Cyber-Physical Business Systems Modelling: Advancing Industry 4.0

A Thesis Submitted in Partial Fulfilment of the Degree of

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By

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Abstract

The dynamic digital age drives contemporary multinationals to focus on delivering world-class business solutions with the use of advanced technology. Contemporary multinationals relate to a present-day business primarily engaged to generate profits. These complex multinationals offer value through the manufacture, sale, and management of products and services. Disruptive strategies in operations driven by emerging technological innovations demand continuous business improvements. These insightful opportunities are inclusive of operations, enterprise systems, engineering management, and research.

Business sustainability is a strategic priority to deliver exceptional digital solutions. The Fourth Industrial Revolutions (4IR) offer significant technological advancements for total business sustainability. The underlying 4IR technologies include Cyber-Physical Systems (CPS). The collective challenges of a large global business are not easy to predict. CPS protocols deliver sustainable prospects required to integrate and model physical systems in real-time driven by the 4IR implementations.

The goal of this thesis is to develop a model (CPS) suitable for self-predicting and to determine ideal operational practice driven by technologies of the 4IR. The model (CPS) seeks a novel tool effective for comprehensive business evaluation and optimisation. The competence of the anticipated tool includes suitability to collaborate current operations and predict the impact of change on a complex business.

The model (CPS) development is driven by technological problem-solving competencies of engineering management and beyond centred on a mixed-method approach. This thesis adopts business processes as a basis for the constitution of the model (CPS). The model data is captured in Visio, validated and subsequently modelled in Accuprocess. The model is tested via two business cases; a single and multiple simplified relationships with the baseline validated. The validated model (CPS) is then adopted to determine the impact of changes on the business. The eighteen change variables are extracted from literature. These variables are defined mathematically and a factorial experimental protocol is adopted to determine the relationship between these variables and its impact on the business (via the CPS). The factorial experimental protocol is constituted and the model is run repetitively with the factorial constraints. The resultant output of the factorial is a multivariable equation representing the impact of each of the change variables on the business.

The model (CPS) articulates four databases; (1) Business processes delivering a digital prototype of a real-world modern multinational, (2) Business process modelling tools for configuration, testing, and analysis of the developments, (3) Business process variables comprising factors with significant influences on business executions, (4) Optimisation database for comparative efficient validation of the model (CPS) outputs. An initial study conducted indicates simulation methods and Design of Experiments (DOE) statistical techniques as basic differentiators for performing predictive analytics. Both approaches are crucial navigators for randomising decision-nodes of process steps and constitute experimental metrics for quantification. The Taguchi method is decisive for streamlining the number of experimental runs of large input factors and interactions.

The key outputs of the investigative scenarios are optimal operational practices for current and future business demand. The results introduce an innovative approach to business analysis tools and decision-support to determine relationships between variables and impact to the business. Proof that modelling a complex business as a CPS to provide a comprehensive input and systems dynamic of a complex business for predictive capability is possible. The results deliver a singular equation effectively representing the business response for comprehensive factors impacting operations set a statistical significance of 95%. This provides clarity that the most significant variables impacting a business can be evaluated with the impacts reduced to simple correlations.

The singular equation implies that any modern business without prepositioning process steps can substitute associated experimental values to predict business demand. The outputs introduce a viable alternative to existing business models with reduced efforts and advancements to implementing business obligations. This offers a shift from traditional analysing methods incapable of self-predicting in real-time. The results provide a validated and generic model (CPS) for detailed business evaluation, optimisation, and sustainability requiring moderate skill competencies.

Keywords

Business processes, Business process variables, Contemporary multinationals, Cyber-physical systems, Design of experiments, Fourth industrial revolution, Modelling, Simulation.

Declaration of original work

I, **Medoh Chuks Nnamdi, student number 201510202,** declare that this thesis is my original work except where referenced, submitted to the University of Johannesburg in partial fulfilment of the requirements for the degree Ph.D. in Engineering Management. This thesis has not been presented to any university in the past.

---------- **31 JULY 2019**

SIGNATURE **DATE**

Publications

S/N	PAPER TYPE	PAPER TITLE	YEAR	STATUS
1	Research Paper	Medoh C.N and Telukdarie A. Industry 4.0: Business Process Optimisation[1]. Benchmarking: An International Journal (BIJ).	2019	In press
2	Research Paper	Medoh C.N and Telukdarie A. Enhancing Enterprise Resource Planning and Manufacturing Execution System efficiency with simulation-based decision support: International Journal of Business Process Management and Benchmarking.	2018	In press
3	Research Paper	Medoh C.N and Telukdarie A. Logistics optimisation a Cyber-physical model. International Journal of Business Analytics (IJBAN).	2018	In press
4	Conference Paper	Medoh C.N and Telukdarie A. A Methodology to Integrate Artificial Intelligence with the Design Structure Matrix Approach. In 2018 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM) (pp. 783-787). IEEE.	2018	Published
5	Conference Paper	Medoh C.N and Telukdarie A. Decision support for BPOM framework based on industry 4.0 enablement. Industrial Engineering and Operations Management (IEOM).	2018	Published
6	Conference Paper	Medoh C.N and Telukdarie A. Factorial model design for BPV. Industrial Engineering and Operations Management (IEOM).	2018	Published
7	Conference Paper	Medoh C.N and Telukdarie A. An evaluation of human resource engagement practices: An African context. Industrial Engineering and Operations Management (IEOM).	2018	Published
8	Conference Paper	Medoh, C. and Telukdarie, A. Cost optimisation decision-support based on Fuzzy logic applications, advancing industry 4.0. In Proceedings of the International Annual Conference of the American	2018	Published

		Society for Engineering Management. (pp. 1-11). American Society for Engineering Management (ASEM).		
9	Conference Paper	Medoh C.N and Telukdarie A. Business Process Modelling Tool Selection: A Review. Industrial Engineering and Engineering Management (IEEM).	2017	Published
10	Conference Paper	Medoh C.N and Telukdarie A. Business process quantification: A holistic approach. In Proceedings of the International Annual Conference of the American Society for Engineering Management. (pp. 1-10). American Society for Engineering Management (ASEM).	2017	Published
11	Conference Paper	Medoh C.N and Telukdarie A. Enhancing Enterprise Resource Planning and Manufacturing Execution System efficiency with simulation-based decision support: American Society for Engineering Management (ASEM), IAC.	2016	Published

Table of contents

List of Acronyms

CPS	Cyber-Physical System
4IR	Fourth Industrial Revolution
3IR	Third Industrial Revolution
BPOM	Business Process Optimisation Model
BPV	Business Process Variables
BPMT	BPMT
BPMN	Business Process Modelling Notation
DOE	Design of Experiments
BP	Business Processes
ERP	Enterprise Resource Planning
MES	Manufacturing Execution System
PCN	Plant Control Network
MESA	Manufacturing Enterprise Solutions Association
ISA	International Society of Automation
ISO	International Standard Organisation
BPMN	Business Process Modelling and Notation
ARIS	Architecture of Integrated Information Systems
AHP	Analytic Hierarchy Process
DE	Discrete Event
ABM	Agent-Based Modelling
SD	System Dynamics
ANOVA	Analysis of Variance
DOF	Degree of Freedom
UML	Unified Modelling Language
BPV	Business Process Variables
APQC	American Productivity & Quality Center
HSE	Health, Safety & Environment
BPA	Business Process Automation
ITIL	Information Technology Infrastructure Library
IT	Information Technology
VHP	Very High Priority

VIF	Very Important Factor
STD	Standard
NC	Not Critical
KPI	Key Performance Indicators
RBPM	Role-Based Process Maps
IDEF	Integration Definition
PERT	Program Evaluation Review Technique
(λ_2)	Two-Factor Interactions
(λ_3)	Three-Factor Interactions
(λ_4)	Four-Factor Interactions
(λ_5)	Five-Factor Interactions
(λ_6)	Six-Factor Interactions
(λ_7)	Seven-Factor Interactions
(σ)	Standard Deviation
FI	Factor Interactions
RN	Random Numbers
SR	Simulation Runs
MS	Mean square
SS	Sum-of-squares
SLA	Service Level Agreement
SLR	Systematic Literature Review
IOT	Internet of Things
IOP	Internet of People
IOS	Internet of Services
RO	Research Objectives
C.I	Consistency Index
R.I	Random Index

List of Figures

List of Tables

Chapter 1: Introduction and Theoretical Background

1.1 Chapter overview

Contemporary multinationals are increasingly navigating through a complex and extremely disruptive business space in which change, competitive threats, and uncertainty persist (Bengtsson, et al., 2018). Multinationals are constantly developing insightful innovations related to enhancing business sustainability (Thomas and Katrin, 2015). The dynamic digital age in executing operations challenges multinationals to continuously integrate sustainable technological business advancements (Jeston and Nelis, 2014). Business sustainability relates to best practice present and future technological solutions employed by corporate establishments for executing business operations (Hoffman, 2018). The implementations of business sustainability have been significantly considered in discussions related to the Fourth Industrial Revolutions (4IR) (De Sousa Jabbour, et al., 2018; Narayanan, 2016; Rüßmann, et al., 2015; Lee, et al., 2015). The investigations commence in chapter one structured in six sections captured in Figure 1.

Figure 1: Scope of chapter one

Source: (Authors own compilation)

The initial section provides clarity on the purpose of this thesis with a discussion relating to the research problem.

1.2 Research purpose

Technological Innovations and dynamic business strategies radically influence the business ecosystem (Hermann, et al., 2016 and Schmidt, et al., 2015). The 4IR technologies deliver exceptional business solutions and digitalisation opportunities to discuss business challenges (Rüßmann, et al., 2015). This

includes total business optimisation, integration, visibility, and sustainability (Stock and Seliger, 2016). The 4IR implementations fuels business growth expected to deliver enhanced business outputs and sustainable multinational efficient operations (Anand, et al., 2013). When faced with innovation, the 4IR protocols indicate traditional analysis methods for business implementations are inadequate (Narayanan, 2016). Present-day analysis tools do not offer multinationals with high-quality strategic insights. This is inclusive of the comprehensive systems positioning and predictive competencies of the available business analysis tools.

Gartner in white paper publications (2013) indicates a superior percentage of existing multinationals in years to come will manage business execution with attention directed to real-time predictive analytics. Multinationals must decide to invest in innovative decision-support tools effective for future predictive analysis. This thesis prepositions a model effective to collaborate with physical systems and serve as a decision-support analysis tool for current and future business implementations.

The theoretical perspectives relating to the model developments cover diverse approaches for modelling and investigating business strategies. The theoretical perceptions are driven by related work available in existing peer-reviewed publications.

1.2.1 Related work

The 4IR technologies support a new integration level to business modelling, analysis, and implementations (Lee, et al., 2015). As increasing numbers of multinationals seek to embark on the transformative 4IR implementations and pilot a maze of opportunities, numerous questions arise (Wan, et al., 2014). The inquiries result in a future research direction, which awaits investigation (Petropoulos, et al., 2018 and Hermann, et al., 2016). This thesis reviews relevant literature related to business model developments. Table 1 details a synopsis of some important literature related to business model developments from (2012 – 2017).

Table 1: Relevant existing business model developments (2012 – 2017)

S/N	AUTHORS	DEFINITION
1	Scholz-Reiter and Stickel, 2012	This research presents a document discussing the importance of developing models to optimise business processes and ensuring sustainability.
2	Weske, 2012	This research presents a systematic review of business process management architectures.

3	Janiesch, et al., 2012	This research developed a proof-of-concept of event-driven business activity monitoring, optimisation, and management.
4	Keong, 2013	This research details a literature review investigating fundamental measuring indicators essential in ensuring business sustainability.
5	La Rosa, et al., 2013	This research presents a document reviewing approaches to business process consolidation essential in optimising multinationals.
6	Julian, et al., 2014	This research details a literature review on the current status of business process management employing complex event processing technology.
7	Ying, et al., 2014	This research proposes a method of investigating minimum depth-first search codes for calculating process fragments distance with graphs.
8	Isel, 2015	This research presents a systematic literature review investigating the state of the art business process optimisation and modelling quality.
9	Riggins and Wamba, 2015	This research investigated the role of technology and facilitates approaches to streamline workflow through automation.
10	Metzger, et al., 2015	This research presents a document empirically comparing and analysing several predictive monitoring approaches effective to optimise a business.
11	Manal, et al., 2017	This research presents a systematic review detailing an evaluation framework for business process modelling techniques.
12	Medoh, 2017 (a)	This research presents vital information on the ability to predict, and simulate business change impact through modelling.

Table 1 detail previous relevant findings relating to how existing peer-reviewed publications have attempted to develop a sustainable business model. The information facilitates insights on the current structure of business model developments and establishing research gaps.

1.2.2 Research Gaps

A review of the peer-review documents detailed in Table 1 summarises the following research limitations. Existing business models are:

(a) Non-predictive and actually repositories: This offers limited competence for predictive business enablement. This thesis investigates business models effective for current and future predictive analysis.

(b) Non-comprehensive: This compromises the comprehensive modelling of physical business structures. This thesis seeks an exhaustive business model capturing all physical systems of a multinational.

(c) Non-system contextualisation: This provides challenges for investigating the interrelated relationships between physical business systems. A system refers to sets of sub-constituents collaborating to function as a whole (Stichweh, 2011). This thesis anticipates for an intelligently networked, holistic, and integrated structure of business models delivering a digital prototype for real-time investigation and analysis.

The research gaps identified results in future research directions for business model developments. The literature (Hoffman, 2018; Bengtsson, et al., 2018; Manal, et al., 2017; Metzger, et al., 2015; Mellat-Parast, et al., 2015; Liu and Shi, 2015) indicates the importance of developing a comprehensive holistic and predictive business models for enhancing business sustainability.

1.3 **Research questions**

(a) Referencing the current knowledge base and business modelling status, can a CPS model be developed to represent a large business?

(b) Are the 4IR technologies (CPS/Integration, Automation) practical to provide a comprehensive input and systems dynamic of a complex business?

(c) Can a validated CPS business model be tested for reliability enabling total business performance and sustainability?

(d) Based in literature and best practice, what are the variables affecting a business, can these variables be integrated into the CPS and impacts determined?

(e) Does the business model proposed, serve as a decision-support analysis tool for current and future business implementations relating to predicting multiple impacts of business demand and change?

(f) Can advanced methods be adopted to determine relationships between variables and impact to business? What is the most significant impacting variables and can the variable impacts be reduced to simpler correlations?

This thesis aims to answer the research questions detailed implementing sustainable 4IR technological advancements fundamental in elevating multinationals into the digital generation of business evolution. The 4IR technologies identified in the literature (Narayanan, 2016 and Metzger, et al., 2015) include Internet of Things (IoT), Internet of People (IoP), Internet of Services (IoS), Cyber-Physical

Systems (CPS), service-oriented computing, and cloud computing. These technologies are cutting edge with effective applications across different business diversities inclusive of manufacturing, agriculture, and supply chain management (Metzger, et al., 2015 and Kagermann, et al., 2013).

A review of the 4IR technologies indicates CPS as a priority differentiator effective for implementations of interrelated sub-systems supporting the comprehensive systems developments of business models (Zander, et al., 2015; Lee, et al., 2015; Wan, et al., 2014). The applications of the CPS protocols prompt sets of pertinent research objectives and model assumptions.

1.4 **Research aim and objectives**

The next sub-sections provide clarity to the research aim and detail sets of research objectives and model assumptions.

1.4.1 Research aim

The aim of this thesis is to develop a model (CPS) effective to collaborate current multinational operations and have the capacity to predict the impacts of change on the business. This is driven by applications of the 4IR technologies and comprehensive constituents of a complex business for total business sustainability.

1.4.2 Research objectives

(a) Conduct a comprehensive literature review to determine the status of various knowledge relevant to this research.
(b) To review existing business models and determine its applicability for effectively predicting impacts of change.
(c) To evaluate the effectiveness of the 4IR implementations for innovative business advancements and total business sustainability.
(d) To develop a comprehensive set of operations which serve as an effective representation of a present-day multinational.
(e) To determine important business constituents essential for developing a comprehensive holistic model (CPS) for a complex business.
(f) To develop a comprehensive holistic model (CPS) which serve as a digital representation of multinationals for total business evaluation.
(g) To test, simulate and optimise the levels of importance, states, and interdependencies of each business constituent influencing the development of a practical model (CPS).

(h) To develop an experimental protocol through a representative model output effective for comparative statistical analysis.
(i) To develop a simplified relationship obtainable from the comparative statistical analysis effectively representing the business response for variables impacting operations.
(j) To critically evaluate the impact that can be determined from the model (CPS) and how multinationals can leverage the inferences for transforming the future of the corporate world.
(k) To validate the individual models and collective results relating to developing the model (CPS) by providing recommendations for operational practice and implementations.

1.4.3 Model assumptions

(a) The model (CPS) developments is a digital representation of a complex business focus on relevant theoretical perceptions and engineering management approach.
(b) Each business constituent in the model (CPS) development is comprehensive and a fundamental subset within multinationals.
(c) The model (CPS) developments are imperative, generic, reproducible and applicable irrespective of the type of business sector.
(d) Applications of the model (CPS) require minimum operational time, technical proficiency and data inputs.

The proposed business model developments and applications detailed extensively details the collective background of this thesis justified in the next section.

1.5 Justification and originality of the research

The next sub-sections justify and provide clarity on the originality of this thesis.

1.5.1 Research justification

This thesis focusses on developing a model (CPS) applicable irrespective of the type of business sector. This thesis aims to contribute to engineering management practice and business implementations specific to a large global business. The collective outputs seek to deliver a novel alternative to existing business models. The results propose a predictive analysis tool for decision-support and detailed multinational evaluation of operational practice, inclusive of 4IR implementations.

1.5.2 Originality of research

Originality comprises the tools, and techniques fundamental in executing an investigation which delivers an innovative discovery. The interrelated theories proposed are unique concepts of this thesis. Figure 2 details a summary of the proposed advanced constituents.

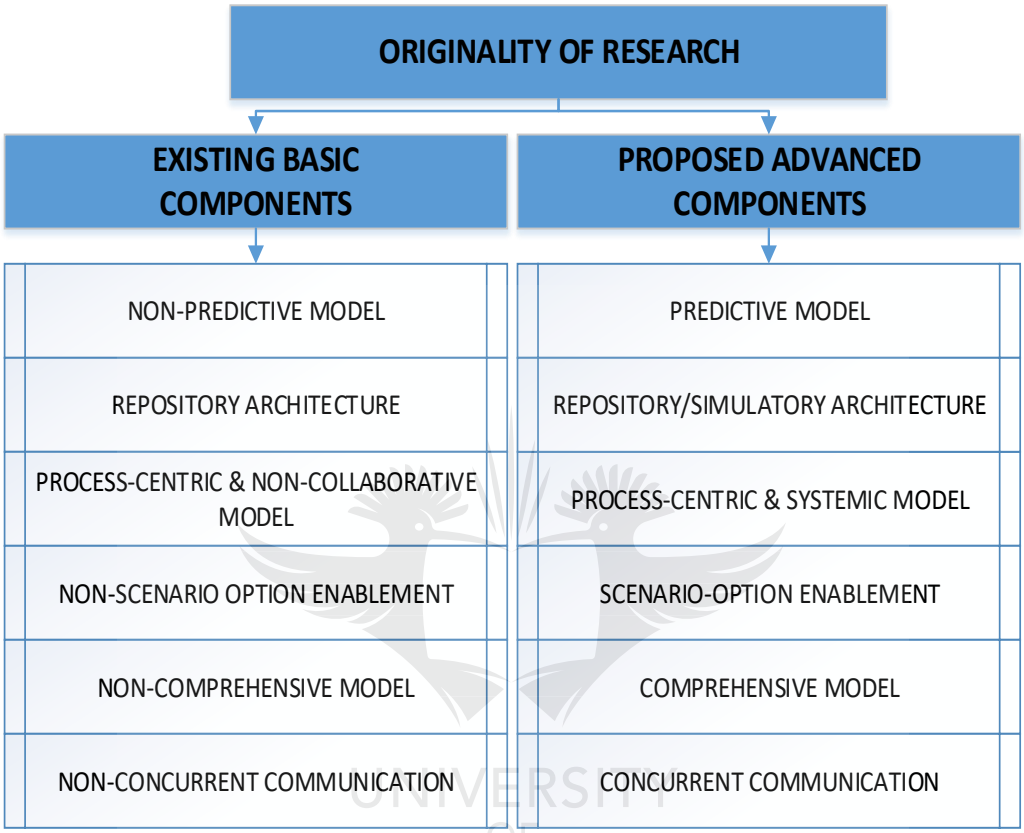


Figure 2: Proposed advanced constituents establishing the originality of this thesis

Source: (Authors own compilation)

The next section summarises the steps unique to each chapter constituted for this thesis.

1.6 Research outline

This thesis layout details sequential logical steps unique to each chapter constituted, comprising seven chapters.

Chapter one (Introduction and Theoretical Background)

Chapter one initiates this thesis with a background on the purpose of this thesis, driven by fundamentals of the 4IR implementations. The discussions define the aim, questions, objectives, and originality of this thesis.

Chapter two (Literature Review)

Chapter two presents an extensive systematic literature review and a detailed literature study for this thesis. The discussions elaborate on the theoretical perceptions relevant to investigate the existing research gaps detailed. The systematic literature review is conducted with defined keywords delivering relevant documents. The keywords investigated potentially include Multinational sustainability, 4IR implementations, and business models. The relevant documents collected are comprehensively reviewed to gather knowledge on:

(a) The purpose of establishing multinationals.
(b) The importance of ensuring sustainability via optimal technological business solutions.
(c) Benchmarks of the 4IR technologies relevant to develop the proposed business model.
(d) The important business constituents applicable to developing a sustainable business model for a large global business.

The systematic literature review is potentially conducted via Scopus database, and online sources provided by the University of Johannesburg library and information resources. The potential vital business constituents identified are investigated in sequential order. The literature review is potentially supported by oral interview engaging relevant business stakeholders to gather expertise and knowledge related to the proposed business model developments.

Chapter three (Research Design and Methodology)

Chapter three discusses the research design and method suitable for this thesis. This chapter potentially develops a conceptual model (CPS) framework of business constituents reviewed in the previous chapter.

Chapter four (Model Development)

Chapter four expands from the previous chapter to present a step-by-step discussion related to developing the conceptual model (CPS) framework. This chapter potentially discusses the steps, applications, and justifies the integrated business constituents selected from concept to implementations.

Chapter five (Model Implementations)

Chapter five progress from the model development to discuss practical implementations of the developed model (CPS). The database of each integrated sub-system related to the proposed conceptual model (CPS) is potentially validated with thin-slice demonstrations.

Chapter six (Model Optimisation)

Chapter six validates the model development and implementations from previous chapters with a discussion on optimisation demand for ideal operational performance. The model optimisation scenarios potentially present comparative statistical analysis to prove the suitability of the predictive tool for future operations and advanced decision-support.

Chapter seven (Summary, Conclusions, and Recommendations)

Chapter seven highlights the comprehensive results collected related to addressing the aim of this thesis. This is potentially detailed and interpreted in a logical sequence combined with discussions on the reliability, validity, impacts and research contributions of the key findings collected from this thesis.

1.7 Summary and conclusions

Chapter one initiates this thesis with a background on the benefits of developing a holistic and predictive analysis tool for detailed business evaluation. The business solutions focus on the fundamentals of the 4IR implementations to optimise a large global business in real-time. The discussions extensively define and justify the related work, current research gaps together with the intentions of this thesis. The next chapter presents an extensive systematic literature review and a detailed literature study for this thesis.

