 4 and 5 below.

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>MIN. CONSTRAINT (Cmin)</th>
<th>NORMAL CONSTRAINT (N)</th>
<th>MAX. CONSTRAINT (Cmax)</th>
<th>DURATION (Days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Resource Resolution Time</td>
<td>Constant</td>
<td>Constant</td>
<td>Constant</td>
<td>30</td>
</tr>
<tr>
<td>Escalation Rate</td>
<td>-0.1</td>
<td>0</td>
<td>+0.1</td>
<td>30</td>
</tr>
<tr>
<td>Critical Factor</td>
<td>-0.1</td>
<td>0</td>
<td>+0.1</td>
<td>30</td>
</tr>
<tr>
<td>System Resolution Time</td>
<td>-0.1</td>
<td>0</td>
<td>+0.1</td>
<td>30</td>
</tr>
<tr>
<td>System Maturity Index</td>
<td>-0.1</td>
<td>0</td>
<td>+0.1</td>
<td>30</td>
</tr>
<tr>
<td>Business State Index</td>
<td>-0.1</td>
<td>0</td>
<td>+0.1</td>
<td>30</td>
</tr>
</tbody>
</table>

Table 4: Critical variable constraints

A 30 days duration is proposed as BP steps cannot be completed in a day and a yearly estimation becomes too long. 30days duration seems ideal for any BU to complete a process step cycle. The result of distinct iteration is adopted in evaluating response time for different trials and conditions set, relative to logistics and maintenance systems. During simulation runs, all critical variables remain set at normal, while the slider is adjusted specific to critical variable constraints adopted for each distinct iteration. Setting normal as a constant parameter value, this iteration condition is adapted to make a comparison with associated business states so as to ascertain best optimization scenarios.
Several iterations are executed to obtain response time for adopted trials and conditions set as summarised in Table 5 below.

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>ATTRIBUTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>STANDARD INDEPENDENT CONSTRAINTS (X-axis)</td>
<td>Normal</td>
</tr>
<tr>
<td>COMPARED INDEPENDENT CONSTRAINTS (X-axis)</td>
<td></td>
</tr>
<tr>
<td>DEPENDENT CONSTRAINTS (Y-axis)</td>
<td>Response Time</td>
</tr>
</tbody>
</table>

Table 5: Simulation iteration parameters

3.7 Variable metrics

This research adopts mixed methodologies detailed earlier together with distinct business states to investigate impacts of proposed critical variables on logistics and maintenance systems relative to optimizing TAT. This research assumed a range of values configured, adopted through simulation
reliability testing and analysis, for all standard, maximum and minimum numeric metrics. Simulation reliability analysis testing is utilised in examining assumed range of values so as to settle for appropriate pre-established scale for measuring these critical variables. Adopted numeric values are utilised for the purpose of measuring and testing the validity of this research critical variables. A detailed presentation of numeric metrics adopted for these critical variables aligned with distinct business states is illustrated in sub-sections below.

These metrics are adopted for configuration purposes utilizing Anylogic simulation tool, thus testing for reliability and validity of this research conceptual model and objectives.

3.7.1 Level

Placing time constraints into considerations and major objectives of this master (MEng.) program, this research seeks to examine just three (3) hierarchical levels for BP’s adopted from (Rosenberg, 2010), as these three levels ought to be intent for the purpose of this research. For future studies with more time availability, attention can be directed to evaluating the whole business functions and levels inclusive of processes and sub-processes relative to automation systems.

<table>
<thead>
<tr>
<th>Level 1 (L1)</th>
<th>Business Area</th>
<th>Described as a high-level aggregation of BU’s functionality presenting mainly logical flows.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 2 (L2)</td>
<td>Process Group</td>
<td>Group of processes belonging to the same area of responsibility.</td>
</tr>
<tr>
<td>Level 3 (L3)</td>
<td>Business Process</td>
<td>Referred to as the level that aggregates process steps to a unit.</td>
</tr>
</tbody>
</table>

Table 6: Process levels

**Human resource resolution time:** This research assumes business functions executed manually requires higher resolution time, thus ascribed a higher numeric value.

**Critical factor:** This research assumes certain process steps ascribed very very important requires higher resolution metric, so as to achieve set targets. This critical variable is utilised aligned with escalation potential rate.

**System resolution time:** ERP, MES and Plant automation system which are automation systems placed under investigation are classified into fully enabled, module specific and manual categories. Module specific category assumes a normal resolution metric, fully enabled category assumes a faster TAT.
hence lowest resolution metric, while Manual category assumes a slower TAT hence highest resolution metric.

**Escalation rate:** This research assumes automated process for both tier 1 and 2 escalations requires higher resolution metric. An escalation wait time of +18000 is adapted for configuration purposes. On expiry of the count time, if the process step(s) remains unresolved, the escalation potential is activated. As detailed earlier, the escalation potential works simultaneously with critical factor matrix.

**System maturity index**

Numeric opt time adopted when configuring and optimizing performance of system maturity index critical variable are:

<table>
<thead>
<tr>
<th>System Condition</th>
<th>Resolution time</th>
<th>Opt time</th>
<th>Multiplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Systems</td>
<td>Full SLA</td>
<td>&lt;2 Hour Resolution</td>
<td>99.98</td>
</tr>
<tr>
<td>Supported</td>
<td>Full SLA</td>
<td>&lt;4 Hour Resolution</td>
<td>99</td>
</tr>
<tr>
<td></td>
<td>Partial SLA</td>
<td>&lt;6 Hour Resolution</td>
<td>98</td>
</tr>
</tbody>
</table>

Table 7: System maturity index.