Chapter 2: Literature Review

2.1 Chapter overview

Present-day multinationals across the globe are operating in a dynamic and uncertain business space (Van Der, et al., 2016; Narayanan, 2016; Trkman, 2010). Multinationals aspiring towards business sustainability requires continual innovation and value creation (Walker, et al., 2014 and Houy, et al., 2010). Chapter two commence with a comprehensive systematic literature review. The review results in documents for a detailed literature study. Figure 3 structures the scope of the systematic literature review is structured in sequential order.

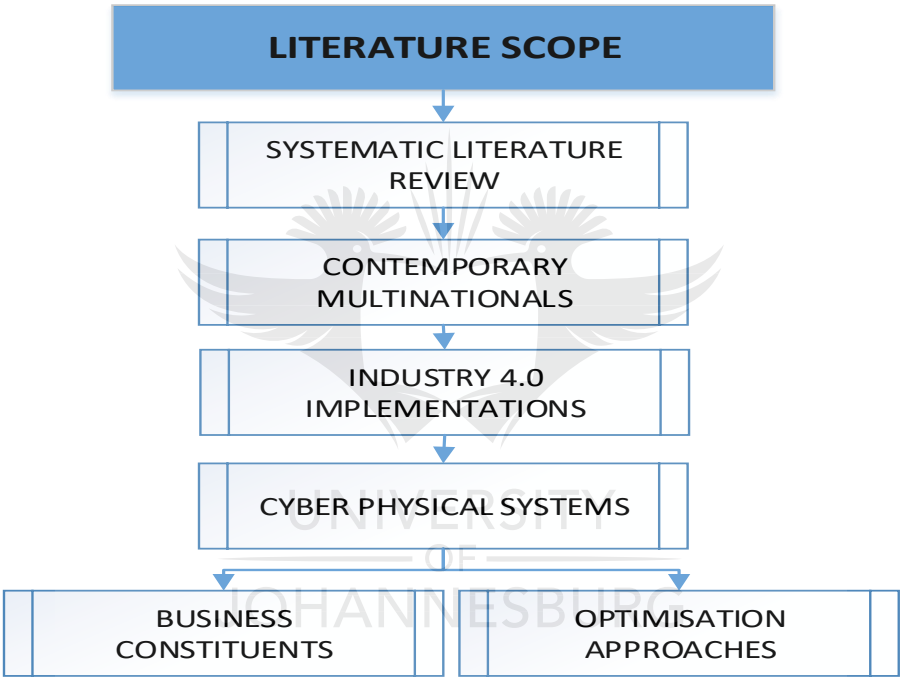


Figure 3: Detailed scope of the literature review

Source: (Authors own compilation)

The first section details an extensive systematic literature review undertaken with relevant keywords.

2.2 Systematic literature review

Systematic Literature Review (SLR) relates to sequential methods effective for gathering applicable data in an investigation (Sternberg, et al., 2011). SLR supports quantitative and qualitative research techniques providing detailed evidence relevant in accomplishing an investigation (Piper, 2013). The quantitative investigation aims for documents with numerical data, while qualitative research

approach focuses on observations and verbal interactions. This thesis details steps defined by (Hye, 2016) to execute a comprehensive SLR. A synopsis of these steps is outlined.

(a) Identify the research questions.
(b) Define the exclusion and inclusion criteria considered in the SLR investigation.
(c) Search for relevant peer-reviewed publications.
(d) Select peer-reviewed publications with emphasis on the pre-defined inclusion and exclusion criteria.
(e) Extract data from the peer-reviewed publications selected.
(f) Evaluate the possibility of bias from the data extracted.
(g) Present results collected from the SLR investigation and assess the effectiveness of the evidence gathered.

Three relevant keywords defined for the SLR investigations include:

(a) "Multinational sustainability" OR "Multinationals" OR "Complex businesses" OR "Large global business" OR "Sustainability" OR "business".
(b) "Fourth industrial revolutions" OR "4IR" OR "4IR technologies" OR "4IR implementations" OR "Industry 4.0".
(c) "Business process optimisation model" OR "Business model" OR "Optimisation model" OR "Business process models".

The SLR with emphasis on the relevant keywords provide documents for a detailed literature study. The documents collected from the SLR investigations are comprehensively reviewed to extract data from the peer-reviewed publications. The data gathered aims to present insights related to the objectives detailed for this thesis. Scopus is selected from the University of Johannesburg database for conducting the SLR investigations. Scopus database is a prevalent global abstract and citation research database comprising peer-reviewed publications. The literature includes books, conference proceedings, and journals, which details topics across several technical, social, arts, humanities and scientific disciplines.

The next sub-section commences the initial SLR investigation with the collaborative keywords defined simultaneously.

2.2.1 Initial SLR investigation

The initial SLR investigation includes the three keywords defined using the "AND" and "OR" operators to ensure that comprehensive and relevant publications are collected. The search is filtered to collect documents from 2007 to 2019, ensuring comprehensive insights on defined keywords are collected. This thesis potentially focuses on documents collected between 5 to 7years from 2019 for fundamental concepts and references. Each SLR investigation is refined to focus on the following:

- Documents with English only.
- Source of documents such as peer-reviewed research articles and books only.
- Publications per year.
- Publication per country.
- Subject areas.

The initial SLR investigation identified one document. This indicates that limited literature currently exists collaboratively discussing multinational sustainability, 4IR implementations, and business models.

2.2.2 Second SLR investigation

The keywords considered in the second SLR investigation includes:

(a) "Multinational sustainability" OR "Multinationals" OR "Complex businesses" OR "Large global business" OR "Sustainability" OR "business".
(b) "Business process optimisation model" OR "Business model" OR "Optimisation model" OR "Business process models".

The search is filtered on similar conditions defined in the initial SLR investigation. Figures 4 – 8 captures the outputs collected from the second SLR investigation.

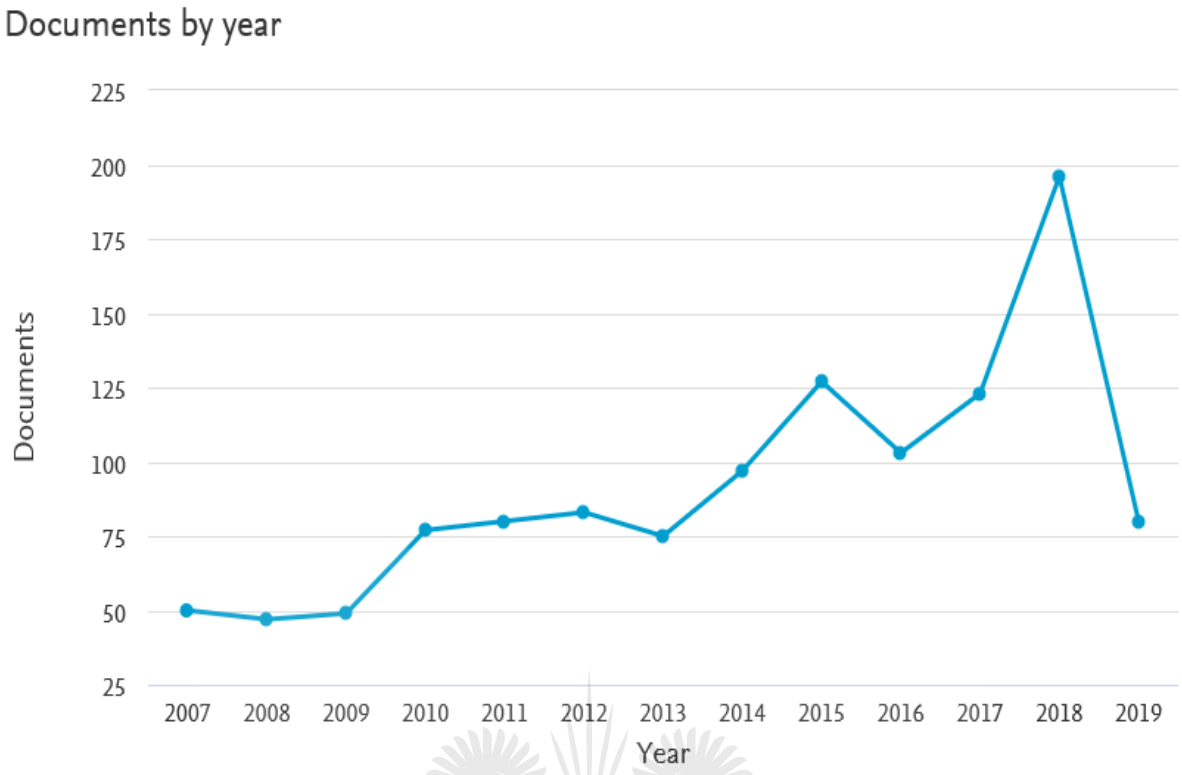


Figure 4: Documents by year for second SLR investigation

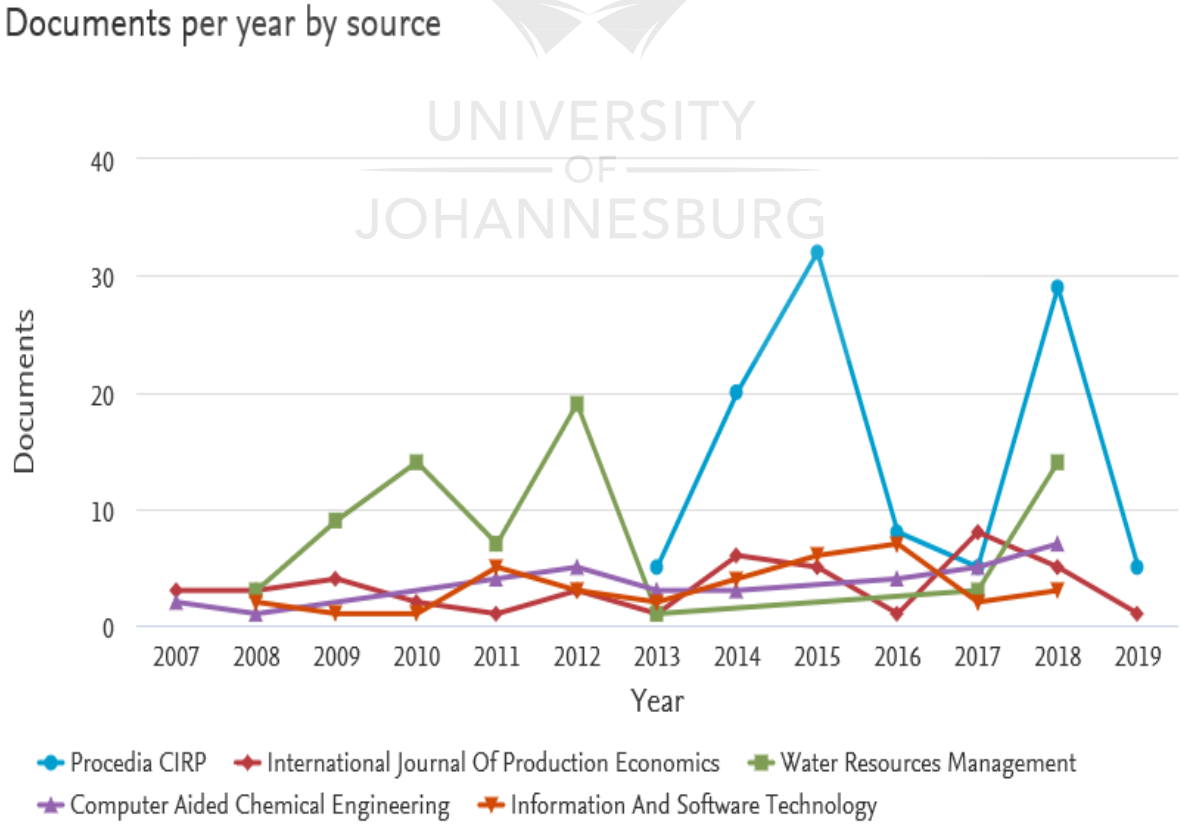


Figure 5: Documents per year by source for second SLR investigation

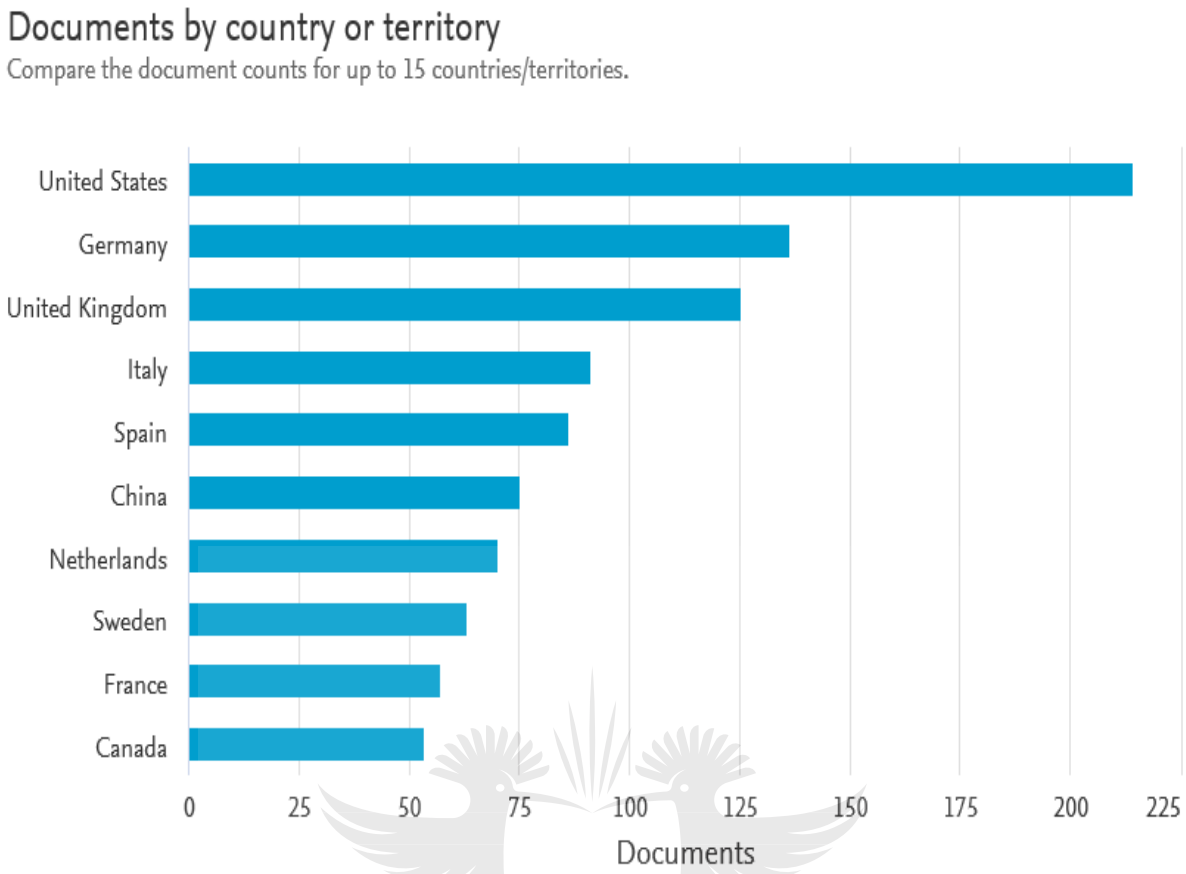


Figure 6: Documents by country or territory for second SLR investigation

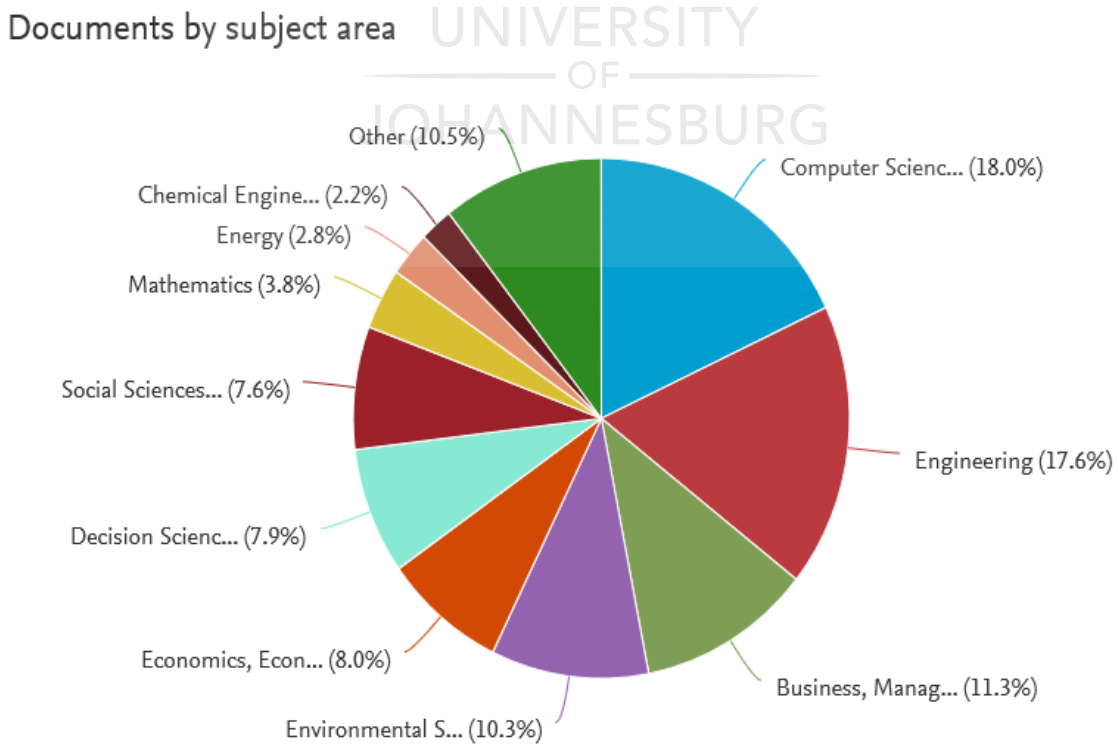


Figure 7: Documents by subject area for second SLR investigation

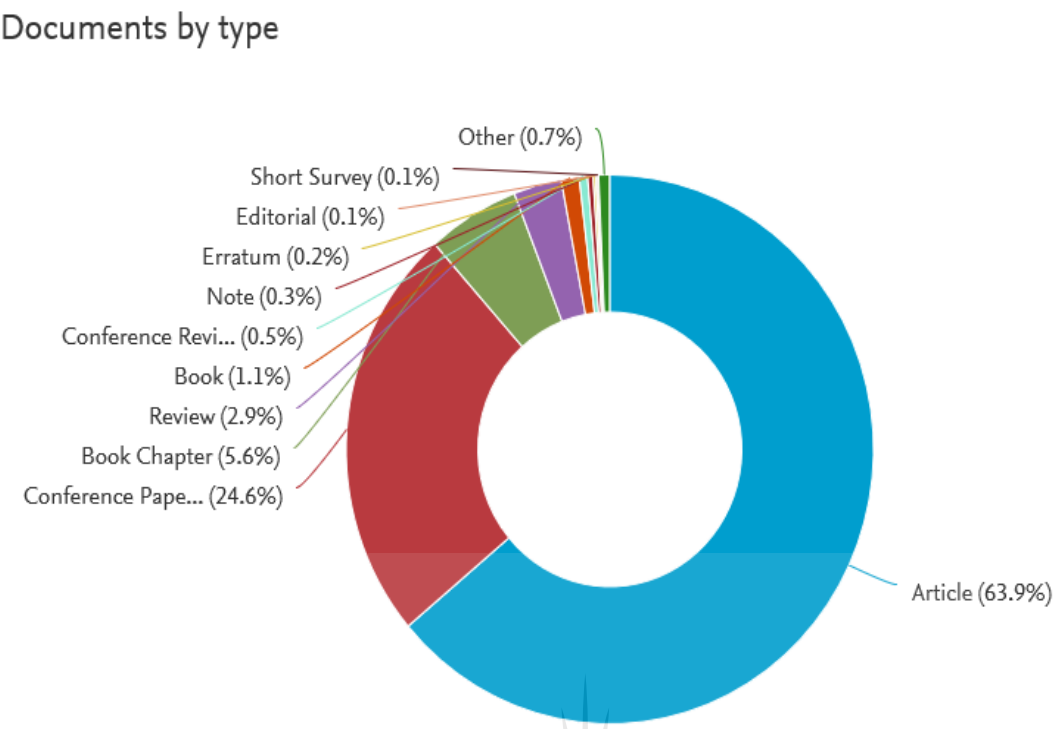


Figure 8: Documents by type for second SLR investigation

(a) The second SLR investigation identified 1187 documents.

(b) The second SLR investigation indicates documents by year per source are from Procedia CIRP.

(c) The second SLR investigation indicates inconsistencies in increasing rate of publications per year.

(d) The second SLR investigation indicates that the United States has the highest number of publications, followed closely by Germany and the United Kingdom.

(e) The second SLR investigation indicates articles (63.9%) and conference papers (24.6%) with the highest percentages of the identified publications by type.

(f) The second SLR investigation indicates computer science (18.0%), engineering (17.6%) and Business & management (11.3%) with the highest percentages of the identified publications by subject areas.

2.2.3 Third SLR investigation

The keywords considered in the third SLR investigation includes:

(a) “Fourth industrial revolutions” OR “4IR” OR “4IR technologies” OR “4IR implementations” OR “Industry 4.0”.

(b) “Business process optimisation model” OR “Business model” OR “Optimisation model” OR “Business process models”.

The search is filtered on similar conditions defined in the initial SLR investigation. Figures 9 - 12 captures the outputs collected from the third SLR investigation.

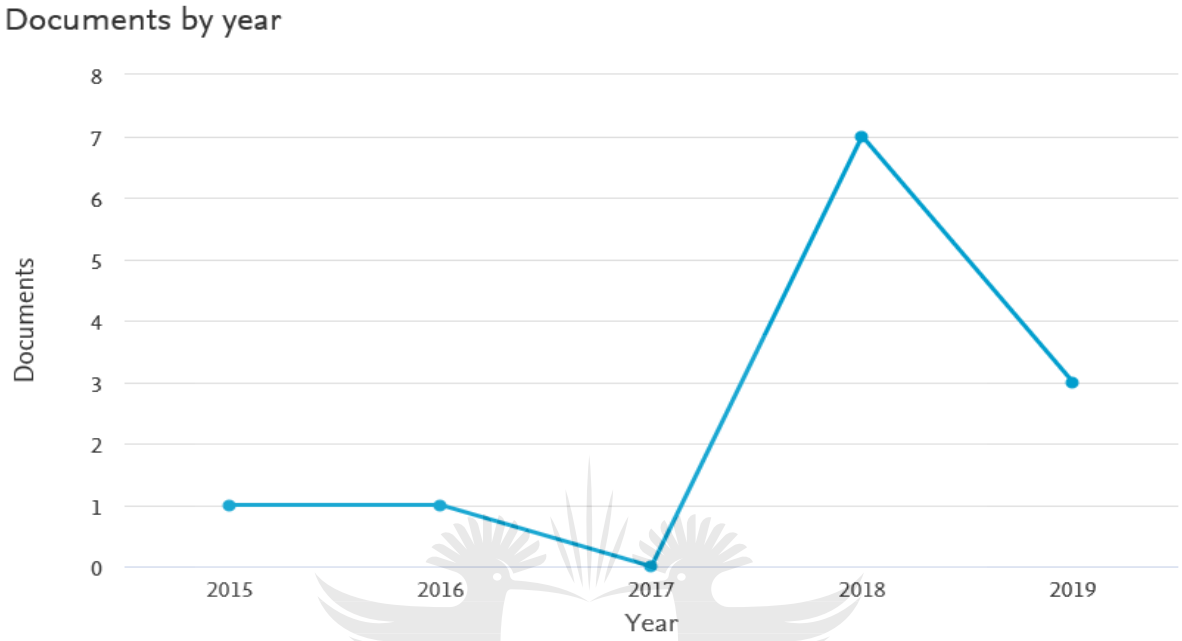


Figure 9: Documents by year for third SLR investigation

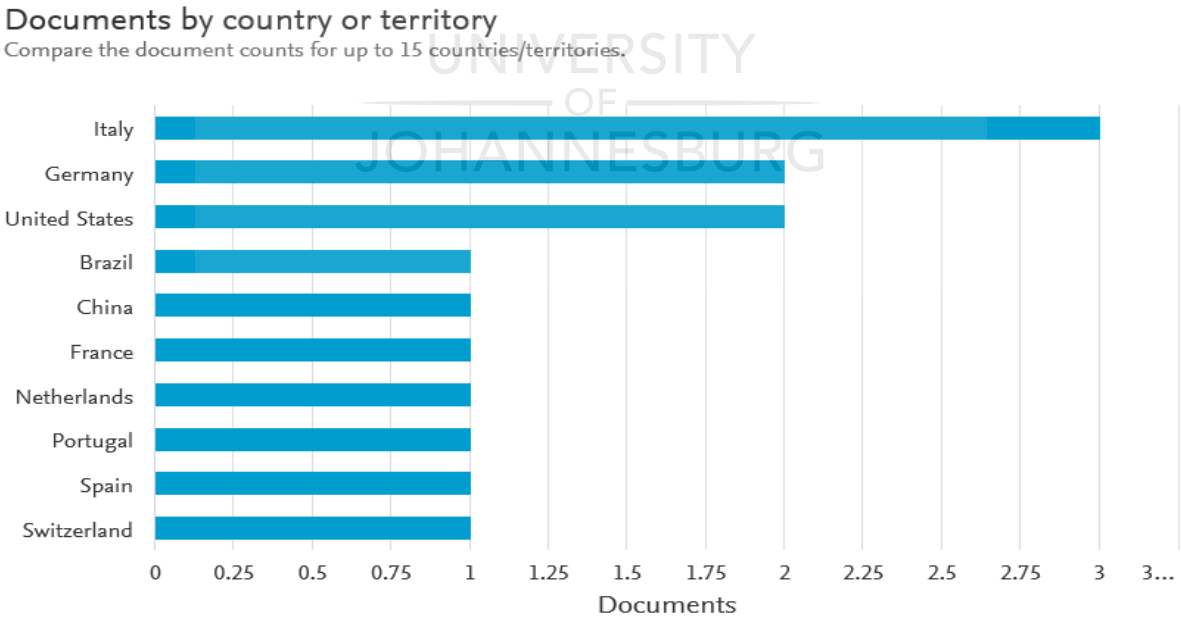


Figure 10: Documents by country or territory for third SLR investigation

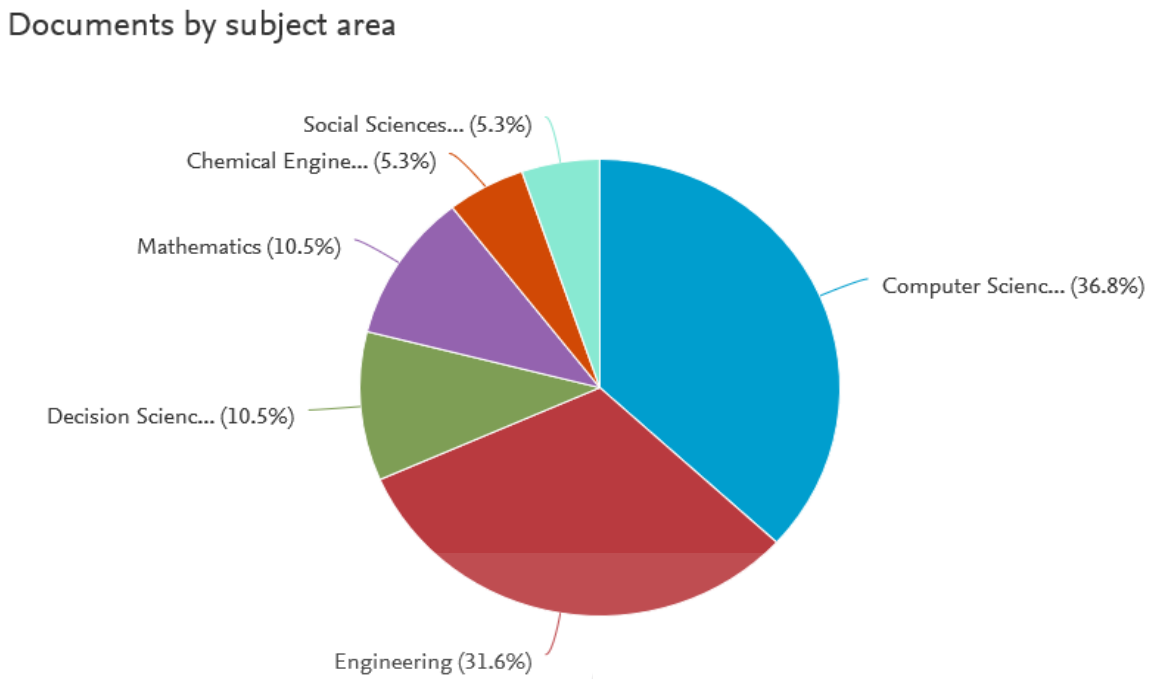


Figure 11: Documents by subject area for third SLR investigation

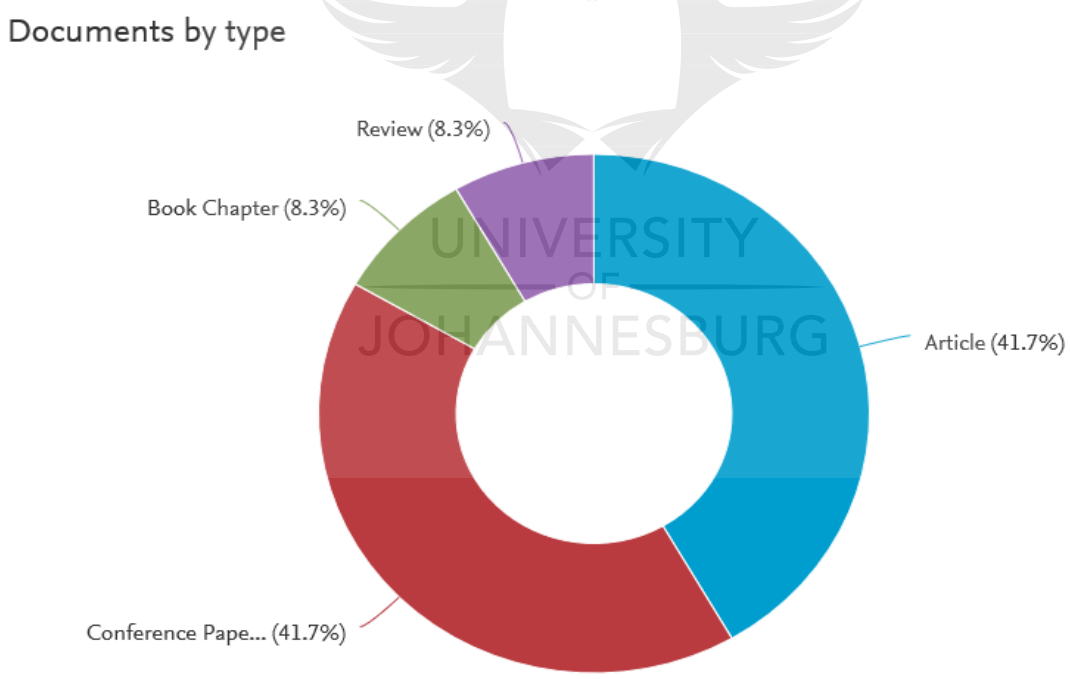


Figure 12: Documents by type for third SLR investigation

(a) The third SLR investigation identified 12 documents.

(b) The third SLR investigation indicates inconsistencies in increasing rate of documents per year with a significant drop in the number of publications from 2016 to 2017.

(c) The third SLR investigation indicates that Italy has the highest number of publications followed closely by Germany and the United States.

(d) The third SLR investigation indicates articles (41.7%) and conference papers (41.7%) with the highest percentages of the identified publications by type.

(e) The third SLR investigation indicates computer science (36.8%), and engineering (31.6%) with the highest percentages of the identified publications by subject areas.

2.2.4 Fourth SLR investigation

The keywords considered in the fourth SLR investigation includes:

(a) "Multinational sustainability" OR "Multinationals" OR "Complex businesses" OR "Large global business" OR "Sustainability" OR "business".

(b) "Fourth industrial revolutions" OR "4IR" OR "4IR technologies" OR "4IR implementations" OR "Industry 4.0".

The search is filtered on similar conditions defined in the initial SLR investigation. Figures 13 - 17 captures the outputs collected from the fourth SLR investigation.

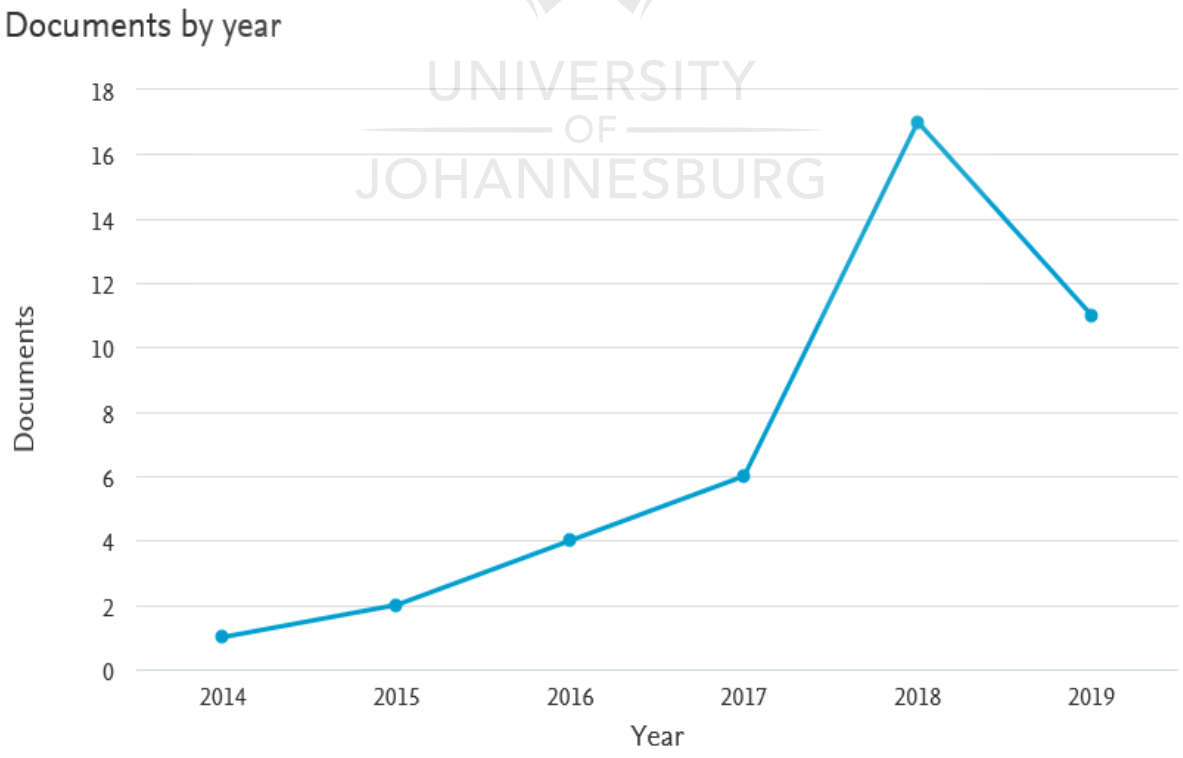


Figure 13: Documents by year for fourth SLR investigation

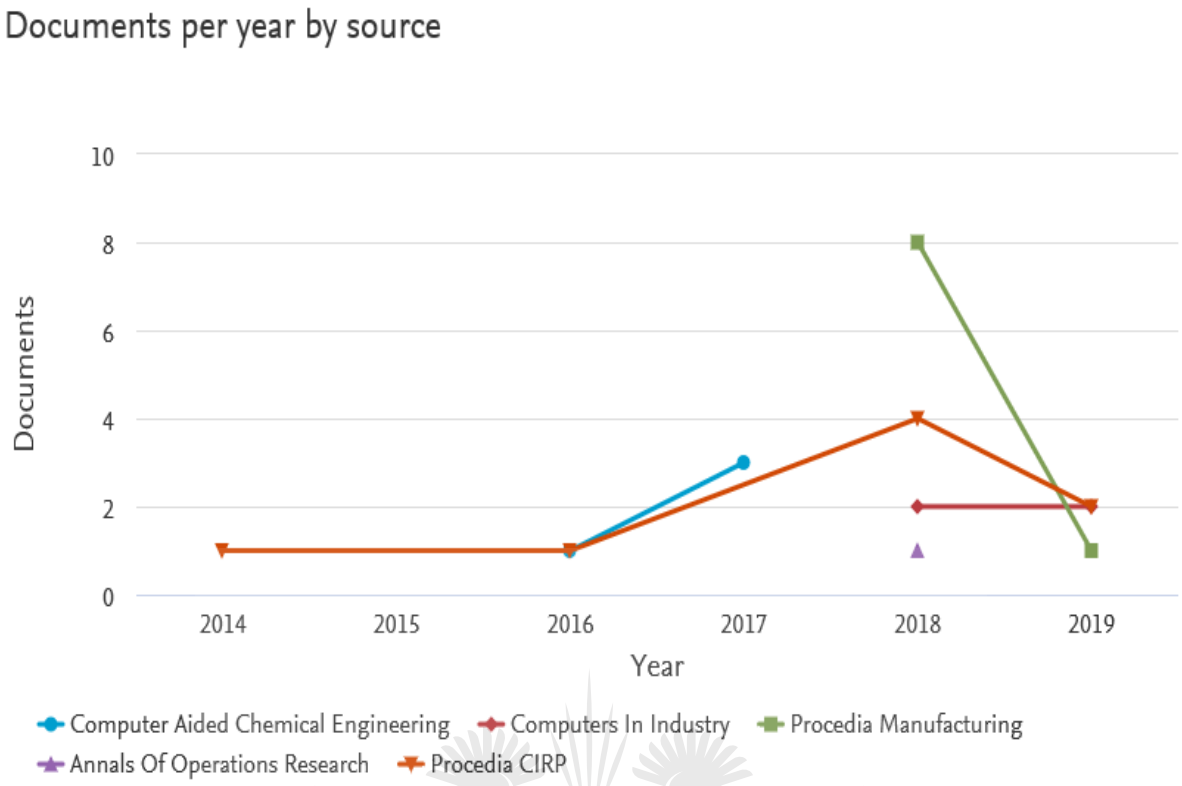


Figure 14: Documents by year of source for fourth SLR investigation

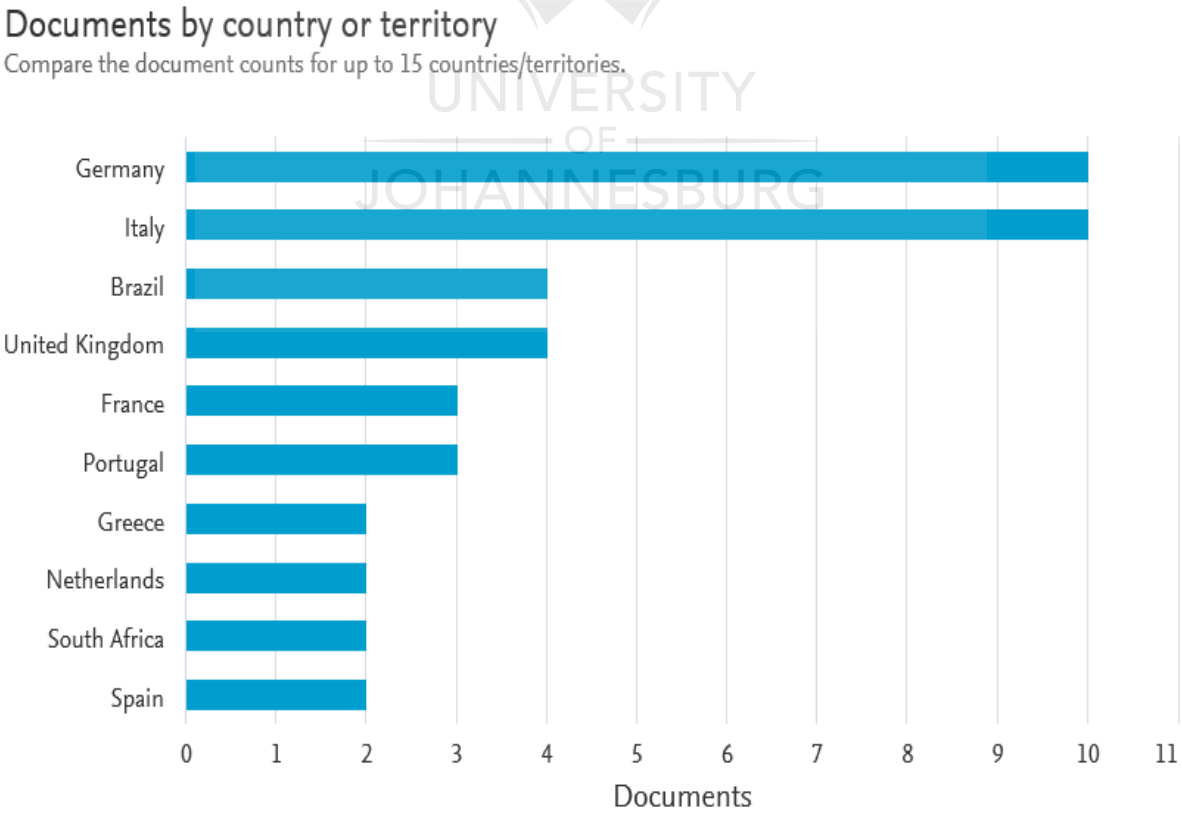


Figure 15: Documents by country or territory for fourth SLR investigation

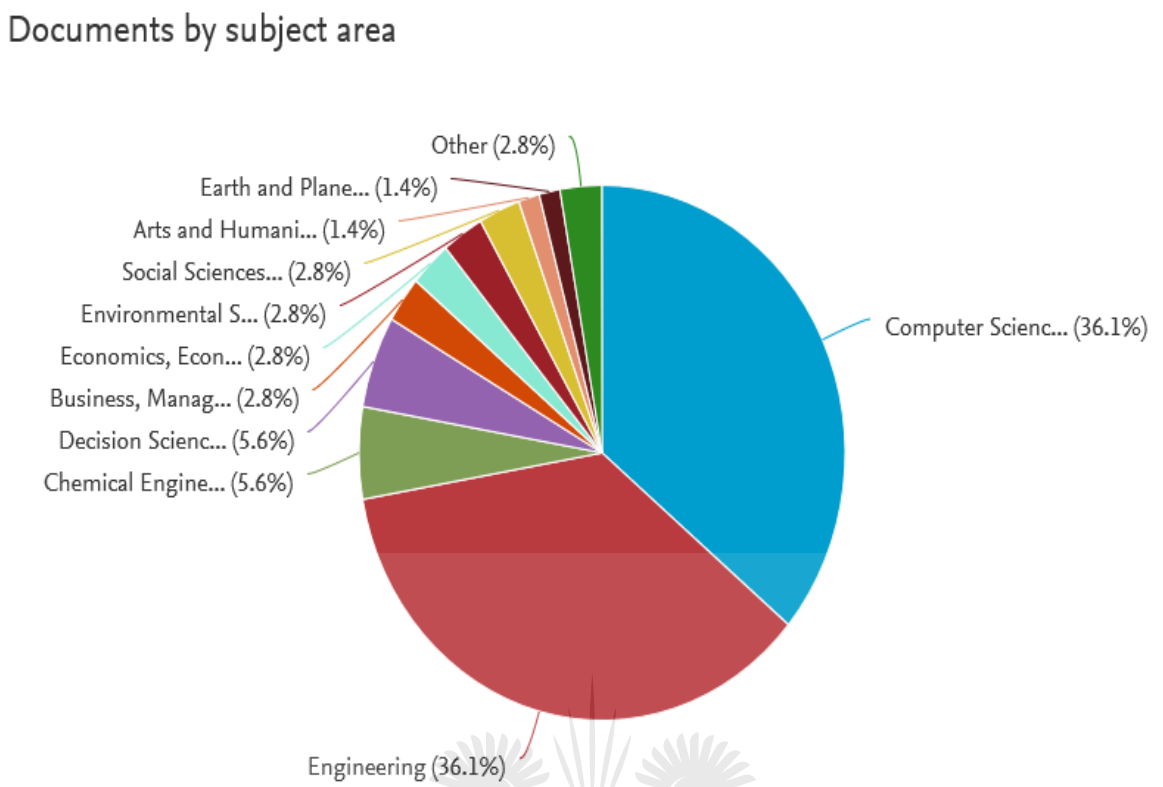


Figure 16: Documents by subject area for fourth SLR investigation

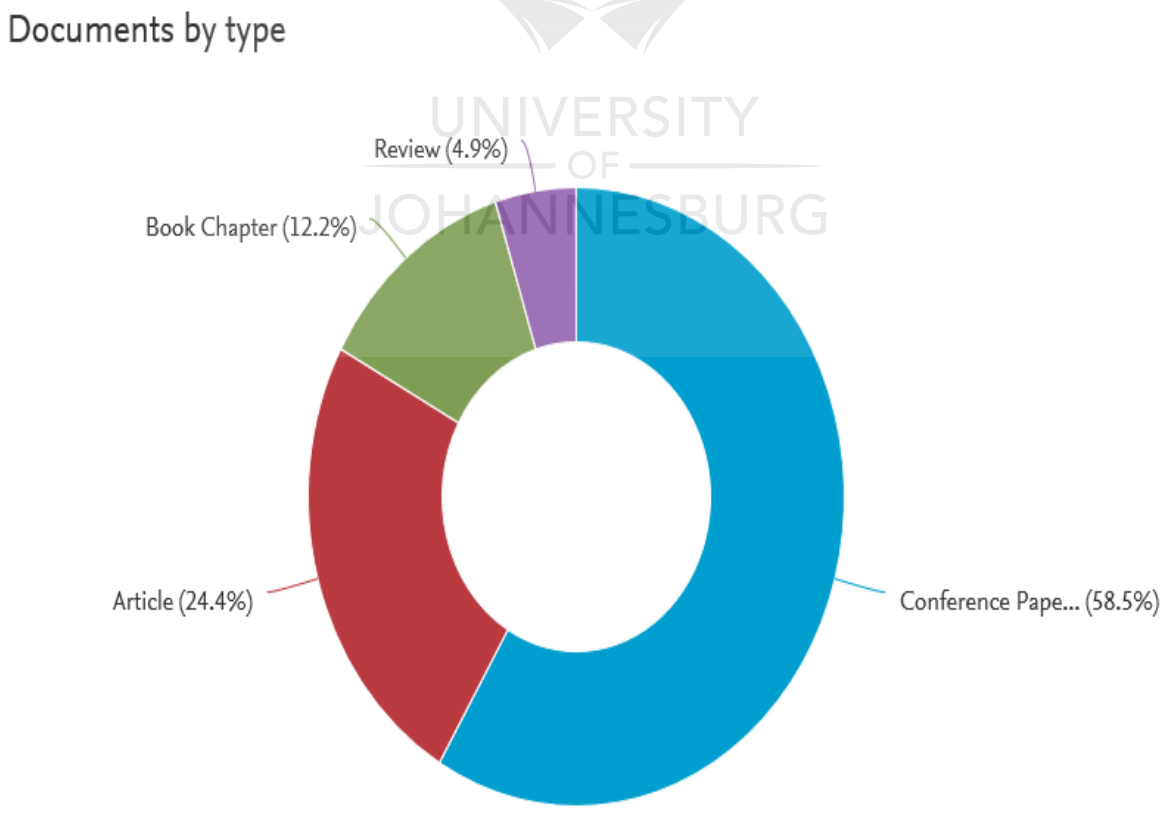


Figure 17: Documents by type for fourth SLR investigation

(a) The fourth SLR investigation identified 41 documents.
(b) The fourth SLR investigation indicates that documents by year per source are from Procedia manufacturing.
(c) The fourth SLR investigation indicates that there has been a consistent increase in the number of publications per year.
(d) The fourth SLR investigation indicates that Germany and Italy have the highest number of publications.
(e) The fourth SLR investigation indicates conference papers (58.5%) and articles (24.4%) with the highest percentages of the identified publications by type.
(f) The fourth SLR investigation indicates computer science (36.1%), and engineering (36.1%) with the highest percentages of the identified publications by subject areas.