This research assumes a full SLA aligned with minimum resolution time would have a minimum time metric. A business entity with less than two hours resolution time is assumed to have a full SLA in place, less than four hours resolution time is assumed to also have a full SLA in place but with higher time multiplier. An entity with less than six hour resolution time is assumed to have partial SLA in place, while less than eight (8) hours resolution time is also assumed to also have partial SLA in place but with higher time multiplier.

**Business state index**

Numeric metrics adopted when configuring and optimizing performance of business state index critical variable are:
Large corporates with a modified business state of greater than two (2) years have a basic or minimum time metric, and also described as having a matured strategy in place. An enterprise with a modified business state of less than two years has a developing or weak business strategy in place, while business entities with a modified business state of less than one year have no strategy in place.

Table 9 below presents a synopsis of adopted numeric metrics of distinct critical variable.
Table 9: Critical variables, associated states and assumed numeric multiplier values

All these critical variables detailed above is strategically positioned at a BU. Inputs captured together with the critical variables aligned with associated business states is adopted in the simulation data manipulation runs. Examining comprehensive business functions or processes in any business entity brings about developments of a more effective and efficient enterprise activity, which necessitates improvements in overall system efficiencies of any BU. The result of distinct iterations is utilised in expediting decision making relative to optimised TAT of logistics and maintenance business systems.

3.8 Visio illustration of process steps

Critical BP steps relative to logistics and maintenance systems developed and configured with Microsoft Visio tool (PM), adopting flow charts and swim lane techniques is illustrated in the appendix section of this research. However, this section presents a snapshot of one of these developed and configured process adopting this tool.

Figure 29: Snapshot of logistics integrated process.
Integrated logistics process presented above segregates a level 1 (L1) and level 2 (L2) process adopting PM blocks and flowchart, together with swim lane techniques in illustrating or mapping out process steps of the integrated logistics system. Level 1 (L1) referred to as business area comprises all logistics management actions which include logistics strategy; logistics execution; and logistics control. Level 2 (L2) known as process group consists of logistics execution processes and sub-processes which include inbound logistics; in-process logistics; and outbound logistics aligned with distinctly associated sub-processes.

These processes and sub-processes are presented adopting Microsoft Visio blocks and separated into distinct level utilizing flow charts together with swim lane technique. As illustrated in the figure above, level 1 (L1) business area is separated from level (L2) process group adopting swim lane techniques.

3.9 Simulation Illustration of Process Steps

Critical BP steps relative to logistics and maintenance systems developed and configured with Anylogic simulation software is presented in the appendix section of this research. However, this section presents a snapshot (Figure 30) of one of these developed and configured process adopting this methodology.

Snapshots presented below illustrates developed and configured simulation approaches adopting Anylogic setup.

![Figure 30: Simulation snapshot](image)

Integrated logistics process presented above segregates a level 1 (L1) and level 2 (L2) process adopting PM blocks and flowchart, together with swim lane techniques in illustrating or mapping out process steps of the integrated logistics system. Level 1 (L1) referred to as business area comprises all logistics management actions which include logistics strategy; logistics execution; and logistics control. Level 2 (L2) known as process group consists of logistics execution processes and sub-processes which include inbound logistics; in-process logistics; and outbound logistics aligned with distinctly associated sub-processes.

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Snapshots presented below illustrates developed and configured simulation approaches adopting Anylogic setup.
The first step in configuring the simulation framework is laying out distinct process steps of logistics and maintenance framework. Illustrating interdependencies or synergies between each process steps. This is followed by integrating distinct process step with detailed critical variables aligned with associated numeric multipliers adopting several simulation blocks and techniques present in the Anylogic simulation software. The configured simulated framework is adopted in testing for scenario impacts of detailed critical variables relative to process execution time.

3.10 Chapter Summary

Chapter three focused on the extensive presentation of mixed methodologies and analysis of variables adopted in this research, Illustrating and interpreting detailed steps adopted in executing methodological approaches proposed in this research. The next chapter directs attention to results/output presentations, analysis and interpretations.
Chapter four: Research findings, analysis, and interpretations

The previous chapter illustrates and empirically presents detailed steps adopted in executing methodological approach proposed in this research. Chapter four presents together with examining data from simulation runs, analyzing and interpreting findings obtained from distinct iterations. Synopsis of each chapter in this research is also presented.

4.1 Introduction

This research seeks to test and recommend the suitability of adopting mixed methodologies detailed in earlier chapters of this research, together with proposed critical variables aligned with distinct business states. With major objectives of enhancing BP maturity or optimization relative to TAT of logistics and maintenance systems. Investigating these business systems developed an integrated case which can be adopted by enterprise human resource and process community carrying out a holistic view of process steps or implementing optimization actions. This research proposed approaches seeks to enhance capabilities of the commonly adopted optimization or reliability analysis methodology. By shifting attention to holistic and dynamic outlook together with presentation or evaluation of automation systems.