This thesis deduces from the SLR investigations that availability of documents related to 4IR implementations is a limitation to the number of publications collected from the third and fourth search. This is evident in comparison with publications collected without the "4IR" keyword (second SLR) and with the "4IR" keyword (initial, third & fourth search). The second SLR search provided 1187 publications, while the initial, third and fourth search presents 1, 12 and 41 publications. The results indicate implementations of the 4IR technologies related to multinational sustainability and business model developments requires innovative investigations.

The publications per year visible from the third and fourth SLR investigations establishes significant rise in 4IR implementations from 2017. This indicates that relevant stakeholders are beginning to consider and execute research related to the potential benefits of the 4IR technologies. The peer-review publications gathered from the SLR investigations are extensively studied to provide directions related to presenting a detailed literature review. The next section extracts data from the SLR investigations, discuss on business relevance, innovation, and magnitude related to a large global business.

2.3 **Contemporary multinationals**

Multinationals are commercial establishments with facilities in different countries. Effectively managing these factories across the globe is challenging. Increasingly underpinning economic prosperity and business sustainability (Hoffman, 2018). A review of relevant literature indicates no singular unified structure for optimising a business from development, execution to operations exist

(Gove and Uzdzinski, 2013). Bryson and Lombardi (2009) establish an estimated 70% of project implementations in a large global business do not result in expected benefits.

Business optimisation facilitates a need for continuous corporate management, research, and innovations (Bider and Jalali, 2016; Çulha and Doğru, 2014). Business optimisation comprises a collection of best practice measures, effective for investigating and enhancing business conditions (Balko and SAP, 2013). Business optimisation results in enhanced productivity and sustainability, ensuring maximum value on a defined business goal (Van Der, et al., 2016).

Business optimisation ensures maximum external and internal productivity in real-time (Vergidis, et al., 2008). This affirms the importance of continuous research related to the effective management of multinationals. This thesis seeks advancements to managing multinationals with the potential effectiveness of the 4IR technologies. The next section extracts data from the SLR investigations to discuss fundamentals of the 4IR implementations for total business evaluation.

2.4 **Industry 4.0 implementations**

The Fourth Industrial Revolutions (4IR) relates to the current best practice industrial trend for automation, integration and data exchange of business technologies (Breunig et al., 2016; Narayanan, 2016; RuBmann, et al., 2015). 4IR model offers a unique structure for real-time monitoring, prediction, competitiveness, sustainability and control of a business (Dolgui, et al., 2018). The 4IR implementations rely on fully networked, adaptive business operations and input enablers resulting in intelligent business outputs. The emphasis for greater productivity results in the evolution from the Third Industrial Revolution (3IR) to 4IR.

The 3IR is a standalone, independent technology inadequate in effectively connecting with information technologies (Narayanan, 2016 and Drath, 2014). Information Technologies (IT) constitutes physical devices such as processes, infrastructures, and networking. Effective to develop, execute, store and secure various forms of data (Jitpaiboon, et al., 2015). 4IR supports the seamless integration of IT with business operations, bridging the gap for enhanced efficiency and throughput (RuBmann, et al., 2015). A system for the unification of key Performance Indicators (KPI) in multinationals brands the 4IR as unique technology.

Data extracted from the SLR investigations details four essential 4IR enablers which include integration, decentralisation, virtualisation, and real-time capability (Hermann, et al., 2016 and

RuBmann, et al., 2015). The 4IR enablers enable the digital interoperability and data exchange of multinational physical systems in a centralised domain. A synopsis of each 4IR enabler is detailed.

Integration

This 4IR enabler facilitates for more communication from "controller to controller"; "subsystem to subsystem"; or "automation systems to automation systems". Integration supports the vertical and horizontal connectivity of a business. Emerging literature details and justifies integration as an essential constituent in optimising and ensuring business sustainability (Kristianto, et al., 2017; Jahre, et al., 2016; Wang, 2016; Vallejo, et al., 2012). Multinationals increasingly function with large volumes of data and services from multiple sources, both internally and externally. Converting the complex data to valuable information and aligning the information with defined business goals presents a challenge (Singh, et al., 2017).

Integration as a critical 4IR enabler is effective to restructure complex current operations and technologies as a unified system of systems structure. This thesis proposes the development of a sustainable business model that is capable of integrating, connecting, and communicating in real-time. This motivates the potential choice of Integration as a 4IR enabler related to the proposed model (CPS) developments.

Decentralisation

Decentralisation relates to the restructuring of a business facilitating a system of co-responsibilities between sub-constituents (Caldwell, 2008). Decentralisation is the competence of the proposed sustainable business model to execute decisions autonomously. Human assistance is only necessary for critical failures and exceptions. This 4IR enabler limits the intricate relationship, which exists when investigating and optimising a complex business.

This thesis intends to develop a sustainable business model majorly functioning autonomously (self-predicting). Decentralisation as a 4IR enabler is potentially considered for the effective development of the proposed business model.

Virtualisation

This 4IR enabler seeks for the capacity and priority separation of a complex business. Virtualisation facilitates system modelling, agility and flexibility of operations (Van Der Lans, 2012; Goodburn and Hill, 2010; Dawson and Bittman, 2008). Virtualisation aims to collaborate complex data from multiple

sources into a unified structure for control analysis (Demirkan and Delen, 2013; Davis and Eve, 2011; Tanaka, et al., 2009).

This thesis aims to develop a business model, which is dynamic and functions with more agility. Virtualisation as a 4IR enabler is potentially considered for the active development of the proposed business model.

Real-time capability

Analysing operations in real-time offer business benefits during implementations (Singh, et al*.,* 2017). This enables multinationals to become more efficient and flexible. The real-time capability enables instantaneous status via tracking and efficient analysis for any seasonal or future failures. With the existence of enormous volumes of data in multinationals, challenges in extracting useful information for significant service improvements exist (Singh and van Sinderen, 2016). There is a need to enable real-time competence for capturing, storage and evaluating data.

This 4IR enabler seeks a structure for estimating, forecasting potential challenges and resolving concerns or issues proactively. Real-time capability as a 4IR enabler is potentially considered for the active development of the proposed business model.

A review of the literature (Best and Holmes, 2010) indicates the 4IR enablers detailed supports the system thinking theories.

2.4.1 Systems thinking

Systems thinking relates to investigating constituents of a structure holistically, observing how changes in individual or multiple subsets are interdependent (Medoh and Telukdarie, 2016; Souvairan, 2014; Martinuzzi and Kopp, 2010). Systems thinking delivers a unified business model in real-time effective to visualise leverage points, synergies, and inter-relationships of dynamic processes (Todd, 2009 and Mcintyre, 2009).

The next section extracts data from the SLR investigations to discuss CPS as a subset technology of the 4IR implementations.

2.5 **Cyber-physical systems**

Prominent 21st-century multinationals are converging the physical, digital worlds and implementing sustainable, innovative technological business solutions (Kim and Chai, 2017; Arnold, and Wade, 2015; Gharajedaghi, 2011). A review of relevant publications extracted from the SLR investigations indicates CPS a subset of the 4IR technologies as potentially effective effectively collaborating physical systems (Rauch, et al., 2016 and Lee, 2015). CPS protocols support a holistic modelling of real-physical world sub-systems effective to change a business logic (Herterich, et al., 2015 and Lee, et al., 2015).

CPS implementations support standards of the 4IR enablers and systems thinking theories detailed (Liu, et al., 2017; Sandkuhl, 2015; Zander, et al., 2015; Monostori, 2014; Frazzon, 2013; Bai and Huang, 2012). This motivates this thesis in considering CPS as an effective 4IR technology to define the research objectives detailed in chapter one and deliver innovative advancements to existing business models.

CPS implementations are potentially considered to develop a holistic model for all business constituents in a multinational, presenting a quasi-structure of real business scenarios. This thesis proposes a model (CPS) effectively collaborating all business constituents (CPS) with fundamental considerations of the 4IR enablers applicable in a comprehensive system contextualisation captured in Figure 18.

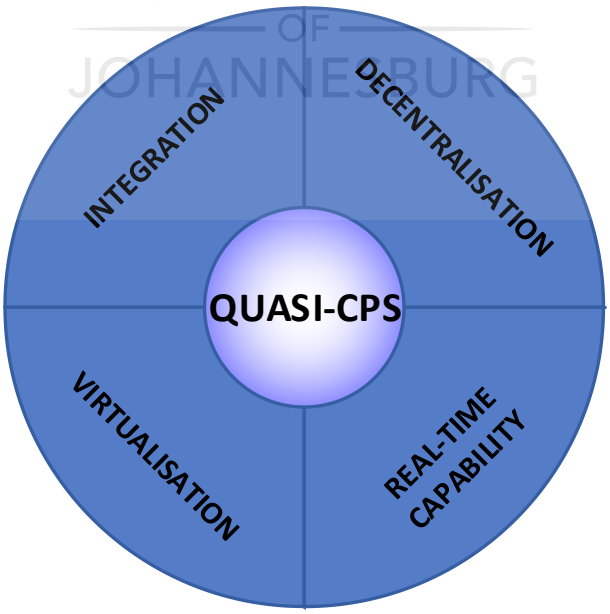


Figure 18: Industry 4.0 enablers

Source: (Hermann, et al., 2016 and RuBmann, et al., 2015)

The next section extracts data from the SLR investigations to present discussions on the background of business process models.

2.6 **Background of business models**

Business modelling is a relatively new research domain. Business modelling via business models is a valuable concept, which facilitates the capturing of business workflows accomplishing defined business goals (Isel, 2015). A business model functions as a useful tool for business modelling, enablement, and optimisation (Isel, 2015; Kastalli and Van Looy, 2013; Zheng, 2012). A business model offers a structure for practical business assessments, management, and decision-support (Coltman and Devinney, 2013; Handley and Benton, 2009; Meziani and Magalhães, 2009).

The business model originated in the 20th century with techniques such as Gantt chart, a control flow diagram, flowchart, functional flow block diagram, Integration DEFinition (IDEF) and Program Evaluation Review Technique (PERT). The business model terminology is invented by a researcher named Williams, from the systems engineering field in the late 1960s. Williams coined the expression business model in his 1967 publication "Business modelling improves administrative control". The publication extensively justifies the rationale behind the expression. This is initiated from the fact that approaches for developing an ideal architecture of physical control systems be aligned in a similar way for corporate operations. Business model elaborates information related to:

(a) Data essential in addressing a defined business goal.
(b) Inputs critical in executing the business objective.
(c) Tasks or actions effective in generating or altering the data.
(d) Decisions nodes essential in developing or modifying the data.
(e) Control points effectively addressing statutory obligations.
(f) Error correction procedures.
(g) Departments or subdivisions obligated to execute an activity.
(h) Outputs generated from the processes.

Business model prevailed in the 1990s when the corporate world became inspired to perceive corporate operations as business processes facilitating developments of traditional business process modelling tools. Business process modelling tools functions to develop business process models

effective for discovering the consistency and optimality from a business challenge to proposing and addressing the solution (Grigoryev, 2015).

Business process modelling tools are integrated with numerous techniques such as swim lane and flowcharts. These techniques distinguish different forms of data, capturing clear, and concise sets of business processes from initiation to completion applicable to a complex business. Based on the data extracted from the background of business models. Business processes and business process modelling tools are potential predictors related to developing a sustainable business model.

2.7 Business processes

Business Processes (BP) are logically related sequential tasks effectively representing physical business activities (Bradford and Gregory, 2015). Business processes are dynamic, stochastic in nature, and defined across several benchmarks to constitute a business process model (Becker, et al., 2013). Business processes benchmarks detailed include BP functional levels, BP functional layers, and automation systems (Purdue enterprise reference architecture and ISA 95-model).

2.7.1 Defining business process functional levels

The American Productivity and Quality Center (APQC) captures a database for BP taxonomy. The APQC database relates to the classification of comprehensive sets of BP delivering a structure for a complex business to internally & externally develop, track, and compare performances objectively. The Purdue enterprise reference architecture combined with APQC (2015) database details five BP functional levels.

Level 0 (Business Area)

Level 0 relates to the business area in multinationals. Level 0 relates to high-level processes capturing mainly logical flows such as human resources, manage customer service, financial organisation, and supply chain.

Level 1 (Process Group)

Level 1 represents process group, which refers to tasks belonging to the same domain of functionalities such as develop a sales strategy, perform after-sales repairs, recruit/source, procurement and accounts payable.

Level 2 (Business Process)

Level 2 refers to business processes, comprising sub-processes aggregating business-oriented steps to a unit (process group). Level 2 delivers a defined business interrelated activity in addition to the fundamental elements required to accomplish the process.

Level 3 (Process variant) Level 3 relates to process variant comprising key events implemented when performing a process. Level 3 supports further decomposition of sub-processes accomplishing the same business-critical task but in a different approach or application. The input and output at this functional level are most generally the same, but the activities performed to deliver the output are different. Examples of level 3 activities include but not limited to receive customer request, negotiate purchasing contracts and resolve customer complaints.

Level 4 (Task) Level 4 consists of processes connected to a single business function, accomplished by an individual. Level 4 implements from a user interaction as a single business function aggregated in an unplanned workflow without a change in role. The workflows are executed with an obligation to carry out such a business function. Examples of a level 4 business function which may vary across multinationals include but not limited to design recognition, obtain funding, create a business case and reward approaches.

2.7.2 Defining business process layers

The Purdue enterprise reference architecture details a structure for defining BP functional layers, which relates to BP planning, execution, and control. The BP executed from level 0 to level 4 vary across the BP functional layers captured in Figure 19.

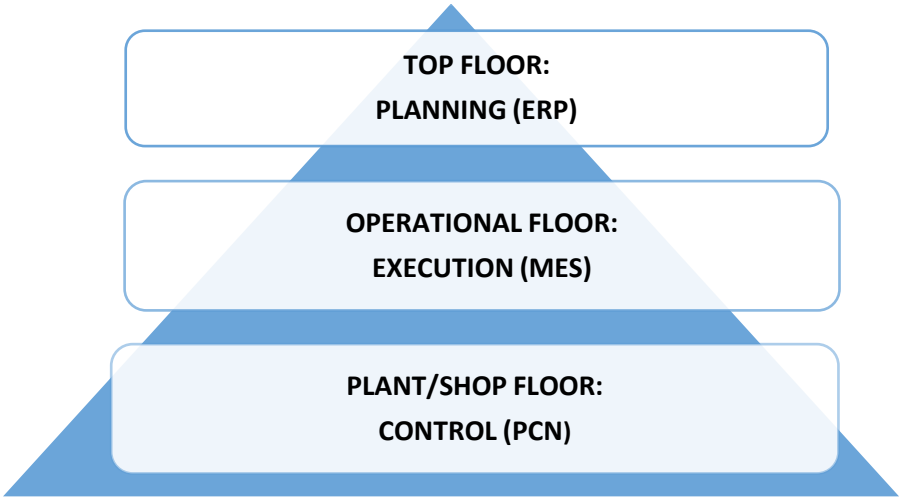


Figure 19: Business process functional layers

Source: (Purdue enterprise reference architecture)

Figure 19 prepositions significant automation systems implemented across the BP planning, execution, and control floors. The automation systems include “Enterprise Resource Planning (ERP)”, “Manufacturing Execution System (MES)” and “Plant Control Network (PCN)”, detailed in the next sub-sections.

2.7.3 Automation systems

A significant number of contemporary business structures are complex and deploy modern automation systems for operations. The automation systems operative at each business floor accelerates the complex business process executions. These automation systems can function independently or collaboratively to enhance business performance. This thesis proposes a business model potentially integrating the ERP, MES, and PCN automation systems to function in a systems contextualisation captured in Figure 20. A system comprises technologies or machinery unified to produce an output (Kasser and Mackley, 2008). A system of systems structure results in more leverage prospects for enhancing business improvements, delivery, and ensuring sustainability.

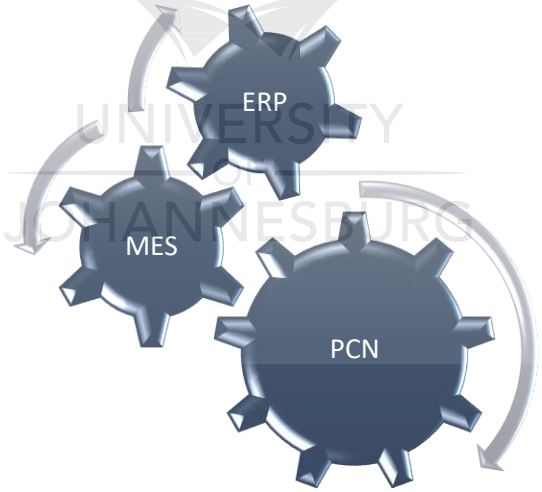


Figure 20: ERP, MES, and PCN

Source: (Purdue enterprise reference architecture)

Manufacturing Enterprise Solutions Association (MESA) model-11, International Society of Automation (ISA) 95-model, and Purdue enterprise reference architecture details the ERP, MES and PCN functional domains. MESA is a global standard organisation obliged with enhancing manufacturing processes. An elaborate discussion and data flow information of the ERP, MES and PCN

functional domains is detailed in (Medoh, 2017a). Figures 21, 22 and 23 captures the ERP, MES and PCN functional domains.

The ERP, MES and PCN functional domains captured in Figures 21, 22 and 23 aims to serve as an effective representation of a large global business. This thesis expatiates the ERP, MES, and PCN functional domains detailed to include marketing, production operations, research, logistics, security, HSE (Health Safety & Environment), and inventory management collected from the literature (Subramaniam, 2009). The collaborative functional domains seek to deliver an extensive representation of multinationals with a considerable amount of details.

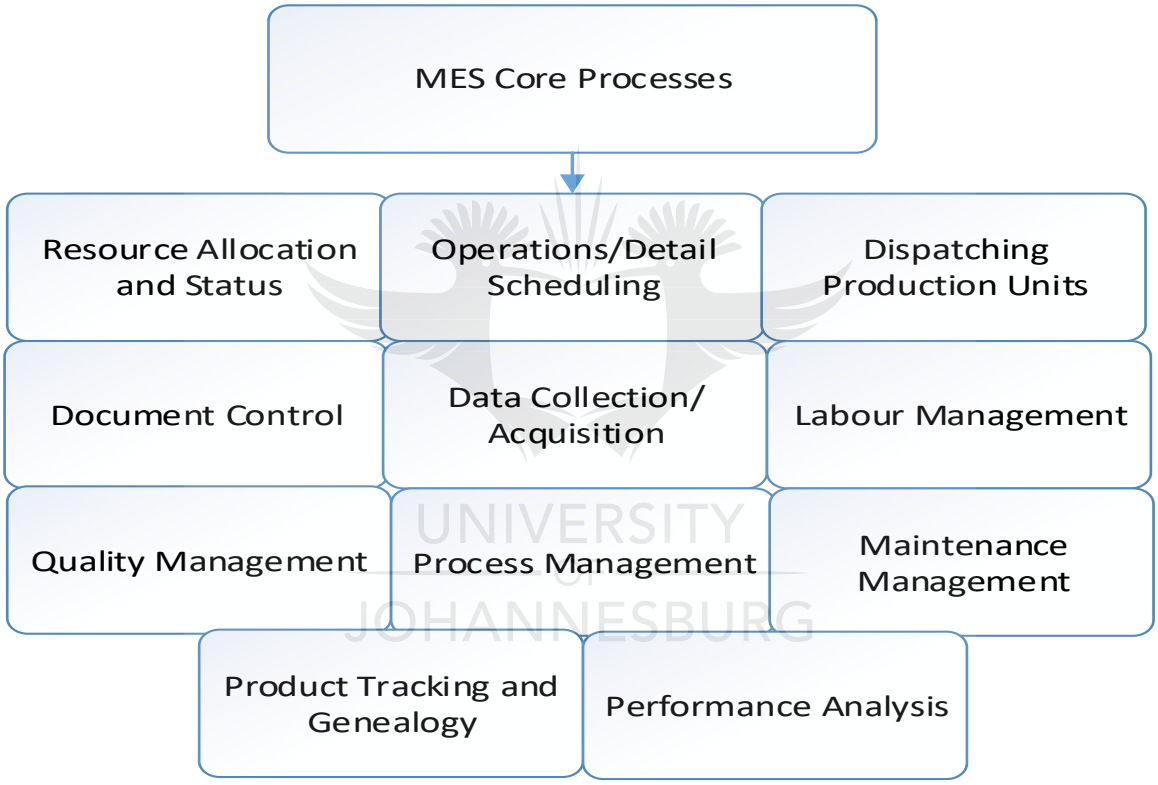


Figure 21: Eleven functional domain of MES (execution)

Source: (Purdue enterprise reference architecture, MESA, and ISA 95-model)

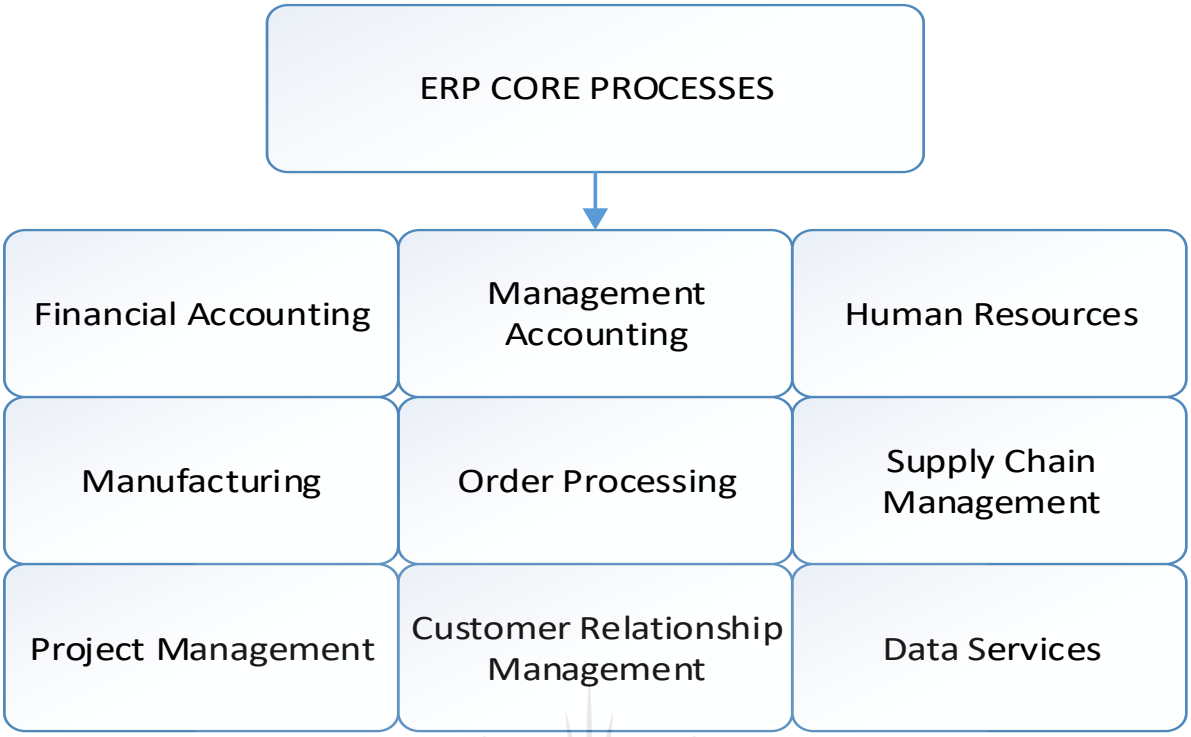


Figure 22: Nine functional domain of ERP (planning)

Source: (Purdue enterprise reference architecture, MESA, and ISA 95-model)

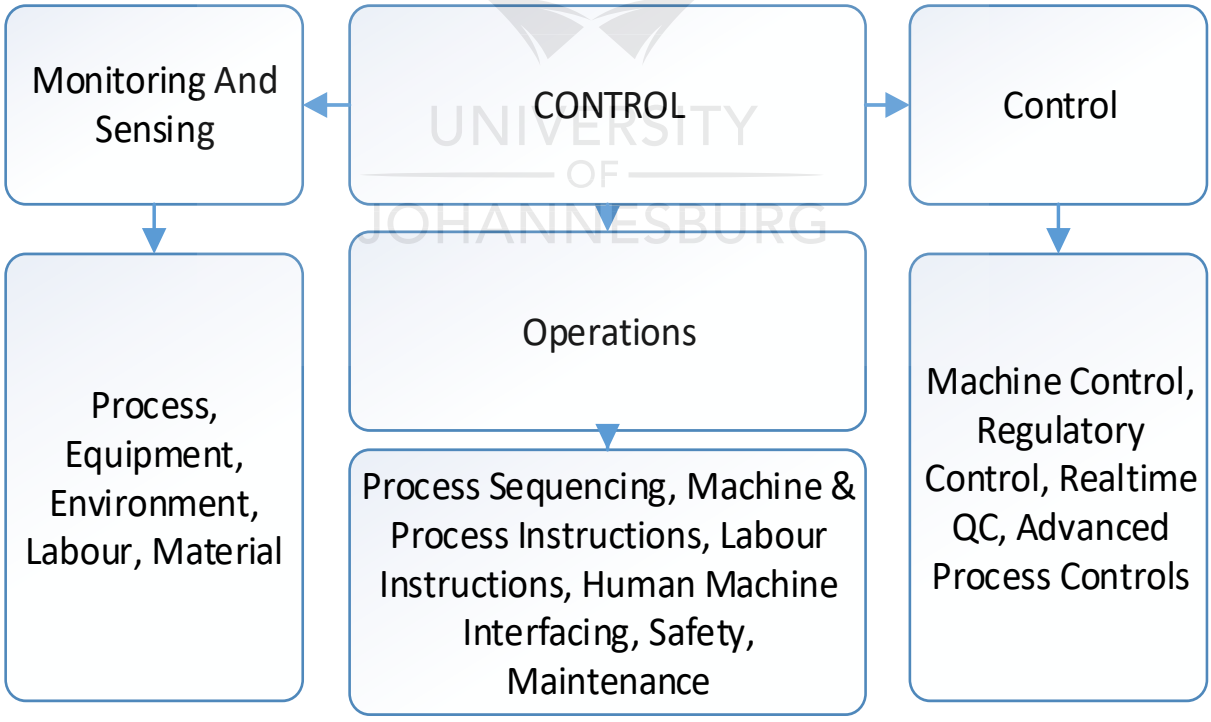


Figure 23: Functional domain of PCN (control)

Source: (Purdue enterprise reference architecture, MESA, and ISA 95-model)

The PCN executed at the shop floor comprises three key constituents, which include Monitoring & sensing, operations, and control. Each constituent is associated with sub-activities captured in Figure 23. The next section extracts data from the SLR investigations to detail a literature review specific to business process modelling tools.

2.8 **Business process modelling tools**

Business Process Modelling Tools (BPMT) are effective to develop a business process model enabling a structure for BP improvement opportunities (Fielt, 2014). This involves investigating where and how BP can optimise (Lambert and Davidson, 2013). This section identifies and reviews BPMTs often utilised for modelling objectives. The capability of each BPMT varies (Gregor, 2015). The essential attributes of each BPMT identified are collected from various BPMT vendor website. The International Standard Organisation (ISO) certifies Business Process Modelling and Notation (BPMN) tools as efficient for modelling purposes. The ISO/IEC 9126 establishes BPMN is an effective modelling method for demonstrating graphical illustrations of BP. Gregor, (2015) indicates the BPMN 2.0 compliance BPMT as mostly utilised for modelling functions. Each BPMN 2.0 compliant BPMT focus on exclusive BP modelling application and functionality (Ringkjøb, et al., 2018). This is a combination of:

(a) Effectiveness in business Process discovery.
(b) Effectiveness in business process modelling.
(c) Effectiveness in business process simulation.

The exclusiveness of BPMTs presents limitations in selecting an effective BPMT for a unique BP modelling application. The BPMTs that is BPMN 2.0 compliant often utilised for modelling functions are collected from the literature (Murali, 2013 and Islay, et al., 2007). The BPMTs include Metastorm provision BPA, Accuprocess Modeler, iGrafx process, Enterprise Architect, ARIS business architect, Holocentric Modeler, Savvion process Modeler, System architect, Mega modelling suite, Casewise corporate Modeler suite, Lombardi blueprint, Microsoft Visio, Process maker, Visual paradigm, Mavim, Lucidchart, Bonitasoft, Adonis and Bizagi. The functionalities of each BPMT is detailed.

System architect

System Architect is a business architecture modelling tool for modelling defined business functions, systems, databases, and applications. System architect BPMN tool is useful for developing and documenting an enterprise architecture across five significant domains. These include strategy, business, information, systems, and technology. System architect BPMN tool supports a structure for

shared work domain among team members. This facilitates swift responses and enables a framework for improvement opportunities, inclusive of business alignment of IT systems, processes, planning, and modelling.

ARIS business architect

ARIS business architect is a business architecture modelling tool for modelling a business, IT and data structures. ARIS business architect BPMN tool is efficient and deployed by multinationals for managing a wide variety of business projects. This is inclusive of business processes communication, observation, analysis, implementation, and optimisation.

Casewise corporate Modeler suite

Casewise corporate Modeler is a Microsoft technology business suite tool for modelling, developing and analysing a repository database of business functions. Casewise corporate Modeler suite supports BPMN methodologies and approaches useful for streamlining together with optimising business operations. This BPMN tool can be deployed for maximising business resources, aligning defined goals with IT systems. Casewise corporate Modeler presents a 360° overview of an enterprise, enabling business stakeholders to model, simulate and manage improvements opportunities.

Enterprise architect

The Enterprise Architect is a computer-aided engineering business architecture modelling tool for developing, observing, analysing and reporting business models. Enterprise architect BPMN tool supports the Unified Modelling Language (UML) 2.1 platforms.

Holocentric Modeler

Holocentric Modeler is a business modelling tool integrated with techniques for defining varieties of business functions. Holocentric Modeler BPMN tool supports the Role-Based Process Maps (RBPM) and UML 2.1 platform, which facilitates the combination of multiple approaches within a defined model. Holocentric Modeler is effective for defining correlations of the constituents of a living model. This offer multinationals with modelling competence effective for swiftly integrating business users, strategies, structures, goals and functions. The holocentric Modeler collaborates with business IT systems for facilitating and implementing business functions.

IGrafx Process

The iGrafx process is a business architecture tool adopted in multinationals for modelling and analysing business functions. The iGrafx process offers an architecture for reducing the total business turnaround time, delivering a framework for identifying and developing improvement opportunities with the least risk and cost. iGrafx modelling solution integrates business functions, resources, data and systems with defined business strategies. iGrafx BPMN tool supports visual workflows inclusive of multidimensional perspectives of business functions.

Metastorm provision BPA

Metastorm provision is a business architecture tool for developing, analysing, understanding, modelling and simulating business functions. Metastorm provision BPA is effective for end-to-end business functions modelling competence, inclusive of process strategies, and roles constituted in a common domain. Metastorm provision BPA has a superior modelling capability integrated with business acclaimed "ease of use" for business and system users. A value-add of this BPMN tool is the integrated shareable web-based repository of business functions knowledge, which is quantifiable and accessible to the entire corporate space.

Savvion Process Modeler

Savvion Process Modeler is a business modelling tool delivering unique and efficient architecture for analysing business functions. Savvion process Modeler facilitates multinationals to collaborate on business functions improvement opportunities. This includes testing, controlling and executing real-world solutions of process-driven business operations. Savvion process Modeler offers role-specific aids for support effects on business operations.

Lombardi Blueprint

Lombardi Blueprint is an AJAX technology business architecture tool for business functions modelling. This business modelling tool is web-based integrated with chat, shared whiteboard and wiki competence. Lombardi Blueprint is an effective tool for ensuring business enablement, which facilitates multinationals to discover and model business functions. This BPMN tool is integrated with web-based business process management packages.

Microsoft Visio

Microsoft Visio is a business tool effective for developing repository structures of business functions via diagrams, layouts, and charts. These graphics are standardised and configured utilising decision

blocks, flowcharts, process mapping, and network charts. Microsoft Visio is a useful tool for business enablement operative for developing, import and export competence of business functions in real-time. This tool supports vector graphics and integration of IT management, professional technical drawings, visual dashboards, and security systems.

Mega Modelling suite

Mega-suite is a business modelling tool designed for defining, developing, analysing and documenting an architecture of business structures, functions, and procedures. Mega modelling suite is effective to develop a dynamic web-based intelligent reporting and analysis of business functions. This BPMN tool is effective for integrating business functions and enterprise architecture.

Process maker

Process maker is a web-based open-source BPMN tool effective for automating business functions inclusive of workflow performances, intuitive drag-and-drop web interface, automated notifications, and dashboard reporting metrics.

Mavim

Mavim BPMN tool is effective for the alignment and prioritisation of ideal initiatives aligned with business goals. Mavim BPMN supports effortless sharing, design, and collaboration of business functions within multinationals.

Lucidchart

Lucidchart is a business modelling tool for developing process flow illustrations. This modelling tool supports all web browsers and operating systems. Lucidchart web-based BPMN tool is effective for developing flowcharts, network diagrams, UML designs, and visual communications. This BPMN tool supports active export and import of files in different formats.

Bonitasoft

The bonitasoft modelling tool is a business architecture for the development, execution, and management of business functions. Bonitasoft is an open-source BPMN tool effective for developing workflow suites, which enables business stakeholders to define, model, monitor and optimise business functions.

Bizagi Modeler

Bizagi Modeler is a freeware business application, effective to illustrate, observe and document business functions graphically. Bizagi Modeler is effective for developing flowcharts of business functions. This BPMN tool supports the swift development, documentation, and analysis of business functions in real-time.

Adonis

Adonis modelling tool is a business architecture for describing the fundamental constituents of a business. Adonis BPMN tool supports Java applications, automation, process evaluations, simulation and publishing competence. This BPMN tool enables efficient collaboration, modelling, monitoring, analysis, reader portal, validation and dashboard metrics of business functions.

Accuprocess Modeler

Accuprocess Modeler is an effective easy-to-use and visual BPMN software product for developing, documenting, observing, analysing and simulating a repository database of business functions. This BPMN tool is cost-effective with efficient customer service packages. This tool offers a solution for modelling and managing multinational processes. Accuprocess modeler supports the discrete event simulation approach effective for modelling and iterating a complex business.

Visual Paradigm

Visual Paradigm is an effective BPMN tool designed for developing and managing a repository information database of business functions. Visual Paradigm is integrated with several modelling languages such as UML. Multinationals deploy this software tool to model and manage development and information processes or systems.

FlexSim simulation tool

This simulation tool is effective for modelling and iterating business processes (Ma, et al., 2011). This simulation tool is mostly deployed for modelling and iterating small processes. FlexSim simulation tool is effective for configuring a discrete-time system.

Anylogic simulation tool

Anylogic simulation tool is a web service architecture effective to iterate, carry-out analytics and share simulation model online with other defined users. This simulation tool is effective for modelling and

iterating complex business processes (Anylogic, 2015). Anylogic simulation tool supports all simulation approaches. This tool, integrated with GIS protocols support the developments of hybrid models. Anylogic simulation tool can function on a variety of custom web control panel, model experiments inclusive but not limited to tablets and phones.

Insight maker

Insight maker is web-based business modelling and simulation solution supporting a multi-user scenario (Insight maker 2015). The insight maker simulation tool is effective for developing casual loop diagrams, dialogue mapping, mind mapping together with stock and flow models.

A publication on the comprehensiveness and effectiveness of each BPMN 2.0 compliance tools detailed is extensively discussed in (Medoh and Telukdarie, 2017b).

A review of data extracted from the SLR publications indicates business implementations in multinationals are impacted by varieties of factors. The next section details a literature review of factors with potential impacts on a large global business.

2.9 Factors affecting a business

Emerging literature discuss several factors with potential impacts on a complex business. These factors are impacted by an increasing number of variables, defined as Business Process Variables (BPV). The impacts of each BPV vary. The BPVs identified are a combination of cost; escalation rate; change; human resource resolution time, critical factor; business state index; efficiency, system resolution time; throughput, Energy; environmental technologies; monitor; value chain design; system maturity index; completeness of process; integration; data/inventory; skills; non-standard and standard, supply chain, machinery, and factory overhead. A summary of each BPV is detailed.

Human resource resolution time

Human resources are a fundamental business process variable with significant impacts on business delivery and optimisation. Human resources refer to the workforce involved directly or indirectly in business executions, which includes effectively managing employees, culture, resources and the work environment (Collings and Wood, 2009). Human resource resolution time is the total time expended by a human resource from initiating to resolving a defined business function. The importance of human resources in a corporate environment cannot be overstated (Chelladurai and Kerwin, 2018). Human resources influence all business domains with a significant effect on employees. This thesis

investigates human resolution time as a business process variable related to effective human resource management. Human resource management aims at addressing issues related to performance management, compensation, development strategies, wellness, hiring employees, safety, benefits, employee engagement, and training.

Escalation rate

Escalation rate is a significant business process variable with substantial impacts on business delivery and optimisation. Escalation refers to the fast lining of business functions that is unattended to or not resolved (Castellanos, et al., 2009). The business processes are transferred automatically or manually to be actioned by an alternative resource line. Escalation rate relates to the delay time a business process step or sets of business processes encounters before being re-assigned to an alternative resource. Escalation rate supports a framework in business executions for escalating a non-response, reducing unnecessary delays in business process execution. The importance of investigating "escalation rate" as a business process variable cannot be overstated. Escalation rate influences business delivery time and management.

System maturity index

System maturity index is an important business process variable with significant impacts on business delivery and optimisation. System maturity enables a framework effective for facilitating business maturity (Gove and Uzdzinski, 2013). A structure presenting multinationals with information about the business status in the global maturity framework is facilitated. This includes evaluating the position of the business in terms of strength and weakness. The importance of system maturity index in a corporate environment cannot be overstated. System maturity index influences business change and maturity. This thesis investigates "system maturity index" as a business process variable related to effective system maturity index management. This aims at addressing issues related to business change and maturity.

Business state index

Business state index is a fundamental business process variable with significant impacts on business delivery and optimisation (Shafiei, 2014). Business state index is a measure of the maturity of business operations (Subramanyam, 2012). The importance of business state index in a corporate environment cannot be overstated. Business state index influences business delivery and change. This thesis investigates "business state index" as a business process variable related to effective business state index management. This aims at addressing issues related to business delivery and change.

System resolution time

System resolution time is a significant business process variable with substantial impacts on business delivery and optimisation. System resolution time refers to the total time expended by a system from initiating an input to generating an output (Subramanyam, 2012). This business process variable is dependent on the uptime of ERP, MES, and PCN automation systems. These automation systems are detailed in earlier chapters as vital constituents in the delivery of business functions. The importance of system resolution time in a corporate environment cannot be overstated. System resolution time influences all business domains. This thesis investigates system resolution time as a business process variable related to effective system resolution time management. System resolution time management aims at addressing issues related to the delivery and effectiveness of automation systems.

Critical factor

The critical factor is an important business process variable with substantial impacts on business delivery and optimisation (Yeoh and Popovič, 2016). Critical factor enables a structure for prioritising, positioning and classifying succession of complex operations. Escalation rate is operationalised by the critical factor business process variable to define areas business process steps must be segregated in order of importance and hierarchy. The importance of "critical factor" in a corporate environment cannot be overstated (Goyal, 2012). Critical factor influences business delivery time. This thesis investigates "critical factor" as a business process variable related to effective critical factor management. This aims at addressing issues related to business delivery time.

Cost

Cost is a significant business process variable with substantial impacts on business delivery and optimisation. This business process variable is a combination of all monetary valuation of business infrastructures. Cost includes effort, materials, resources, time, the risk incurred, utilities consumed and opportunity forgone in transforming inputs to outputs. Cost management facilitates a structure for thinking beyond short-term savings and estimating impending business expenditures (KPMG, 2008). This includes defining systematic measures directed at collecting, planning, evaluating, documenting and controlling the budget of multinationals. This cushion the possibility of escalating over the proposed budget (Baharudin and Jusoh, 2015). The importance of cost in a corporate environment cannot be overstated. Cost influences all business domains. This thesis investigates cost

as a business process variable related to effective cost management. Cost management aims at addressing issues related to business optimisation and delivery.

Value chain design

Value chain design is an important business process variable with significant impacts on business delivery and optimisation (Goyal, 2012). This business process variable facilitates a structure to integrate, monitor and optimize supply chain enhancing business efficiency (Felea and Albastroiu, 2013). Multinationals get deliveries of goods and services from external sources. Numerous factors may result in a glitch or delay in these supplies. Value chain design facilitates a framework for reconfiguring succession of business process steps involved in the deliveries of supplies. Value chain design management identifies and reduces potential inefficiencies in the distribution network (KPMG, 2008). The importance of value chain design in a corporate environment cannot be overstated. Value chain design influences all business domains. This thesis investigates value chain design as a business process variable related to effective value chain design management. This aims at addressing issues related to business integration, monitoring, and optimisation.

Monitor

This is a significant business process variable with consequential impacts on business delivery and optimisation. This business process variable facilitates a structure for monitoring working capital and unlocking cash flows (Lukkari, 2011). This ensures financial sustainability in multinationals reducing reliance and exposure to short-term financial demands. Key Performance Indicators (KPI) of this business process variable are “Assets” and “Current liabilities. These are a combination of inventory, payables, receivables and cash management. The importance of monitor in a corporate environment cannot be overstated. Monitor influences all business domains. This thesis investigates monitor aimed at addressing issues related to monitoring working capital and unlocking cash flows.

Completeness of processes

Completeness of processes is an important business process variable with significant impacts on business delivery and optimisation. Completeness of process refers to the summation of time expended by multinationals from initiating and completing a business function. The KPI of this business process variable is turnaround time, lead time and throughput time. This is a combination of total production time and actual delivery time of supplies (Rajaniemi, 2012). Completeness of process ensures business continuity in the long and short-term business goals. The importance of completeness of process in a corporate environment cannot be overstated. Completeness of process

influences all business domains. This thesis investigates “completeness of process” as a business process variable related to effective completeness of process management. This aims at addressing issues related to business delivery and sustenance.

Integration

Integration is a significant business process variable with enormous impacts on business delivery and optimisation (Guo, et al., 2015). Business integration relates to the collaboration and streamlining of operations with complex business processes, goals, strategies, financial performance and philosophies in real-time (Karande and Kalbande, 2015). This business process variable facilitates a structure for aligning management system with complex business processes and IT systems. These ensure seamless delivery of business functions. The importance of integration in a corporate environment cannot be overstated. Integration influences all business domains. This thesis investigates integration as a business process variable related to effective integration management. This aims at addressing issues related to business optimisation and sustainability.

Data/Inventory

Data/inventory is an important business process variable with significant impacts on business delivery and optimisation (Jin and Luo, 2017). This business process variable investigates how multinationals manage, position and track inventory orders, sales, and deliveries (Amrani and Khmelnitsky, 2017). These optimise warehouse performance ensuring an effective balance of supplies and demand. The importance of data/inventory in a corporate environment cannot be overstated. Data/inventory influences all business domains. This thesis investigates data/inventory as a business process variable related to effective data/inventory management. This aims at addressing issues related to business optimisation and delivery.

Automation

Automation is a significant business process variable with enormous impacts on business delivery and optimisation (Papajorgji, 2015). Automation facilitates a structure for employing machinery and software in digitally executing business operations. These include development, collection, positioning, and storage of complex business process data essential in actualising defined business goals. The importance of automation in a corporate environment cannot be overstated. Automation influences all business domains. This thesis investigates automation as a business process variable related to effective automation management.

Efficiency/Energy

Efficiency is a significant business process variable with impacts on business delivery and optimisation (Petro and Gardiner, 2015). Efficiency facilitates a structure for the effective management of operational platforms and internal processes (Tetiana, et al., 2018). An optimally defined efficiency strategy reduces process inefficiencies, process completion time and minimizes the use of resources. The importance of efficiency/energy in a corporate environment cannot be overstated. Efficiency/energy influences all business domains. This thesis investigates efficiency as a business process variable related to effective efficiency/energy management. This aims at addressing issues related to optimising internal and operational corporate processes. Efficiency/energy as a BPV is operationalised to varying level of responsiveness.

Skills

Skills is a fundamental business process variable with significant impacts on business delivery and optimisation (Ighelogbo, 2016). Multinationals employ numerous skills in the execution of business operations. These skills are employed for the effective execution of machinery and lightening up of a business workspace. These skills are a combination of communication, computer, implementation and writing skills. The importance of skills in a corporate environment cannot be overstated. Skills influences all business domains. This thesis investigates skills as a business process variable related to effective skills management. This aims at addressing issues related to performance management, compensation, development strategies, wellness, hiring employees, safety, benefits, employee engagement, and training.