This chapter presents together with examining outputs of this research objective and questions. Specific attribute(s) of this research developed integrated case is detailed below:

1. Critical analysis of existing together with discovering alternative methodologies and standards in evaluating system maturity.
   a. Systems thinking approach: Seeks to investigate for synergies, inter-dependencies and integration between these automation systems.
   b. Microsoft Visio tool and techniques: Adopted PM techniques inclusive of the detailed flowchart and swim lane methods.
   c. Simulation-based decision support approach: Utilised discrete event paradigm available in Anylogic simulation software to analyze limitations and strengths of these standard methodologies relative to automation systems in any BU.

2. Determine critical variables together with distinct business states and analysis capacity in investigating process maturity.
   a. Literature review: Carried out to define and develop this research critical variables aligned with distinct business states. Global best practice investigations towards discovering process steps making up logistics and maintenance systems are also executed. In addition, a literature review of automation systems is carried out specific to MES, ERP and plant systems.
b. Oral interview: Besides information’s gathered from literature review, this research also engaged key enterprise human resource to garner more knowledge about automation systems together with distinct process steps. Critical variables impacting on enterprise maturity or optimization is also ascertained.

c. Reliability testing: Adopted when testing for suitability of a range of numeric values associated with distinct critical variables aligned with business states.

d. Simulation approach: To determine appropriate measuring scale for investigating these critical variables.

3. Set up a simulation integrated case to be adopted in presenting scenario impacts and benefits on a time analysis of business functions.
   a. Set up the process: This research Mapped out logistics and maintenance BP’s, adopting Microsoft Visio and Anylogic simulation tools, techniques, and methodologies.
   b. Set up variables: Adopted Anylogic simulation tools and techniques to configure adopted critical variables.
      i. Constraints on these critical variables: Three business states (Cmax, Normal, and Cmin) is defined and developed.
      ii. Configured the simulation model aligned to processes, critical variables, and constraints.

4. Investigating and simulating the scenarios.
   a. Running logistics under standard conditions or constraints:
      i. Limits (Cmax, Normal, and Cmin): Normal is adopted as the standard numeric value of measurement, while the slider is adjusted specific to critical variable constraints (Cmax and Cmin) for each distinct iteration to ascertain best optimization framework for these critical variables.
      ii. Trials & Conditions: This research iterated several trials and conditions. Synopsis of these iterations is presented in later subsections of this chapter.
   b. Running maintenance under standard conditions or constraints:
      Same limits, trials, and conditions as utilised during logistics iterations is adopted.
   c. Interaction scenarios:
      i. Distinct trials, scenarios, and conditions are executed. Investigating this critical variable as a singular entity and also in multiples.
      ii. Cross-case iteration for logistics and maintenance process steps: This research seeks for synergies between these two (2) systems, and iterated the collaborated system as a single process entity.
      iii. Cross-case iteration for a fully automated entity: Simulation runs is executed assuming business functions of these systems is integrated, with all process steps assumed to be fully automated.
iv. Cross-case iteration for a fully manual entity: Iterations is carried out on aligned process steps of these automation systems, assuming a fully manual state of business functions.

v. Iteration on auto/manual escalations.

vi. Iteration on escalation potential on human resource variables.

5. Evaluate the overall impact of automating business functions: All distinct iterations inclusive of the single, multiple, cross-case scenarios, and other iteration conditions are analysed.

The proposed integrated case presents an outlook framework in holistically viewing business activities, and can also be adopted when executing optimization tasks. Sections and sub-sections below presents a detailed analysis of iteration results, inclusive of graphical illustrations of distinct trials, scenarios and conditions set.

4.2 Data validation

One superior objective of this research is discovering exceptional business states aligned with critical key variables for BP steps relative to TAT. In analyzing and ensuring outputs of this research conforms to good quality and standards, four tests as described by (Yin, 2009) is adopted. Synopsis of these tests is presented in Table 10 below:

<table>
<thead>
<tr>
<th>TEST</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construct Validity</td>
<td>This research adopts suitable constraints and variables for the topic being evaluated. Synopsis of the six (6) critical variables together with distinctly associated business states has been detailed during the course of study of this research.</td>
</tr>
<tr>
<td>Internal Validity</td>
<td>These tests illustrate thoughts, that certain components necessitate other circumstances, compelling applications of multiple numbers of evidence. This research is able to demonstrate that adopted critical variables together with distinctly associated business states have an impact on process TAT. Business states (Cmax &amp; Cmin) is adapted to execute multiple pieces of evidence for iterations comparing with standard devised numeric value (Normal).</td>
</tr>
<tr>
<td>External Validity</td>
<td>External validity presents a framework in testing if outputs or results are generalizable when considering the issue(s) other than the immediate study in focus. This research is able to configure a simulated framework which can be adopted during optimization activities or having a holistic view of business activities.</td>
</tr>
</tbody>
</table>
functions. Developed framework is generalizable, as it is not only applicable for optimizing logistics and maintenance business functions but adopted in configuring a standardised system of the entirety of BP’s in an enterprise.

| Reliability | These tests measure the accuracy of outputs or results. Sequential investigations are adopted in measuring the accuracy of outputs. Iterations from configured framework show that results of each simulation runs or scenarios are reliable and can be adopted by enterprise human resource. Results illustrate that proposed critical variables together with distinctly associated business states have a consequential impact on business TAT. |