Standard and Non-Standard

Standard and non-standard as a business process variable involves the developments, positioning, implementing and validating of technical standards (Xie, et al., 2016). This business process variable facilitates a structure to stimulate and implement best practice opportunities inclusive of firms, users, interest groups, standards organizations, and government. This results in optimal compatibility, interoperability, safety, repeatability, and quality. The importance of standard and non-standard in a corporate environment cannot be overstated. Standard and non-standard influences all business domains. This thesis investigates standard and non-standard as a business process variable related to effective standard and non-standard management. This aims at addressing issues related to implementing and validating performance management in the execution of business processes.

Change

Change is a fundamental business process variable with significant impacts on business delivery and optimisation (Goyal, 2012). This business process variable is vital for multinationals to focus on continuously developing insightful and significant innovations. Change as a business process variable facilitates a structure for the multinationals to constantly adopt new technologies and policies, ensuring business sustainability. The importance of change in a corporate environment cannot be overstated. Change influences all business domains. This thesis investigates change as a business process variable related to effective change management. This aims at addressing issues related to developing insightful innovations in the execution of business processes.

Environmental Technologies

Environmental technologies are a significant business process variable with impacts on business delivery and optimisation. Environmental technologies facilitate the development of a business system to stimulate sustainable management of resources and waste (Acemoglu, 2015). Multinationals adopt IT systems to monitor, position and conserve natural resources towards reducing the possible impacts on machinery and human resources. Schneider, et al., (2010), defines environmental technologies as a clean or green technology system. The system applies theories in conserving business resources and waste of the natural environment. The importance of environmental technologies in a corporate environment cannot be overstated. Environmental technologies influence all business domains. This thesis investigates environmental technologies as a business process variable related to effective environmental technologies management. This aims at addressing issues related to resources, performance and waste management.

A publication on the comprehensiveness and impacts of a selected set of BPV from the list detailed is extensively discussed in (Medoh and Telukdarie, 2017c). The title of the publication is “Business Process Quantification: A Holistic Approach”, presented at the America Society for Engineering Management IAC conference proceedings.

The impacts of each BPV on a large global business is tested with defined sets of experimental scenarios employing best practice optimisation approaches. The next section extracts data from the SLR investigations to detail a literature review specific to comprehensive sets of optimisation approaches.

2.10 **Optimisation methods**

Optimisation methods relate to sets of mathematical, stochastic and statistical approaches effective for investigating the ideal solutions of differentiable functions (Mohamed, et al., 2015). This is inclusive of unconstrained minima or maxima parameters. This section reviews several best practice optimisation methods often used for investigations detailed by (Kumar, 2017) and captured in Figure 24.

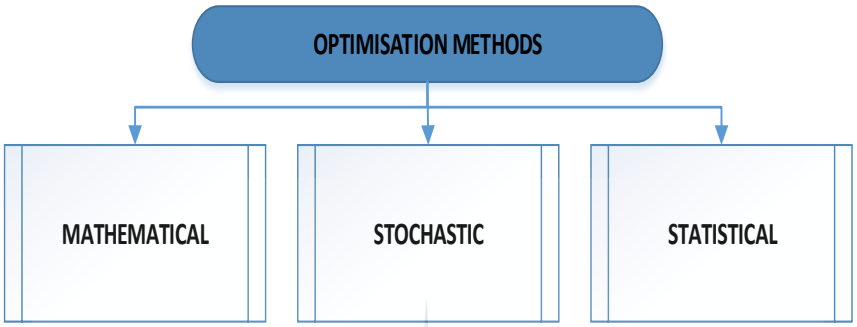


Figure 24: Optimisation methods

Source: (Kumar, 2017)

Each optimisation method further expatiates into sub-optimisation approaches captured in Figure 25.

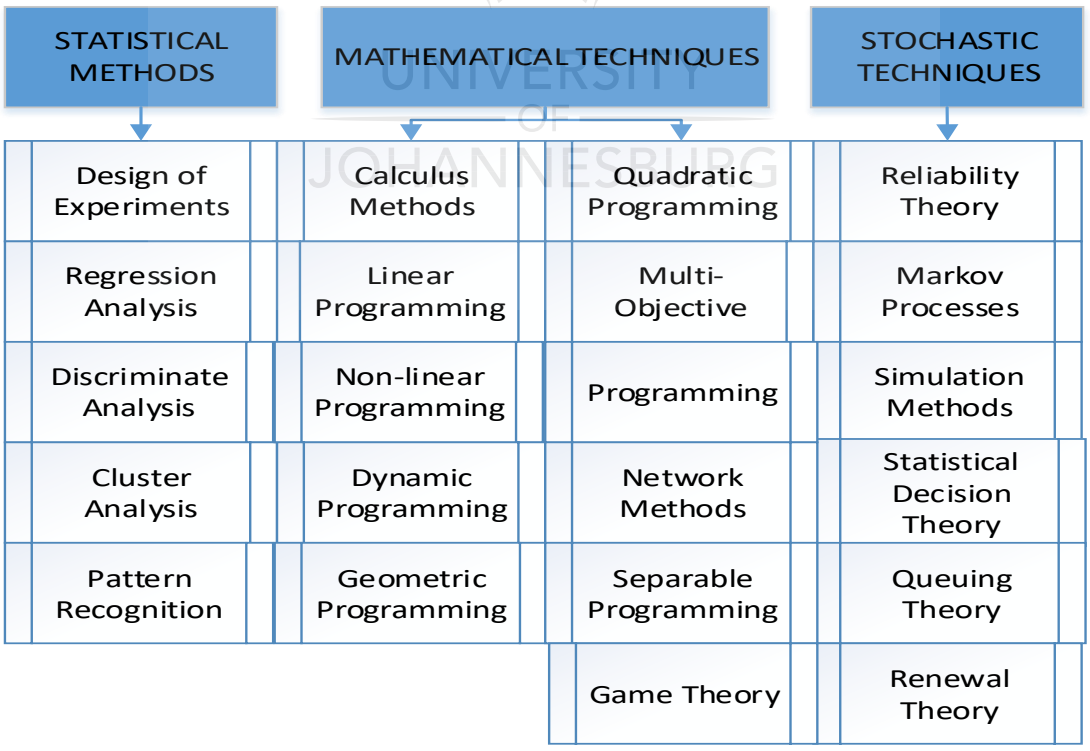


Figure 25: Sub-optimisation approaches

Source: (Kumar, 2017)

Optimisation approaches seek to achieve an ideal design centred on defined sets of prioritised constraints (Safa and Bhatti, 2011). The design aims at maximising factors such as strength, productivity, efficiency, reliability, and resource use. A synopsis of each optimisation method associated with sub-optimisation approaches captured in Figure 24 and 25 is detailed.

2.10.1 Stochastic optimisation method

Stochastic optimisation method relates to activities, which involves minimising or maximising a statistical function (Ramazan and Dimitrakopoulos, 2018). This optimisation method is suitable when single or multiple input variables are subject to randomness. The stochastic sub-optimisation approaches captured in Figure 25 is detailed.

Reliability theory

This stochastic optimisation approach is suitable when the aim is to allocate reliabilities uniformly among defined parameters (Gnedenko, et al., 2014). This thesis seeks to model a large global business and not basically to apply or distributing reliabilities. Hence, the reliability theory as a stochastic optimisation approach might not be a potential method selected for the proposed business model developments.

Markov processes

Markov processes as a stochastic optimisation approach is suitable when optimising for discrete-time control functions via dynamic reinforcement and programming learning (Ethier and Kurtz, 2009). This is not a fundamental objective of this thesis. The Markov processes as a stochastic optimisation approach might not be a potential optimisation method selected for the proposed business model developments.

Statistical decision theory

Statistical decision theory as a stochastic optimisation technique tests sets of quantitative approaches for achieving optimal decisions (Liese and Miescke, 2007). The statistical decision theory is a required objective of this thesis. The statistical decision theory might be a potential optimisation approach selected for the proposed business model developments.

Queuing theory

Queuing theory, as a stochastic optimisation technique investigates challenges involving real-life waiting systems (Vilaplana, et al., 2014). The queuing systems waiting time and lengths are predicted and optimised based on an effective mathematical model. This is not a necessary objective of this thesis. The queuing theory as a stochastic optimisation approach, might not be a potential optimisation method selected for the proposed business model developments.

Renewal theory

Renewal theory involves the subdivision of probability theory tests Poissons principles for random holding times (Feller, 2015). This is not the main objective of this thesis. The renewal theory as a stochastic optimisation approach might not be a potential optimisation method selected for the proposed business model developments.

Simulation methods

The simulation approach is an effective stochastic method suitable for process modelling and optimisation (Stauffer, et al., 2018; Karnon, et al., 2012; Malamura and Murata, 2012). Simulation tools and procedures have a positive influence when modelling and optimising a business (Karnon, et al., 2012). This is a fundamental objective of this thesis. The stochastic simulation method might be a potential optimisation method to be selected for the proposed business model developments.

A search in literature details simulation approaches often employed for research purposes. Four simulation approaches defined in emerging research is discussed in the literature (Jahangirian, et al., 2010). The simulation approaches include “Discrete Event (DE)”, “Hybrid Simulations”, “Agent-Based Modelling (ABM)” and “System Dynamics (SD)”. The four simulation approaches define a level of abstraction detailing relevant constituents. This feature makes a simulation structure less complicated in comparison with an original system (Grigoryev, 2015). A synopsis of each stochastic simulation approach is detailed.

(a) **System dynamics simulation approach:** This simulation approach is effective for understanding non-linear features of intricate systems over time. This is accomplished by employing stocks & flows, time delays, and internal feedback loops. A dynamic system model facilitates insights into the dynamic behaviour of a simulation structure over time (Karnopp, et al., 2012).

(b) **Agent-based simulation approach:** This simulation approach is composed of reciprocating and independent agents. The agent-based simulation approach is efficient for developing

computational simulation structures. The framework is effective for simulating complex business process interactions via autonomous agents (Macal and North, 2010).

(c) **Discrete event simulation approach:** The discrete event simulation approach is a process-centric based simulation method. This simulation approach is effective for representing the behaviour of a complicated structure as a sequence of ordered events (Karnon, et al., 2012). The discrete event simulation approach is effective for developing complex business processes, where there are constraints, inconsistencies or limited resources of complex systems interactions. This facilitates for an intricate and non-rigid approach to demonstrating intricate systems (Sharma, 2015).

(d) **Hybrid simulation approach:** A search in literature present limitations in the DE; ABM; and SD simulation approaches. The hybrid simulation approach is effective to address limitations associated with the DE; ABM; and SD simulation approaches (Lattila, 2012). Hybridisation involves combining two or more simulation approaches to enhance the quality of simulation structures (Thaler, et al., 2012).

Simulation stochastic optimisation approach comprises sequences of steps adapted from (Klee and Allen, 2018) and captured in Figure 26.

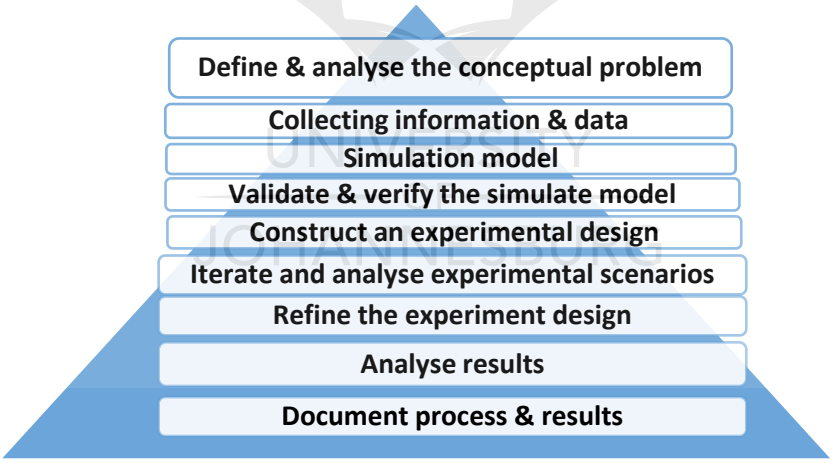


Figure 26: Simulation stochastic steps

Source: (Klee and Allen, 2018)

(a) **Define and analyse the conceptual problem:** The simulation user must define a conceptual problem. This step is accomplished from the very initiation of developing the simulation model.

(b) **Collecting information and data:** This simulation step defines the strategies implemented by the simulation user in collecting information used in developing the proposed simulation model. This step is achieved from a detailed literature review. The information and data collected at the initiation of developing the simulation model are not final, as the simulation model is adjusted

from several defined instances. This is essential to ensure the precision of the simulation architecture resulting in optimal outputs. Information and data collection, therefore, occurs all through the initiation and completion process of the simulation model developments.

(c) **Simulation model:** This step commences the development of the proposed simulation model premised on the information and data collected from the previous step.

(d) **Validate and verify the simulation model:** This step ensures the simulation model is a virtual structure of the real system under investigation. Validation aims for the comprehensiveness of the simulation model related to illustrating the real system, while verification directs attention to the effectiveness of the simulation model in accomplishing the required activity.

(e) **Construct an experimental design:** This step aims at configuring experimental scenarios effective for selecting defined sets of alternatives investigated in the simulation model. The experimental scenarios result in an analysis structure setting up an iterative framework. The alternatives include but not limited to several defined policies of the real system investigated.

(f) **Iterate and analyse experimental scenarios:** This step iterates and analyse the sample experimental scenarios to test and validate the effectiveness of the configured simulation model in addressing the defined simulation objective.

(g) **Refine the experiment design:** Based on the iteration results collected and analysed from the previous step, this step supports the possible modification of the experimental design configured.

(h) **Analyse results:** Based on the test and validity related to the effectiveness of the simulation model, this step iterates a comprehensive set of experimental scenarios and analyse the results collected.

(i) **Document process and results:** This step records the comprehensive process and results obtained from the simulation model.

The effectiveness of the stochastic simulation approach in optimising a system from computer simulations of a defined real structure cannot be overstated (Klee and Allen, 2018). The simulation model facilitates a framework to ideate how real-time structures conduct functions over time (Mansour, 2012). The results from the simulation model enable a comparison of the model constituents via different defined scenarios configured. An outline of some attributes of the simulation method adapted from (Grigoryev; 2015) is summarised.

(a) Supports a structure for training combined with investigating the interactions of a defined real-time or complex system. This supports the performance improvement of the investigated constituents configured in the simulation model.

(b) Supports a structure for simulating and observing differently defined alterations which are inclusive but not limited to creativity fostering and inventory reductions.
(c) Facilitates a framework for generating information on the sensitive variables enabled by the divergent inputs. This facilitates the simulation model users to analyse the defined systems and propose solutions where other procedures such as analytical calculations and linear programming is a limitation.
(d) The simulation model is adequate for predicting the effects developed by modifying the defined constituents of the structure.
(e) Supports a structure for evaluating capacity usage, control logic, inventory levels, integration, bottle-necks and sequencing/scheduling of the defined system.
(f) Facilitates a framework for proposing ideal layouts resulting in a standardised, incremental and resizable process.

Despite the attributes of the simulation method, there exist certain limitations of the simulation tool or approach. An outline of some limitations adapted from (Robinson, 2014) is summarised.

(a) The simulation method, techniques, and applications are extremely intense, requiring certain expertise.
(b) The simulation approach is very time-consuming.
(c) Simulation tools are extremely expensive.
(d) Simulation tools are highly data intensive.
(e) Simulation tools require special expertise and training.

2.10.2 Statistical optimisation method

A statistical optimisation method is an optimisation approach effective for investigating optimal decisions which function on uncertainty (Casalino, et al., 2015). The statistical sub-optimisation approaches captured in Figure 25 is detailed.

Design of experiments

The Design of Experiments (DOE) is an effective statistical approach for process optimisation activities extensively discussed in the literature (Dennison, 2016; Weissman and Anderson, 2014; Barad, 2014). The DOE is effective in presenting a structure for modelling, and predicting defined experimental scenarios. This attribute makes the DOE a potential optimisation approach to be selected for the proposed business model developments. This thesis seeks the effectiveness of the DOE approach in

investigating the impacts of change on multinationals resulting in factorial model design. The factorial model is a DOE method configured with two or more factors, each factor associated with discrete possible levels or values. The experimental units are integrated with a comprehensive combination of the defined levels across associated factors. The factorial model design supports a framework, which facilitates users to investigate how multiple factors (independent variable) affects a defined dependent variable. An investigation consisting of two independent factors associated with two levels is a (2 * 2) factorial model design. The (2 * 2) factorial model design result has four different conditions set.

Factorial model design develops on multiple factors; considering two factors A and B, where the factors are alternative sets and captured in a "A x B" notation.
"A" = Number of levels of the single independent factor.
"B" = Number of levels of the second independent factor.
The main effect is the effect of a dependent factor alternative on a defined response. An interaction occurs when the effect of a factor alternative on the defined response changes, which is dependent on the level of alternate factor options. A relation enabling sets of interaction columns via a design matrix is defined. The design matrix is operationalised by simulation combinations (I) captured in columns of signs (+, -). The positive (+) sign indicate a factor alternative at a high level and the negative (-) sign signifies a factor alternative at a low-level. Simulation combinations relate to the level each factor alternative is held during each experimental iteration.

A search in literature details two types of factorial model designs. This includes the full and fractional factorial model design (Bergquist, 2015). Numerous literature details application scenarios of the full and fractional factorial model design. Both factorial approaches apply in business, engineering, management and manufacture processes (Landsheer and van den Wittenboer, 2015). A full factorial model relates to the statistical design of two or more factors with the response for all possible combinations of the input factors (Dennison, 2016). The full factorial steps extensively discussed in the literature (Bergquist, 2015) is captured in Figure 27.

The fractional factorial model develops from an alias structure generated via a full factorial design (Kumar, 2017). Considering an enormous number of factors affecting a business to be potentially considered in this thesis. The fractional factorial approach might be considered as an initial screening method for investigating the effects of defined factor alternatives. Several fractional factorial

techniques exist. A search in literature elaborates on the Taguchi fractional factorial technique as a best practice fractional factorial method used for DOE research purposes (Khorasani, et al., 2011).

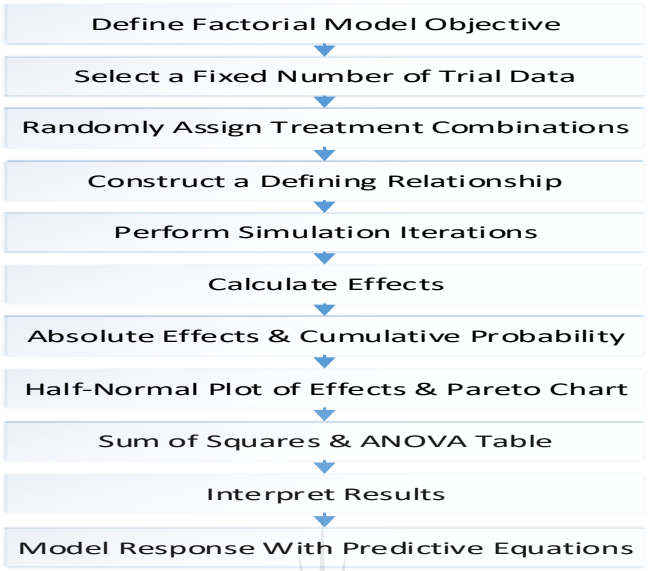


Figure 27: Full factorial steps

Source: (Bergquist, 2015)

The Taguchi fractional factorial technique is an effective tool for business enablement operative for developing an ideal simulation design, resulting in desired responses (Sarıkaya and Güllü, 2014). The Taguchi method offers a model for investigating optimum value, significance, and percentage combination of process parameters (Jaharah, et al., 2013). Taguchi fractional factorial method is effective for reducing the number of experimental runs of large input factors and interactions (Barad, 2014). This is based on orthogonal arrays which serve as an alternative to full factorial designs (Kumar, 2017). Input factors and interactions are integrated into the orthogonal array columns via linear graphs (Sarıkaya and Güllü, 2014).

The orthogonal array is an experimental method where the columns for the independent constituent alternative are orthogonal to each other. The orthogonal arrays enable a structure for investigating information on the physical system and confounding nature of the constituent alternatives(Taguchi, et al., 2004). The Taguchi fractional factorial method enables a scenario for percentage error testing of the experimental framework. Literature sets the ideal limit at less than 5%, and if above 5% the experiment is insignificant. Obtaining an ideal limit of above 5% relative to the experimental framework might be a result of either non-optimum array choice or assignment of the column. The fractional factorial steps extensively discussed in the literature (Kumar, 2017) is captured in Figure 28.

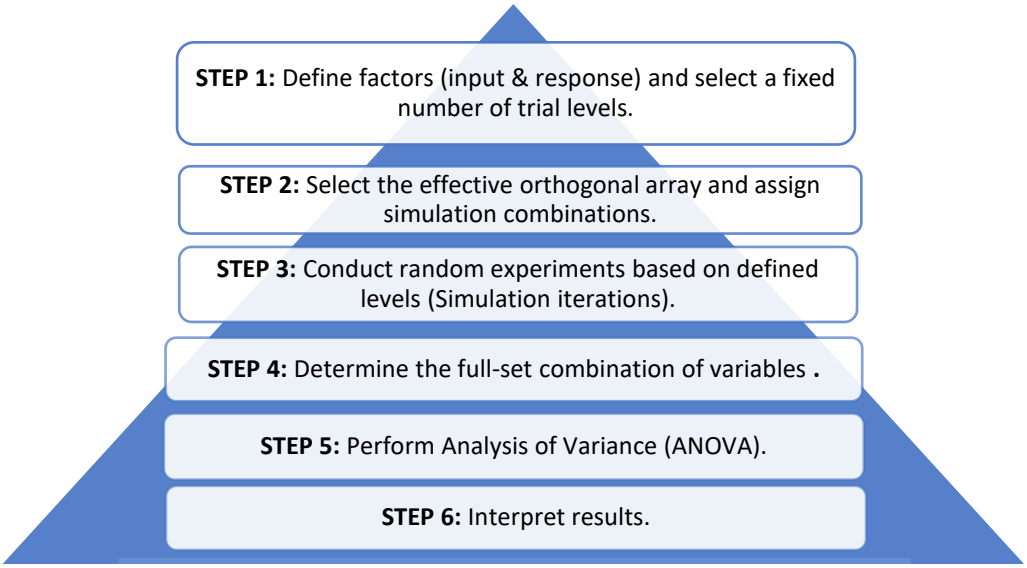


Figure 28: Taguchi fractional factorial design steps

Source: (Kumar, 2017)

The Taguchi (orthogonal array) method is an effective fractional factorial design for identifying optimum control factors obtaining optimal results of a defined scenario. The orthogonal arrays are efficient for identifying constituent alternative influences without loss of accuracy. This functions on mathematical theories such as Latin squares (Patnaik and Bhatt, 2011). The orthogonal arrays configured via Latin squares enables optimisation protocols that involve setting a sequence of procedures to:

(a) Explore important designs for constituent alternative defined.
(b) Obtain estimated constituent alternative effects.
(c) Investigate for maximum responses on constituent alternative effects.
(d) Identify the most effective configuration of constituent alternative defined.
(e) Optimize constituent alternative design.
(f) Deliver optimal performances for constituent alternatives and factorial model.

The orthogonal arrays configured via Latin squares tests a traditional mathematical scenario **"L*a* (*b* ^ *c*)"** for describing orthogonal arrays (Jose, et al., 2012). Where a = number of experimental runs; b = number of levels of individual constituent; c = number of constituents. Selecting an effective orthogonal array relative to the number of factor constituents investigated across several defined levels presents a challenge (Sorana and Lorentz, 2007). A search in literature details the importance of selecting orthogonal arrays with the highest number of constituent alternative possible. Facilitating

a structure for the least number of experimental runs. The steps considered when defining an orthogonal array includes:

(a) Identify the number of constituent alternatives for investigation.
(b) Define the factor levels of individual constituent alternatives for investigation.
(c) Identify and outline the factor interactions to be estimated.
(d) Define unique challenges to be encountered during experimental iterations.