Table 10: Data analysis testing adopted from Yin (2009)

4.3 Simulation outputs

One question posed by this research is how an enabled simulation integrated case would impact or enhance process TAT relative to ERP, MES, and plant automation systems. When developing and obtaining distinct iteration outputs, this research configured a framework aligned together with proposed critical variables, business states at different conditions set. This research adopts charts and variable blocks available in Anylogic simulation software to present, analyze and interpret distinct iterations, in a bid to optimize TAT of logistics and maintenance systems. When calculating TAT for distinct process at different critical variable condition set, the slider block is adapted to vary each state set at:

**Normal:** Standard numeric constraint value for a measurement, adapted to make a comparison with other adopted business states. Synopsis of how numeric metric for this business states are obtained has been detailed in an earlier chapter of this research. These business states serve as a base to make optimization comparison of proposed critical variables.

**Cmax and Cmin:** Business states aligned with distinct numeric metric adopted in drawing conclusions on the effects of proposed critical variables on business optimization relative to process TAT.

This research adopts sequential investigations in developing, exploring and presenting insights to proposed integrated case. Executed by investigating interactions together with significant impacts, between adopted critical variables aligned with associated business states. Adopting this sequential methodology is one major limitation of this research, but ought to appropriate for the major objectives of this research at masters’ level. Attention is directed into developing an established experimental design/model for future studies. As detailed in earlier sections, this research adopts six (6) critical variables aligned with associated business states. These critical variables include “human resource
resolution time”, “escalation rate”, “critical factor”, “system resolution time”, “system maturity index”, and “business state index”. This research seeks to test the impacts of these six (6) variables (independent variables) on a dependent variable (response time) relative to TAT of BP’s. Three (3) business states levels which includes Normal (N), Cmax and Cmin is adopted in examining effects of these critical variables on business functions. Investigating impacts of these critical variables on BP's, develops an integrated case, for any BU holistically viewing the entirety of processes (auto & manual) making up the business enterprise. The proposed integrated case illustrates effects of these critical variables on processes, as it relates ERP, MES, together with Plant automation systems integrated as a unit, relative to logistics and maintenance business functions.

This research adopts three trials in streamlining configurations of these critical variables, so as to logically understand the effect(s) of the distinct variable on response time. Trial 1 adjusted these critical variables individually one at a time, trail 2 examines these critical variables in multiples of two, while trial 3 investigates these critical variables grouped in three(s), four(s), and five(s). Each trial investigates impacts of these critical variables at distinct business states set (Normal, Cmax, and Cmin).

This research assumes activation of the escalation rate potential is dependent on certain critical factor states (VHP, VIF, STD, NC, and Basic) aligned with distinctly associated multipliers. Thus, these two variables (escalation rate and critical factor) is executed in any large corporate aligned with each other. This research, therefore, integrates these two variables as one unit, in testing for impacts together with interactions of these critical variables on response time. Patterns, results, graphs, analysis and deductions of distinct iterations are presented in below.

**TRIAL 1: Single variable**

Three associated business states at Normal (N), Minimum (Cmin) and Maximum (Cmax) are investigated.

**At Normal**

At normal associated business state, all detailed critical variables are set at the midpoint to obtain response times. This response time is adopted when testing together with comparing for best optimization scenarios of detailed critical variables. The normal associated business state is compared with Cmax and Cmin associated business states respectively.

For simplicity of iteration Tables and Figures for each trial, this research assigns each critical variable with letters as presented. Letters L = Logistics and M = Maintenance is also adopted.

<table>
<thead>
<tr>
<th>Critical Factor</th>
<th>Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
At Cmax

Individual critical variable detailed is adjusted one at a time setting at Cmax, investigating for distinct impacts on response time. At the initiation of this associated business state, all critical variables are set at normal.

At Cmin

Individual critical variable detailed is adjusted one at a time setting at Cmin, investigating for distinct impacts on response time. At the initiation of this associated business state, all critical variables are set at normal.

Outputs and graphical illustrations obtained from Trial 1 scenarios relative to logistics and maintenance business domains are presented below.

<table>
<thead>
<tr>
<th>CONDITIONS</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min (L)</td>
<td>45</td>
<td>18</td>
<td>47</td>
<td>53</td>
</tr>
<tr>
<td>Normal (L)</td>
<td>56</td>
<td>56</td>
<td>56</td>
<td>56</td>
</tr>
<tr>
<td>Max (L)</td>
<td>68</td>
<td>16</td>
<td>66</td>
<td>59</td>
</tr>
<tr>
<td>Min (M)</td>
<td>386</td>
<td>151</td>
<td>402</td>
<td>460</td>
</tr>
<tr>
<td>Normal (M)</td>
<td>483</td>
<td>483</td>
<td>483</td>
<td>483</td>
</tr>
</tbody>
</table>

Table 11: Critical factor acronym
Deductions

Findings from outputs and combined statistical graphs presented in the Figure above illustrate after comparison with Normal (N) that:

- Critical Variables system maturity index (B), business state index (D) and system resolution time (E) increases when setting at Cmax and decreases setting at Cmin.
- Outputs illustrate a significant time reduction in response time when integrated with critical variable escalation rate (C).
- Response time decreases when setting critical variable escalation rate (C) at Cmax and increases when setting at Cmin.
Aligning with results obtained from trial 1 investigations above, this research test for the impacts of detailed critical variables as a multiple of two.