A search in the literature indicates software such as the Minitab software is effective for generating orthogonal arrays from a list of array levels. This is based on the number of constituent alternatives and factor levels defined. The Minitab experimental commands present design resolutions and aliasing relationships, enabling a scenario for specifying properties, statistics testing, graphical illustrations, and result interpretations.

Regression analysis

Regression analysis is a best practice statistical optimisation technique effective for estimating the interactions between a dependent parameter and single or multiple independent variables (Draper and Smith, 2014). Investigating relations between important business constituents is an objective of this thesis. The regression analysis statistical optimisation approach might, therefore, be a potential optimisation method selected for the proposed business model developments.

Discriminate analysis

The discriminate analysis is a statistical optimisation technique effective to analyse sets of research data when the dependent criterion is categorical, and the independent predictor is an interval in nature (Al-Atiyat, 2009). This is not an essential objective of this thesis. The discriminate analysis as a statistical optimisation approach might not be a potential optimisation method selected for the proposed business model developments.

Cluster analysis

Cluster analysis also referred as segmentation or taxonomy analysis group sets of variables in such a way parameters belonging to same domain are more similar to each other relative to those in other groups (Wilks, 2011). This is not a significant objective of this thesis. The cluster analysis as a statistical optimisation approach might not be a potential optimisation method selected for the proposed business model developments.

Pattern recognition

Pattern recognition as a statistical approach involves the classification of regularities in a data pattern employing a machine learning algorithm (Nasrabadi, 2007). The algorithm is dependent on statistical information collected from pattern representations. This is not an essential objective of this thesis. Pattern recognition might not be a potential optimisation method selected for the proposed business model developments.

2.10.3 Mathematical method

Mathematical optimisation methods simulate real-life situations via mathematical equations (Menabde, et al., 2018). The results from simulations enable a framework for forecasting future behaviour. The mathematical sub-optimisation approaches captured in Figure 25 is detailed.

Calculus methods

Calculus mathematical approach is effective for counting and calculations involving continuous change (Barles, et al., 2018). This is not a fundamental objective of this thesis. Calculus method might not be a potential optimisation method selected for the proposed business model developments.

Linear programming

Linear programming is an optimisation approach suitable for achieving an ideal outcome of a mathematical model (Dantzig, 2016). The requirements implemented in linear programming are captured via linear relationships. The business model proposed functions on mathematical modelling. Linear programming might be a potential optimisation method selected for the proposed business model developments.

Non-linear programming

Non-linear programming is a mathematical optimisation approach suitable for solving optimisation challenges centred on non-linear objective functions (Garg and Arora, 2018). This is not the primary objective of this thesis. Non-linear programming might not be a potential optimisation method selected for the proposed business model developments.

Dynamic programming

Dynamic programming is an optimisation approach suitable for achieving an ideal outcome of a mathematical computer model (Bellman and Dreyfus, 2015). The business model proposed does not

function on mathematical computer modelling. Dynamic programming might not be a potential optimisation method selected for the proposed business model developments.

Geometric programming

Geometric programming is a mathematical technique effective to solve optimisation challenges centred on monomials and posynomials (Boyd, et al., 2007). This is not a vital objective of this thesis. Non-linear programming might not be a potential optimisation method selected for the proposed business model developments.

Quadratic programming

Quadratic programming is an optimisation approach suitable for resolving special mathematical optimisation quadratic challenges involving multiple variables configured from linear constraints, bounds and linear inequality (Wainwright, 2009). This is not an important objective of this thesis. Quadratic programming might not be a potential optimisation method selected for the proposed business model developments.

Multi-objective

The Analytical Hierarchy Process (AHP) is an effective multi-objective mathematical optimisation approach suitable for prioritisation tasks (Vargas-Ricardo, 2010). This thesis seeks to investigate and prioritise the selection of BPMN tool alternatives. This makes the AHP mathematical optimisation method a potential approach selected for the proposed business model developments. The AHP is a multi-objective mathematical optimisation decision-support tool effective for facilitating operationalisation and converting qualitative data to quantitative scales (Awasthi, et al., 2018). The AHP mathematical optimisation method is effective as a pre-decision-support approach for positioning the constituents of a problem into a hierarchic order (Saaty, 2009). The AHP approach developed by Thomas L. Saaty in the 1970s is a mathematical model supporting decision theory for modelling and decomposing an unstructured problem into smaller and smaller constituent parts (Vargas-Ricardo, 2010). A framework guiding decision-makers through a sequence of “pair-wise” comparison judgments are developed (Awasthi, et al., 2018). The judgments are translated into numbers, expressing the relative strength or intensity of the importance of individual constituent in the hierarchy. The framework is effective to determine the best of numerous alternatives, allocating resources and setting priorities (Saaty, 2008). The steps considered in adopting the AHP mathematical optimisation method is extensively discussed in the literature (Vargas-Ricardo, 2010) and captured in Figure 29.

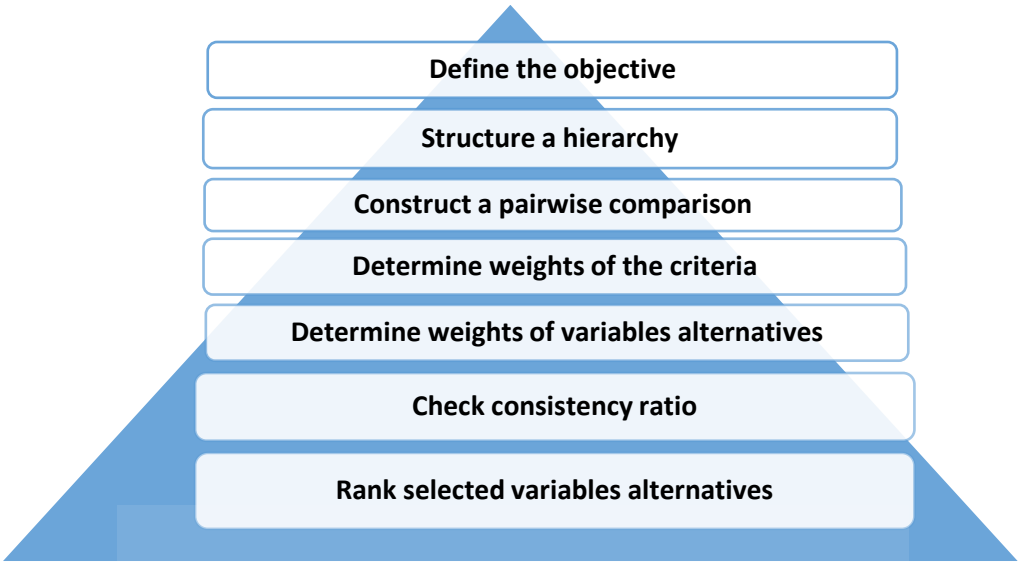


Figure 29: AHP steps

Source: (Vargas-Ricardo, 2010)

(a) **Define the objective:** This step involves defining the problem, specifying the solution desired and determining factors influencing the situation.

(b) **Structure a hierarchy:** This step involves structuring a hierarchy from the top-level to the level at which decisions to solve a problem is possible. This usually initiates from the top (objectives from an executive viewpoint), followed by intermediate levels (predictors on which ensuing levels depend) then the lowest level (generally a list of alternatives). In designing a simple hierarchy, every constituent in the lower level is dependent on constituents in the upper level. These constituents at the lower level are compared to each other in relation to the impacts of the governing constituents. This results in square matrix judgments with each element in the matrix interdependent.

(c) **Construct a pairwise comparison:** This step assigns numeric integers or values to subjective judgments premised on the relative importance of each criterion defined. The hierarchy structured in the previous step is assigned a scaling system for converting qualitative assessments to quantitative scales. The scaling system (pairwise comparison) results in a structure for quality evaluations executed by decision-makers. Given two elements A and B: If element B is dominated by element A, a numeric value is entered in row A and column B, while the reciprocal (fraction) is entered in row B and column A. If element A is dominated by element B, a reverse occurs. The numeric values are placed in the B and A positions while the reciprocal is automatically assigned to the A and B positions. If elements A and B are judged equal, a numeric value of one is assigned to both positions. Saaty in a previous publication defined and certifies measurable scales for

designing an AHP model. These measurable scales quantify the relative importance of a variable and are considered in constituting a pairwise comparison.

(d) **Determine the weights of the business criteria defined:** This is obtained by normalising the measurable scales constituted from the pairwise comparison. The criteria weight for each business criterion is then calculated.

(e) **Determine the weights of variable alternatives selected:** The same approach detailed in steps three and four above is repeated to calculate the criteria weights of variables alternatives selected.

(f) **Check the consistency ratio:** This step synthesizes the judgments to determine priorities. This is implemented by evaluating consistency ratios of the detailed hierarchy structured. Fuzzy logic, eigenvector techniques, Delphi, and other numerous approaches can be used in this regard. The consistency of comparison is calculated by obtaining a product of the pairwise comparison matrix and the vector of priority. The value computed from the Consistency Index (C.I.) is then compared with the Random Index (R.I) values detailed by Saaty in a previous publication. Saaty establishes a C.I: R.I < 10 % as an acceptable matrix and C.I: R.I up to 20 % as a tolerable matrix.

(g) **Rank selected variable alternatives:** The weights of BPMN tool alternatives calculated (step five) is multiplied by the criteria weights (step four).

Programming

Programming is an optimisation approach effective for encoding an algorithm through a computer into a programming language and notation (Preskill, 2018). This is not a necessary objective of this thesis. Programming might not be a potential optimisation method selected for the proposed business model developments.

Network methods

Network methods is an approach suitable for analysing the network of similarly connected variables (Donner, et al., 2011). The interconnected variables are linked in a systems perspective. Network methods might not be a potential optimisation method selected for the proposed business model developments.

Separable programming

Separable programming is an optimisation approach presenting a framework for convex nonlinear programs to be estimated with arbitrary accuracy from a linear programming model (Stefanov, 2013). Separable programming supports the replacement of nonlinear variables with a piecewise linear

estimation. This is not a key objective of this thesis. Separable programming might not be a potential optimisation method selected for the proposed business model developments.

Game theory

Game theory is a mathematical model useful for investigating the strategic interactions between decision-makers, which must be rational (Camerer, 2011). The game theory is not a significant objective of this thesis. Game theory might not be a potential optimisation method selected for the proposed business model developments.

The literature review of several best practice optimisation methods (stochastic, mathematical and statistical) often used for investigations is expected to serve as a guide in selecting relevant approaches for the proposed business model developments.

2.11 **Summary and conclusions**

Chapter two details a comprehensive literature review for this thesis with discussions on the primary keywords relevant to developing the proposed business model. This chapter discusses the protocols of the 4IR technologies. The 4IR enablers detailed potentially resolve the research gaps detailed relating to the systemic contextualisation of existing business models. Chapter two identifies all probable business constituents related to investigating a vast global business. The business constituents possibly deliver a comprehensive evaluation of a multinational, a limitation to existing business models. The discussions detailed in chapter two directs the execution of the proposed business model developments. The next chapter extracts information gathered from the detailed literature review to discuss the research design and method constituted for the proposed business model developments.

Chapter 3: Research Design and Methodology

3.1 **Chapter Overview**

Contemporary multinationals emphasise on continuous innovation, technology, and sustainable advancements delivering maximum business revenues (Dolgui, et al., 2018). Business sustainability and optimisation are fundamentals when addressing collective business challenges (Dolgui, et al., 2018). Business sustainability and optimisation deliver ideal financial, social, economic and environmental corporate benefits (Malihi, and Aghdasi, 2014). Chapter three details the research design and method related to the proposed business model developments, structured in five sections captured in Figure 30.

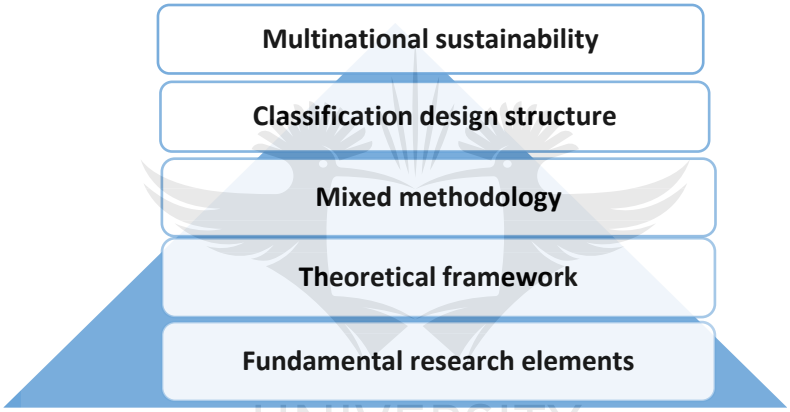


Figure 30: Scope of the Methodology structure

Source: (Authors own compilation)

The first section highlights the discussions related to business implementations in multinationals.

3.2 **Multinational sustainability**

Present-day multinationals execute complex operations with a primary focus to generate and optimise earnings. The literature review detailed in chapter two indicates multinationals carry out operations in multiple functional domains requiring sustainable business interventions. The ability to develop a business model effectively collaborating all operations and technologies is crucial for ensuring a sustainable multinational. Enhancing the sustainability and optimisation of the collaborative corporate physical systems delivers improved business outputs (Chen, et al., 2018; Dalenogare, et al., 2018; Monostori, et al., 2016; Jazdi, 2014).

The next section constitutes and discusses a classification design structure for developing the proposed business model driven by the advanced constituents detailed in Figure 2. The advanced constituents offer significant value add to traditional business analysis tools focus on improving multinational sustainability.

3.3 Classification design structure

Figure 31 captures the sequential steps for the classification design structure adapted and modified from the literature (Lambert and Davidson, 2013).

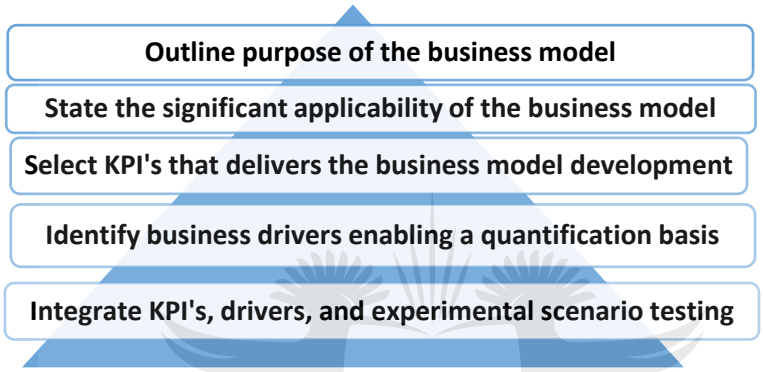


Figure 31: Classification design structure related to the conceptual BPOM developments
Source: (Lambert and Davidson, 2013)

A synopsis of each constituent captured related to the classification design structure is detailed.

Outline purpose of the business model

This step ensures clarity in defining the essential purpose of the proposed business model. This thesis seeks for a comprehensive and holistic business model effective to collaborate all business constituents of a present-day multinational.

State the significant applicability of the business model

This step ensures clarity in defining the significant applicability of the proposed business model. This thesis seeks a business model effective to serve as a decision-support tool for current and future predictive analysis of a complex business.

Select KPI's that delivers the business model developments

This step ensures KPI's delivering the defined purpose and applicability of the proposed business model are selected from the extensive list discussed in the literature review detailed in chapter two.

This thesis proposes and considers technologies and benchmarks of the fourth industrial revolutions.

Identify business drivers enabling a quantification basis

This step ensures drivers delivering the defined purpose and applicability of the proposed business model are selected from the comprehensive list discussed in the literature review detailed in chapter two. The data extracted from the background relating to business models and information collected from the SLR publications indicates BP, BPV, BPMT, and optimisation approaches are constituents of a present-day multinational.

Integrate the KPI's, drivers, and experimental scenario testing

This step ensures the KPI's and business drivers identified are comprehensively integrated when developing the proposed business model. This step test and validate if the proposed business model delivers the defined purpose and applicability detailed in steps one and two.

The classification design structure guides the selection of a suitable research method for developing the proposed business model. This thesis ensures each step in the classification design structure is considered for selecting each business constituent from the extensive list reviewed. Based on the purpose of each step in the classification design structure and information collected from peer-review publications. The mixed-method approach discussed in the next section is found appropriate for developing business models.

3.4 Mixed-method

The mixed-method approach facilitates the combinations of multiple investigations and strategies across different research domains (Creswell and Creswell, 2017). The mixed-method approach delivers a comprehensive holistic model of physical systems in a complex business. The mixed-method approach unifies business process science, modelling, simulation, statistics, experimentation and analysis through qualitative and quantitative investigations (Brinch et al., 2018; Sekaran and Bougie, 2016; Liu and Shi, 2015; Creswell and Plano Clark, 2011).

Table 2 captures some of the important literature (2011 – 2018) relating to developing business models based on the mixed-method approach.

Table 2: Relevant mixed-method literature

REFERENCE	DEFINITION
Brinch, et al., 2018	This research evaluates the influences of 4IR implementations such as big data to develop a model for supply chain management employing a sequential mixed-method approach.
Creswell and Creswell, 2017	This research developed an architecture based on a mixed-method assisting business globally to successfully initiate and strategize a business on critical success factors of a model for implementation.
Sharma et al., 2017	This research developed a decision-support model to rank critical indicators influencing 4IR implementations such as cloud computing across several organisations in India employing a mixed-method approach.
Sekaran and Bougie, 2016	This research presents a detailed review of several best practice research methods for business. This literature highlights the effectiveness of the mixed-method approach in research.
Cortimiglia, et al., 2016	This research presents a document investigating business model strategies and innovation employing a mixed-method approach.
Bocken, et al., 2014	This research presents detailed literature related to developing a sustainable business model archetypes employing a mixed-method approach.
Nakagawa and Schielzeth, 2013	This research explores a general and simple approach for investigating diverse effects models employing a mixed-method approach.
Zott, et al., 2011	This research presents an extensive complex review of business models. The review is based on a mixed-method approach.

The information detailed in Table 2 indicates effective applications of the mixed-method approach related to business model developments. This motivates and justifies the choice of the mixed-method approach for investigations. A theoretical framework is constituted to expatiate on the applications of the mixed-method approach.

3.5 **A review of the theory**

A theoretical framework defines the theories and concepts crucial in an investigation (Potschin-Young, et al., 2018; Lederman, 2015; Grant and Osanloo, 2014). Important implications from established concepts detailed in the literature review are refined in a theoretical framework to demonstrate applications of the mixed-method approach. The interrelated business constituents captured in Figure

32 are sub-systems of the proposed business model. Each business constituent is fundamental and serves as selection inputs related to developing the proposed business model.

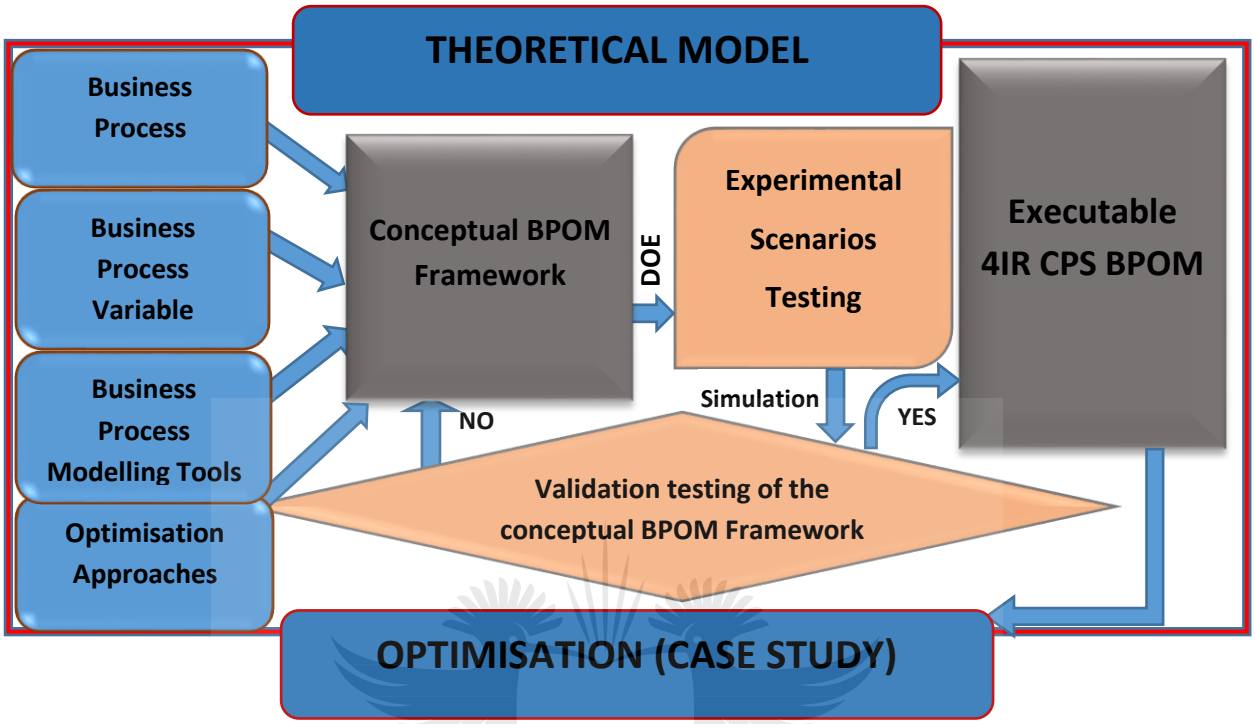


Figure 32: Theoretical framework

Source: (Authors own compilation)

The mixed-method approach combines the interconnected concepts of BP, BPV, BPMT, and optimisation approaches captured in Figure 32. The initial step is to define and develop a repository of business processes. This is followed by effectively configuring and collaborating each business constituents as a model (CPS) delivering a conceptual BPOM framework. A scenario testing and validation (simulation & DOE) of the conceptual BPOM is performed, which results in an executable 4IR CPS BPOM. The simulation and DOE optimisation methods deliver an experimental protocol for this thesis. This is achieved through a representative model output effective for comparative statistical analysis. A negative validation returns the theoretical framework to re-development of the conceptual BPOM. A positive response establishes the effectiveness of the executable 4IR CPS BPOM.

The next sub-sections expatiate and validate the selection of individual business constituent captured in the theoretical framework.

3.5.1 Multinationals represented by business processes

Business processes defined and developed with a considerable level of details are suitable to represent real-world operations of a large global business. Business processes are a fundamental constituent of the theoretical framework. Contemporary multinationals are considered process-centric with core business functions captured via BP (Bradford and Gregory, 2015). Business processes are crucial and play a significant role in enabling business integration across multinationals (Becker, et al., 2013). BP consists of logically related fundamental building blocks, procedures, methods, tasks and a series of actions designed to accomplish a business goal (Bradford and Gregory, 2015). Developing an effective repository of BP is an ideal way to deliver defined, competitive and sustainable business productivity. An effectively developed repository of BP serves as a suitable representation of a large global business. This motivates this thesis in selecting BP as an important and integral constituent of the conceptual BPOM framework.