**TRIAL 2: Multiple Variables (two collections at a time)**

Two associated business states at Minimum (Cmin) and Maximum (Cmax) are investigated as a multiple of two investigating for impacts of double critical variables on response time.

**At Cmax**

Two critical variables are adjusted one at a time setting at Cmax, investigating for impacts on response time. At the initiation of this associated business state, all critical variables are set at normal.

**At Cmin**

Two critical variables are adjusted one at a time setting at Cmin, investigating for impacts on response time. At the initiation of this associated business state, all critical variables are set at normal.

Outputs and graphical illustrations obtained from Trial 2 scenarios relative to logistics and maintenance business domains are presented.

<table>
<thead>
<tr>
<th>CONDITIONS</th>
<th>Min (L)</th>
<th>Max (L)</th>
<th>Min (M)</th>
<th>Max (M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BC</td>
<td>14</td>
<td>19</td>
<td>121</td>
</tr>
<tr>
<td>2</td>
<td>BD</td>
<td>38</td>
<td>79</td>
<td>322</td>
</tr>
<tr>
<td>3</td>
<td>BE</td>
<td>43</td>
<td>71</td>
<td>368</td>
</tr>
<tr>
<td>4</td>
<td>CD</td>
<td>15</td>
<td>19</td>
<td>126</td>
</tr>
<tr>
<td>5</td>
<td>CE</td>
<td>16</td>
<td>17</td>
<td>144</td>
</tr>
</tbody>
</table>
Table 13: Trial 2, Critical variables outputs

Figure 32: Trial 2, Critical variables graphical illustration

Deductions

Findings from outputs and combined statistical graph presented in Figure above illustrate:

- Optimization scenarios for detailed critical variables occur at conditions integrated with critical variable escalation rate (C).
- Critical variables system maturity index (B), business state index (D) and system resolution time (E) has higher response times when setting at Cmax and lowest response times when setting at Cmin associated business states.

Observations from trial 2 above are considered for Trial 3 investigations, which serves as a confirmatory framework of investigations.

TRIAL 3: Multiple Variables (three, four, five & six collections at a time)
Trial 3 investigates how a collection of critical variables grouped in three(s), four(s), and five impacts on response time. Permutation and combination calculations presented detailed critical variables in complex multiples. This research is unable to iterate these critical variables arranged in these multiples, rather simplified configurations is iterated aligned with observations from previous Trials (1 and 2) investigations to make generalizations. Outputs and graphical illustrations obtained from Trial 3 scenarios relative to logistics and Maintenance business domains are presented.

<table>
<thead>
<tr>
<th>CONDITIONS</th>
<th>LOGISTICS</th>
<th>MAINTENANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABCDE (Cmax)</td>
<td>24</td>
<td>23.3%</td>
</tr>
<tr>
<td>ABDE (Cmax) &amp; C (Normal)</td>
<td>83</td>
<td>34.9%</td>
</tr>
<tr>
<td>ABDE (Cmax) &amp; C (Cmin)</td>
<td>26</td>
<td>29.1%</td>
</tr>
<tr>
<td>ABCDE (Cmin)</td>
<td>11</td>
<td>7.1%</td>
</tr>
<tr>
<td>ABDE (Cmin) &amp; C (Cmax)</td>
<td>9</td>
<td>5.6%</td>
</tr>
</tbody>
</table>

Table 14: Trial 3, Critical variables outputs
Figure 33: Trial 3, Critical variables graphical illustration

Deductions

Comparing response times as presented in the Figure above:

- Best optimization scenario occurs when setting critical variables system maturity index (B), business state index (D), system resolution time (E) at (Cmin) and escalation rate (C) at (Cmax).
- Outputs present confirmatory assertions that detailed critical variables aligned with critical variable escalation rate (C) have a significant decrease in response time.

Trial 3 therefore infers and confirms that minimal numeric multipliers for critical variables system maturity index (B), business state index (D), and system resolution time (E) together with maximum numeric multipliers for critical variable escalation rate (C) results in a proportionate decrease in response time.

Overall deductions

Outputs of distinct iteration trials together with graphical illustrations presented is examined and overall deductions are summarised. These assertions are proposed for investigating optimal optimization framework for detailed critical variables.
• Response time is best optimised in a large corporate with **lowest** numeric multipliers for critical variables system maturity index (B), business state index (D), system resolution time (E) and **maximum** numeric multipliers for critical variable escalation rate (C).

• A full SLA system maturity index policy, with a resolution time of less than two (2) hours for critical variable system resolution time (E) is essential.

• A business state index change policy of greater than (2) years is recommended for critical variable business state index (D).

• An escalation potential activated up to auto tier 2 escalation is essential for every process step.

This research further investigated three scenarios as detailed below.

<table>
<thead>
<tr>
<th>SCENARIOS</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Results for Distinct Iterations: Cross-Case Iterations</td>
</tr>
<tr>
<td>2</td>
<td>Results for Distinct Iterations: Automatic and Manual Escalation Iterations</td>
</tr>
<tr>
<td>3</td>
<td>Results for Distinct Iterations: Escalation Potential on Human Resource Variables</td>
</tr>
</tbody>
</table>

**Table 15: Additional Iterated scenarios**

**Scenario 1: Cross-Case Iterations**

Cross case simulation iterations of different trials are explored to investigate for similarities and/or differences between different iteration frameworks set.

<table>
<thead>
<tr>
<th>Tier 1</th>
<th>Auto/Manual Entity</th>
<th>Process steps are manually and automatically executed.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tier 2</td>
<td>Fully Automated Entity</td>
<td>All process steps are automatically executed.</td>
</tr>
<tr>
<td>Tier 3</td>
<td>Fully Manual Entity</td>
<td>All process steps are manually executed.</td>
</tr>
</tbody>
</table>

**Table 16: Cross-case iteration conditions**
This research configures different cross case iteration frameworks (Trial 1 – Trial 3) presented, so as to test for respective conditions set and make generalizations together with drawing conclusions. Cross case iterations assume logistics and maintenance BP steps is integrated so as to function as a unit, obtaining total response time.

<table>
<thead>
<tr>
<th>CONDITIONS</th>
<th>TIER #1: MANUAL &amp; AUTOMATED PROCESS</th>
<th>TIER #2: FULLY AUTOMATED PROCESS</th>
<th>TIER #3: FULLY MANUAL PROCESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIME DISTRIBUTIONS</td>
<td>70 HRS</td>
<td>56 HRS</td>
<td>126 HRS</td>
</tr>
<tr>
<td></td>
<td>27.8%</td>
<td>22.2%</td>
<td>50.0%</td>
</tr>
</tbody>
</table>

Table 17: Cross-case iteration outputs

![Graphical Illustration](image-url)

Figure 34: Cross-case iteration graphical illustrations
Deductions
Analysing outputs and graphical illustration presented in the Figure above. Results indicate a significant response time decrease for Trial 2 condition (Fully Automated Entity), and a significant response time increase for Trial 3 condition (Fully Manual Entity) when compared with trial 1 (Auto/Manual Entity) condition. Although it is technically impossible to automate the whole functional activities present in a large corporate, as certain process step has to be executed by a manual resource. Enterprise managers should, however, strive to automate a large number of business functions as possible. Cross-case analysis and graphical depiction illustrate that the more process steps automated necessitate a significant decrease in response time, resulting in an optimised or standardised system.

Scenario 2: Automatic and manual escalation iterations
Effects of manual and automatic escalation states together with critical factor states on process steps is investigated. This scenario assumes all process steps are fully automated and integrated with an escalation potential. Distinct escalation state aligned with associated multiplier is multiplied by total response time and then divided by distinct critical factor states aligned with the associated multiplier.

<table>
<thead>
<tr>
<th></th>
<th>VHP</th>
<th>VIF</th>
<th>STD</th>
<th>NC</th>
<th>BASIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto tier 1</td>
<td>4.2</td>
<td>5.3</td>
<td>8.4</td>
<td>14</td>
<td>42</td>
</tr>
<tr>
<td>Auto tier 2</td>
<td>3.9</td>
<td>4.9</td>
<td>7.8</td>
<td>13</td>
<td>39.2</td>
</tr>
<tr>
<td>Manual tier 1</td>
<td>4.8</td>
<td>6</td>
<td>9.5</td>
<td>15.9</td>
<td>47.6</td>
</tr>
<tr>
<td>Manual tier 2</td>
<td>4.5</td>
<td>5.6</td>
<td>9</td>
<td>14.9</td>
<td>44.8</td>
</tr>
</tbody>
</table>

Table 18: Auto/Manual escalation iteration outputs
Analysis from the Figure presented above indicate lowest response time for process steps escalated at autotier2 and manaultier2 escalation potential respectively.

Comparison between autotier2 and manaultier2 states indicate minimal response time for process steps integrated with autotier2 escalation potential.

Critical factor state (VHP) indicate lowest response time for process steps.

Though it might be technically impossible to automatically escalate BP’s up to a tier2 escalation potential as certain BP’s has to be manually executed. This research, however, recommends that enterprise human resources strive to escalate most process steps automatically, aiming at autotier2 escalation potential. For BP’s executed manually, it is recommended that business entities endeavor to escalate up to manaultier2 escalation potential. These recommendations necessitate an overwhelming decrease in a response time of process steps.

Scenario 3: Escalation potential on human resource variables

This scenario assumes all process steps are integrated with an autotier2 escalation potential. Effects of escalation potential integrated with distinct critical factor states on human resources presented in previous sections are examined.
<table>
<thead>
<tr>
<th></th>
<th>VHP</th>
<th>VIF</th>
<th>STD</th>
<th>NC</th>
<th>BASIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Executive</td>
<td>39</td>
<td>49</td>
<td>78</td>
<td>130</td>
<td>392</td>
</tr>
<tr>
<td>Manager</td>
<td>19.5</td>
<td>24.5</td>
<td>39</td>
<td>65</td>
<td>196</td>
</tr>
<tr>
<td>Supervisor</td>
<td>7.8</td>
<td>9.8</td>
<td>15.6</td>
<td>26</td>
<td>78.4</td>
</tr>
<tr>
<td>Operations</td>
<td>3.9</td>
<td>4.9</td>
<td>7.8</td>
<td>13</td>
<td>39.2</td>
</tr>
<tr>
<td>Administrator</td>
<td>2</td>
<td>2.5</td>
<td>3.9</td>
<td>6.5</td>
<td>19.6</td>
</tr>
<tr>
<td>Manual</td>
<td>11.7</td>
<td>14.7</td>
<td>23.4</td>
<td>39</td>
<td>117.6</td>
</tr>
</tbody>
</table>

Table 19: Escalation potential on human resource iteration outputs

Figure 36: Escalation potential on human resource outputs and graphical illustrations.

- Analysis from Figure presented above indicates lowest response time for human resource critical variable “Administrator” escalated at autotier2 escalation potential.
• Critical factor state VHP indicates lowest response time.

This research suggests escalation potential is activated in a large corporate aligned to an alternate human resource with minimal response time.

4.4 Overall result analysis
This section illustrates a synopsis of analysed outputs, presenting evidence of this research objectives. Outputs detailed above presents a clearer illustration of this research set objectives. Inferring that “Human resource resolution time’, “Escalation rate”, “Critical factor”, “System resolution time”, “System maturity index”, and “Business state index” critical variables would have a consequential impact on business optimization relative to process TAT.

![Figure 37: Result in summary](image)

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>CONDITION (Cmax &amp; Cmin)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Resource Resolution Time</td>
<td>IMPACT (BP’s)</td>
</tr>
<tr>
<td>Escalation Rate</td>
<td>Optimized TAT</td>
</tr>
<tr>
<td>Critical Factor</td>
<td></td>
</tr>
<tr>
<td>System Resolution Time</td>
<td></td>
</tr>
<tr>
<td>System Maturity Index</td>
<td></td>
</tr>
<tr>
<td>Business State Index</td>
<td></td>
</tr>
<tr>
<td>Human Resource Resolution Time</td>
<td>Simulation outputs illustrate the more enterprise human resource delay in responding to business functions, necessitates a relative increase in business TAT.</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Escalation Rate/Critical Factor</td>
<td>Results illustrate that a swift escalation rate response aligned with critical factor leads to a consequential decrease in business TAT.</td>
</tr>
<tr>
<td>System Resolution Time</td>
<td>Simulation results illustrate the faster BU systems responds to BP’s, a consequential decrease in business TAT is attainable.</td>
</tr>
<tr>
<td>System Maturity Index</td>
<td>Outputs show a consequential delay in upgrading any business corporate automation systems results to a relative increase in TAT.</td>
</tr>
<tr>
<td>Business State Index</td>
<td>Results illustrate when sufficient time is allowed for enterprise human resource to adapt to modification in business state index, it results in accelerated response time.</td>
</tr>
</tbody>
</table>

Table 20: Iteration results in summary

4.5 Summary of chapters

Chapter one

This research started in chapter one, presenting a background context of this research. The background context addressed issues which included: introduction, originality, objectives, Problem statement, questions, and organization or outline of this research.

Chapter two

Chapter two presented the readers with a comprehensive background context and support literature examinations. The review focused on the synopsis of published literature(s) relative to systems thinking, PM techniques, enterprise systems, BP models, systems engineering, logistics together with maintenance systems and simulation-based decision support approach.

Chapter three

In this chapter, detailed research methodology and design adopted to gather, examine, interpret inputs and outputs are scrutinised. The chapter presented an extensive description of this research constraints together with associated critical variables and adopted standard data.
Chapter four
Presentation, analysis, interpretations and summary of research results in relation to this research objectives is provided in this chapter.

Chapter five:
This chapter sheds light on this research by synthesizing the study into conclusions. The contribution of this research and recommendations is also presented in this chapter.

4.6 Conclusion
After investigations, this research is able to establish the suitability of adopted methodologies, identifying certain critical variables aligned with distinct business states which can be adopted for optimization purposes. Distinct iterations presented a graphical depiction of this research outputs, illustrating and affirming that adopted variables aligned with associated business states have a consequential impact on process optimization relative to TAT in a BU. Optimizing TAT of these BP’s can be quite substantial as a number of processes or projects within a BU increases. Results align with key objectives of this research, developing an international best practice benchmark for optimizing TAT of BP’s in any BU. Outputs of distinct iterations show that value can be added to optimizing BP’s through simulation-based approach together aligned with other BP modelling tools and techniques. This documented outputs and results can serve as an integrated case for enterprise human resource optimizing TAT of BP’s relative to automation systems.

4.7 Chapter summary
This chapter presented, analysed, and interpreted outputs from distinct iterations. Summary of each chapter in this research in relation to research objectives and questions is also presented. The next chapter presents conclusions and recommendations for this research.
5 Chapter five: Conclusions and recommendations

The previous chapter presented, analysed and interpreted outputs of distinct iterations when aligned with this research objective and questions. Chapter five wraps up this research with conclusions, inclusive of this research contribution to the body of knowledge. Recommendations and further research are also proposed in this chapter.

5.1 Introduction

This research finding(s) can be put to practical use by enterprise human resource or developers in developing together with configuring a standardised or optimised system. Contributions of this research to the body of knowledge, recommendations, suggestions for further research, and overall conclusions of this research are presented in this chapter.

5.2 Contributions to the body of knowledge

Several bodies of knowledge predicted an overflow of new complexities relative to business automation systems. Enterprise professionals and researchers are already responding together with grappling with modern methods inclusive of mapping out and executing dedicated philosophies towards cushioning the impact(s) of these intricacies (Kontoravdis, 2005). Business corporates are beginning to adjust BP steps towards preserving a competitive edge and enhancing or maintaining productivity. One major motivation of this research is to attract the attention of enterprise professionals and researchers by preparing an integrated case document. This document becomes a handy reference for conducting studies on BP optimization. Some of the contributions of this research are detailed in corresponding paragraphs below.

Results illustrate that interdependent processes can be modelled and simulated, together with investigating impacts of multiple variables in reducing interdependent business process time. This is achieved by defining together with developing application toolset for system prioritization and optimization. The effectiveness of adopted toolsets together with respective distinct analysis capacity in directing organizational, system and business states is investigated.

Results of this research substantiate a simulation model potentially benefits any large corporate, specific to evaluating time taken to conduct BP’s and holistically viewing the entirety, interactions, and interdependencies of processes (auto & manual) making up enterprise integrated systems (top floor to shop floor).

This research presented an optimised business state. Developing and configuring an integrated case together with investigating the impacts of change on the process, business and system maturity relative to business response time.
This research presented a holistic view of core enterprise activities of a large business together with the definition of these processes relative to global standards. This research presented all pertinent implementation and execution details of logistics and maintenance business functions, necessary to evaluate and enhance distinct process steps.

This research developed and defined potential critical variables aligned with distinct business states having a significant effect on BP optimization activities specific to BP response time.

This research Presents enterprise professionals and researchers with a document, detailing impacts and potential benefits of distinct critical business variables relative to optimize response time.

5.3 Recommendations

The frenetic mode of global businesses together with distinct impacts on business functions has transformed the delivery of services and products into a more complicated enterprise activity (Kontoravdis, 2005). More research methodologies and objectives relative to system thinking approach on lessening the impact of these complications enhances overall enterprise functions.

“System Thinking” is recommended as an approach to enterprise human resource optimizing or standardizing communications between BP's from “top floor to shop floor” and vice versa. (Gharajedaghi) established that systems thinking describes a system in the context of a larger framework, and studying functions of these systems as it relates to bigger entities.

5.4 Suggestions for further research

Automation and System thinking present enterprise processes in the context of a larger framework. Developing a structure for visualizing interdependencies or interrelationships of processes, rather than static activities of these processes (Senge, 2006). Numerous fascinating research questions still exist, when further investigating enterprise systems as detailed in corresponding paragraphs below.

One area to explore in further study is presenting an integrated case detailed research, evaluating; modelling; and simulating the whole functional processes of enterprise automation systems in any BU as it relates “top floor to shop floor” communication and vice versa.

A second research focus might be investigating interdependencies of the whole BP's of enterprise automation systems as it relates “top floor to shop floor” optimization and vice versa. Developing a framework towards optimizing business outputs inclusive of TAT, and cost implications.

Investigating synergies between enterprise operations serve as a toolset for enterprise human resource(s) when studying how each of these processes influences or communicates with one another in a BU.
5.5 **Overall conclusions**

Bryman established conclusions must align with detailed research questions and objectives, presenting impacts or implications of the research findings. Despite limitations of this research in detailing six critical variables out of a large number of critical factors influencing business processes execution, and adopting sequential investigations in analyzing outputs. Results corroborate that a simulation model potentially benefits any large corporate, specific to evaluating time taken to conduct business processes.

The results indicate that collaborated processes can be modelled and simulated. Investigating impacts of multiple critical variables in maximizing interdependent business process time. Future studies can be carried out in evaluating the whole critical factors affecting enterprise processes and adopting a statistically established methodology (factorial technique) in analyzing outputs.

5.6 **Limitations and envisaged research challenges**

Despite positive prospects of this research, few limitations and challenges are observed during the course of executing this research set objective. Some of these limitations and challenges are detailed.

- Simulation modelling requires expertise in modelling.
- Different policies on confidentiality and privacy issues is a limitation as documents presenting a synopsis of core process steps describing logistics and maintenance systems isn’t easily accessible.
- Simulation software’s are very expensive.
- Professionals and enterprise human resource in BU’s having a working knowledge of these BP’s are not easily accessible.
- Only six critical variables as detailed in previous sections of this research out of a large number of essential business factors impacting on BP’s is investigated. However, the six detailed critical business variables are intent towards meeting this research set objective(s) and presenting an integrated case.
- Only two essential business functions (logistics and maintenance) is investigated out of a large number of core enterprise activities of automation systems under consideration in this research. However, the two core enterprise functions are intent in meeting this research objective(s) and presenting an integrated case.

5.7 **Chapter summary**
Chapter five concluded this research with a synopsis of this research contribution to the body of knowledge. Recommendations together with suggestions for further research is also presented.
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Appendix

INTEGRATED LOGISTICS

Level 1 (L1): BUSINESS AREA

- Logistics Management
- Logistics Strategy
- Logistics Execution
- Logistics Control

Level 2 (L2): PROCESS GROUP

- Inbound Logistics
  - Order Processing
  - Goods Receiving
  - Warehousing
- In-Process Logistics
  - Inventory Processing
- Outbound Logistics
  - Goods Receiving