3.5.2 Multinationals evaluated by business process variables

Business process variables is a fundamental constituent of the theoretical framework. Multinationals are significantly influenced by impacts of numerous business factors (Jin and Luo, 2017; Amrani and Khmelnitsky, 2017; Medoh and Telukdarie, 2017c; Baharudin and Jusoh, 2015; Karande and Kalbande, 2015; Shafiei, 2014; Felea and Albastroiu, 2013; Gove and Uzdzinski, 2013; Subramanyam, 2012). This thesis aims to develop a business model effectively collaborating and investigating these business factors detailed as BPV. The objective of this thesis inspires the selection of BPV as an important and integral business constituent of the conceptual BPOM framework.

3.5.3 Multinationals modelled and simulated with business process modelling tools

The development of a sustainable and predictive business model is essentially a creative process requiring business process modelling tools that can support the improvements. This makes business process modelling tools a fundamental constituent of the theoretical framework. The success or failure of business process modelling actions is dependent on the selection of an effective BPMT (Hussain, 2015). A search in the literature indicates BPMT as being deployed globally in modelling projects for a variety of business functions (Sargeant, 2013). This thesis aims to develop a BPOM via a BPMT effective for developing a repository of BP and simulation model of all business constituents. This motivates this thesis in selecting BPMT as an important and integral business constituent of the conceptual BPOM framework.

3.5.4 Integral best practice optimisation approaches

Optimisation methods are a fundamental constituent of the theoretical framework. Based on a comprehensive review of numerous optimisation methods detailed in chapter two. The DOE (statistical), simulation (stochastic), and AHP multi-objective (mathematical) optimisation methods are selected. This optimisation approaches applicable across several engineering, and business disciplines are propositioned appropriate relative to developing the conceptual BPOM framework (Stauffer, et al., 2018; Karnon, et al., 2012; Vargas-Ricardo, 2010).

(a) Analytical Hierarchy Process (AHP): The AHP is a decision-support approach effective for ranking constituents of a system (Awasthi, et al., 2018). The AHP optimisation method facilitates multi-objective ranking suitable for pre-decision-support related to the selection of an effective BPMT for developing the conceptual BPOM framework.

(b) Simulation methods: Simulation approach enables experimentation to analyse, simulate, optimise and predict a real-world system. Simulation tools are configured with mathematical rules and languages for implementing in-depth statistics of real-world business scenarios (Grigoryev, 2015). Simulation tools are effective for stimulating tactical and strategic decisions in the design and redesign of business systems (Garwood, et al., 2018; Malamura and Murata, 2012). The simulation method is considered applicable for developing a digital and valid prototype of a real-world system.

Selecting an inappropriate simulation approach results in an inaccurate simulation model which deliver a deceptive output (Karnon, et al., 2012). Four best-practice simulation approaches mostly used in emerging literature is detailed in chapter two. Based on the review the discrete event simulation approach is selected related to developing the conceptual BPOM framework.

(c) Design of Experiments (DOE): The DOE optimisation method includes a systematic statistical approach effective for investigating the relationships between factors with significant impacts on a defined response (Dennison, 2016 and Barad, 2014). This results in a factorial model design of the DOE model constituents (Weissman and Anderson, 2014). Factorial model design is an experiment with multiple factors (Medoh and Telukdarie, 2018b). The DOE optimisation method is considered appropriate for comparative statistical testing, analysis, and validation of the business model.

The next section summarises extensive discussions detailed from chapters one to three. A research framework is developed, highlighting the fundamental elements of this thesis. This is related to the purpose of this thesis and important benchmarks related to addressing the objectives defined.

3.6 **Fundamental research elements**

This section reviews the discussions detailed from chapters one to three. A research framework is captured in Figure 33, segregating the discussions in three phases. Each phase highlights the fundamental objectives of this thesis and relevant elements related to developing the BPOM.

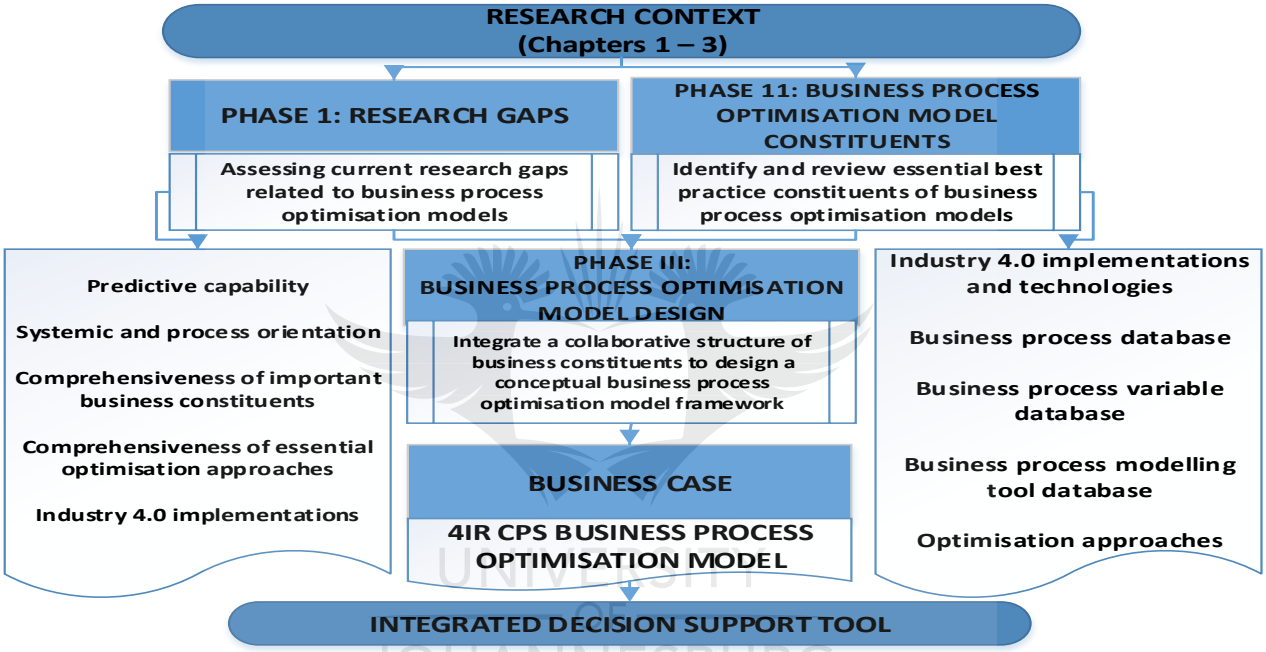


Figure 33: Fundamental research elements

Source: Authors own compilation

Phase 1 assess the current research gaps related to developing a predictive business model. Key indicators reviewed in the assessments of existing business models include:

(a) The predictive competence.
(b) The systems and process-orientation considerations.
(c) The comprehensiveness and integration of important business constituents.
(d) The development of business models driven by the 4IR implementations.

The research gaps defined related to traditional business models results in sets of research questions to be potentially addressed. The questions, research objectives, and model assumptions are

extensively discussed and justified in chapter one, which facilitates the need for a comprehensive literature study detailed in phase 2. The literature discussions present direction to the purpose of this thesis, inclusive of selecting suitable research design and methodology for execution. This is discussed in chapter three and summarised in phase 3.

3.7 **Summary and conclusions**

The correlated theoretical concepts reviewed in chapter two necessitated a mixed-method approach relating to developing the proposed model (CPS). Chapter three justifies the selection of the mixed-method design and propose the implementations through a developed theoretical framework. The theoretical structure highlights the relevant business constituents of a complex business selected from the extensive list discussed in the literature review. The fundamental business constituents selected are business processes, business modelling tools, business process variables, analytical hierarchy process, simulation method and design of experiment statistical approach. Chapter three concludes with a summary of the discussions detailed from chapters one to three. The next chapter progress on information extensively detailed in the theoretical framework to discuss the step-by-step approach and developments related to each business constituent selected for developing the model (CPS).

Chapter 4: Model Development

4.1 Chapter overview

A model capture and drives the dynamics of a real-life physical system to define diverse abstractions relating to operational practices. An effectively developed model constitutes only fundamental constituents crucial for addressing collective business challenges. Chapter four improves the previous chapter to detail step-by-step model developments related to each business constituent selected and captured in the theoretical framework. The discussion justifies the selection of each business constituent. This chapter is structured in four sections captured in Figure 34.

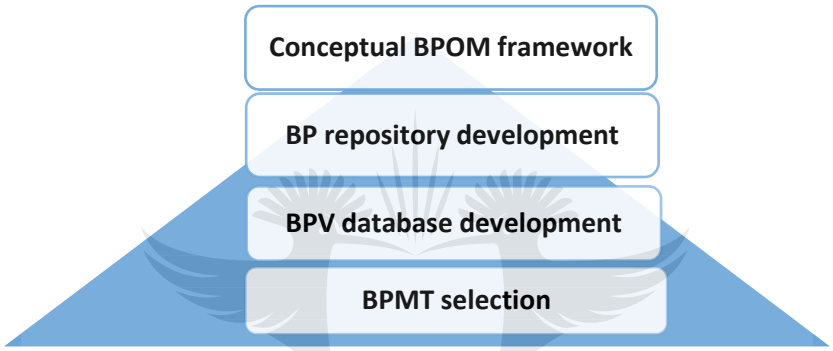


Figure 34: Scope of the conceptual BPOM developments

Source: (Authors own compilation)

4.2 Conceptual business process optimisation model framework

This section constitutes and details a conceptual BPOM framework captured in Figure 35. The conceptual structure guides the step-by-step discussions related to developing the proposed business model. The conceptual BPOM framework elaborates on each business constituent detailed in the theoretical framework into the following strategic pointers.

(a) **Business processes:** The information gathering related to business processes are documented across BP functional levels, BP functional layers, and automation systems.

(b) **Business process variables:** The investigations related to business process variables is dependent on the factors, the business states, and the experimental metrics associated with each factor.

(c) **Business process modelling tools:** The business process modelling tools are selected with an emphasis on the suitability to develop a repository of BP, simulation competence and statistical factorial capability.

(d) **Optimisation approaches:** The optimisation methods are employed for selecting an effective BPMT (AHP) and undertaking experimental scenario assessments (Simulation & DOE) of the proposed business model.

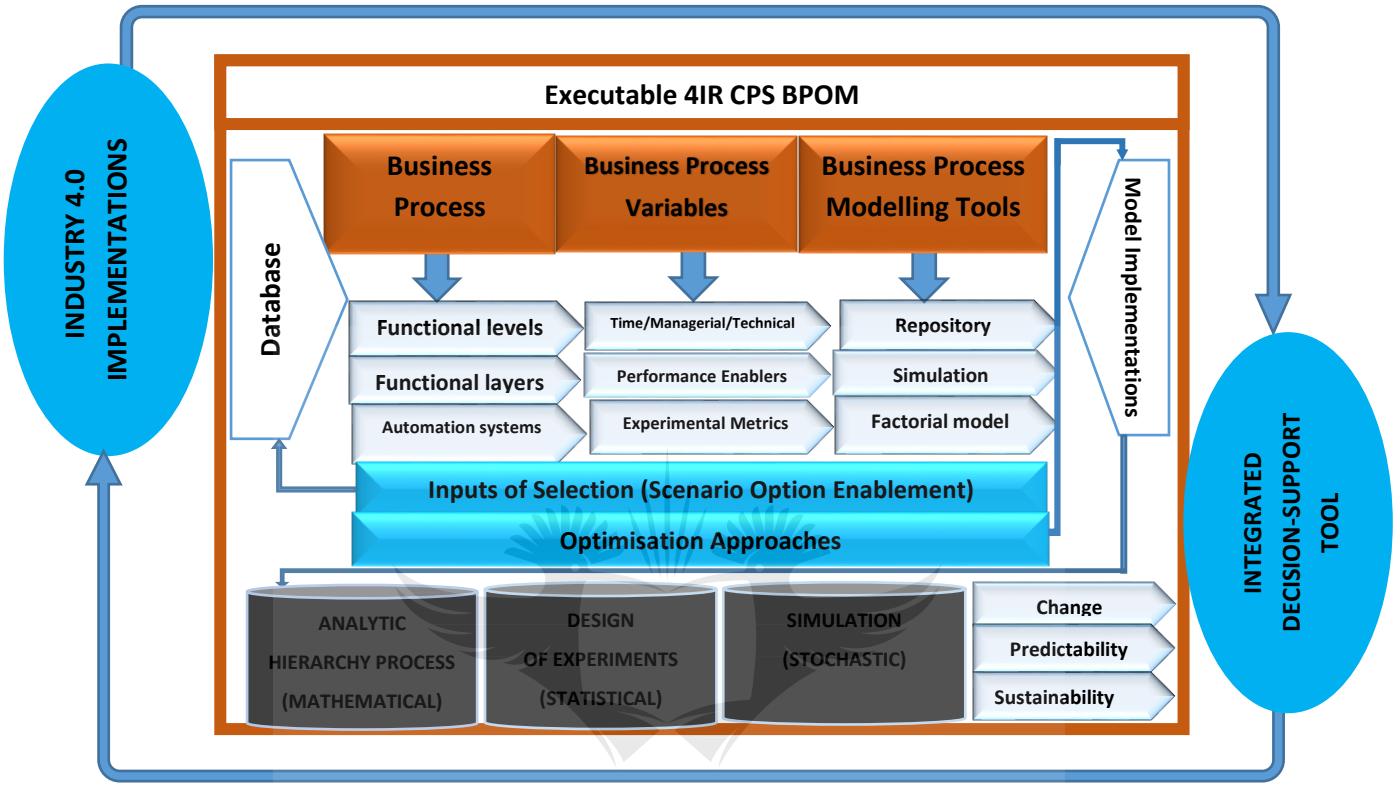


Figure 35: Conceptual BPOM framework

Source: (Authors own compilation)

To predict a present-day multinational, an effective representation through a repository of multinational functional domains is required. This research segregates and represents the multinational functional domains as business processes. The next section details a step-by-step repository development of business processes.

4.3 Business process repository development

A repository of BP comprehensively constituted serves as an effective representation of a modern multinational (Lehnert, et al., 2017; Fosso and Mishra, 2017; Bradford and Gregory, 2015). This is extensively discussed in previous chapters. This section details step-by-step BP repository developments providing clarity from BP data gathering, documentation, analysis, interpretation to final value creation. Figure 36 captures benchmark constituents related to BP repository development steps.

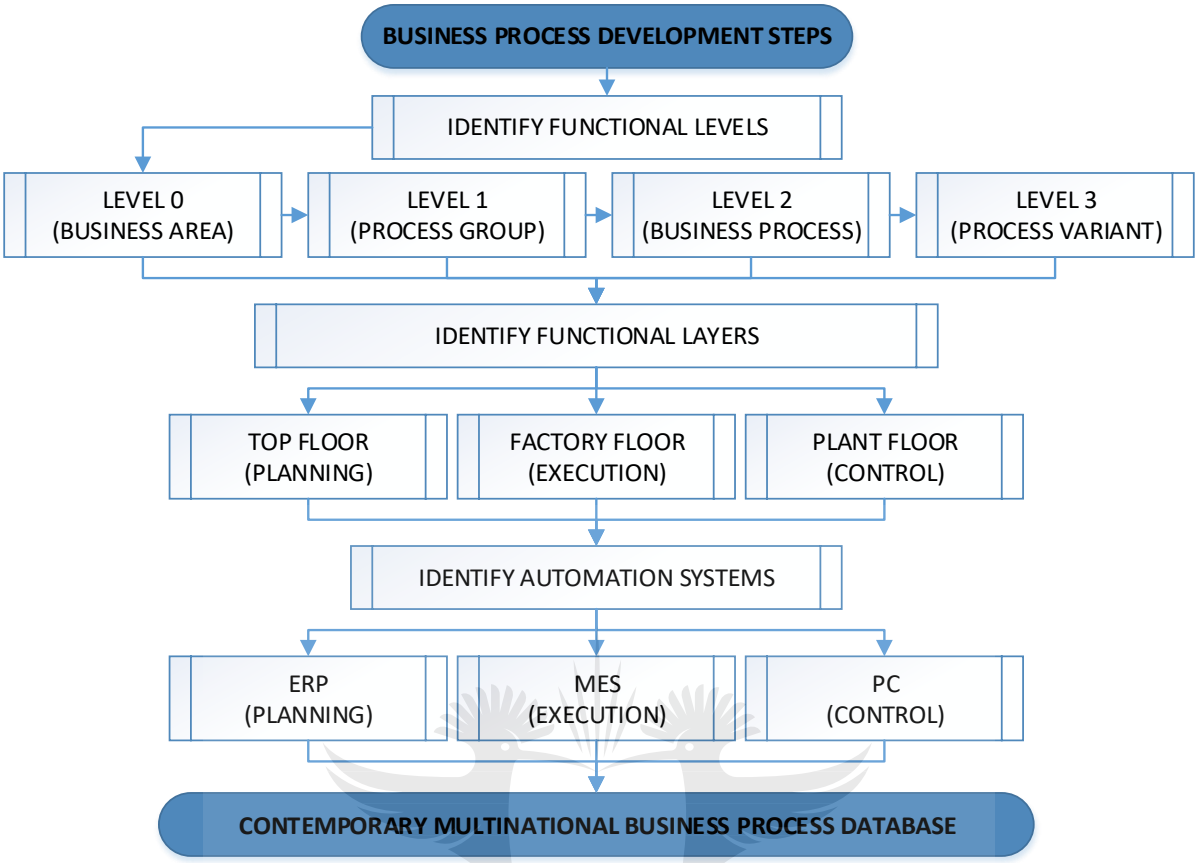


Figure 36: Business process development steps

Source: (Authors own compilation)

The BP repository captures diverse operations of multinationals and a selection input related to developing the conceptual BPOM. The next sub-sections details a synopsis of each benchmark element significant to the BP repository development steps.

4.3.1 Database of functional levels

The initial step in the development of the BP repository is identifying high-level abstraction of BP to distinct sub-processes across each BP functional level. The BP functional levels limit the complexities in capturing complex sets of BP as a singular assessment (SAP, 2016). Based on an extensive discussion of BP functional levels detailed in the literature review presented in chapter two. This thesis limits the repository developments of BP from level 0 to level 3 (where required).

The BP repository configured from level 0 to level 3 is sufficient for the conceptual BPOM applications. The comprehensive sets of BP steps across each functional level is collected, modified, and modelled from the literature (SAP, 2016 and APQC, 2015) databases. Both databases are a generic business

architecture effective for gathering detailed proprietary information relative to BP executed in multinationals (SAP, 2016 and APQC, 2015).

The definitions of the four functional levels (0 - 3) considered for BP repository development is detailed in Table 3.

Table 3: Business process functional levels

Source: APQC (2015)

FUNCTIONAL LEVELS	DEFINITION
Level 0 (Business Area)	High-level combination of complex BP, illustrating mainly logical flows.
Level 1 (Process Group)	Represents BP belonging to the same domain of functionalities.
Level 2 (Business Process)	Sub-processes aggregating business-oriented steps to a unit.
Level 3 (Process Variant)	Further divisions of sub-BP fulfilling the same business-critical task.

The BP functional levels ensure an all-inclusive sets of BP developed is an effective representation of a modern multinational. The BP functional levels are executed across diverse business floors, which relates to BP functional layers. This is extensively detailed in the next sub-section.

4.3.2 Database of functional layers

The subsequent step in the development of the BP repository is identifying BP functional layers, which details business floors where each BP is executed. The literature review detailed in chapter two discusses the planning, execution, and control floors (Purdue enterprise reference architecture).

(a) The planning stage of business processes is captured on the top floor.
(b) The execution implementations represent the operational floor for business processes.
(c) The control stage of business processes is captured at the plant floor.

The BP functional layers ensure detailed sets of BP developed delivers an effective representation of present-day multinationals. Several automation systems are deployed at each business floor. This is extensively detailed in the next sub-section.

4.3.3 Database of automation systems

The subsequent step in the development of the BP repository is identifying automation systems, which clarifies relevant technologies operational at each business floor identified. The literature review

detailed in chapter two identifies the ERP, MES and PCN automation systems (Purdue enterprise reference architecture).

(a) ERP executes business processes at the planning stage.
(b) MES executes business processes at the execution stage.
(c) PCN executes business processes at the control stage.

The three benchmark elements captures high-level abstraction of BP to distinct sub-processes in a repository comprising thousands of process steps collected and modelled over one year. The operational performance of the collective process steps are significantly influenced by several factors (BPV). This is extensively discussed in chapter two. The next section details a step-by-step database development of BPV related to developing the model (CPS).

4.4 **Business process variables database development**

A detailed database development of business process variables delivers a structure to investigate the impacts of each factor on multinationals. This is extensively discussed in previous chapters. This section details step-by-step BPV database developments. Figure 37 captures benchmark elements related to BPV database development steps.

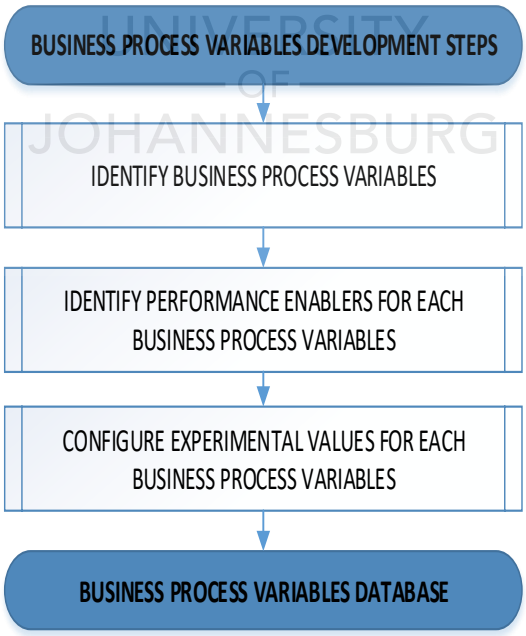


Figure 37: **Business process variables development steps**

Source: (Authors own compilation)

The BPV database is a fundamental and selection input related to developing the conceptual BPOM. The next sub-sections details a synopsis of each benchmark element significant to developing the comprehensive database of BPV.

4.4.1 Identify business process variables

The initial step in the development of the BPV database is identifying diverse sets of factors with significant impacts on multinationals. The literature review detailed in chapter two extensively discuss comprehensive sets of factors with substantial influences on operational performances of a complex business. The BPV identified are either time-variant, managerial, technical configurations or indicators.

The BPV identified and detailed includes: human resource resolution time; escalation rate; system maturity index; business state index; system resolution time; critical factor; cost; change; efficiency, throughput, Energy; environmental technologies; monitor; value chain design; completeness of process; integration; data/inventory; skills; non-standard and standard.

The comprehensive sets of factors are collected from the literature (Tetiana, et al., 2018; Jin and Luo, 2017; Amrani and Khmelnitsky, 2017; Yeoh and Popovič, 2016; Xie, et al., 2016; Ighelogbo, 2016; Guo, et al., 2015; Papajorgji, 2015; Karande and Kalbande, 2015; Acemoglu, 2015; Baharudin and Jusoh, 2015; Petro and Gardiner, 2015; Shafiei, 2014; Felea and Albastroiu, 2013; Gove and Uzdzinski, 2013; Subramanyam, 2012; Rajaniemi, 2012; Paschke and Lukkari, 2011; Best and Holmes, 2010; Castellanos, et al., 2009; Collings and Wood, 2009; KPMG, 2008).

The identified business process variables are considered to have varying levels of impacts on multinationals (Cosenz and Noto, 2018; Amrani and Khmelnitsky, 2017; Ighelogbo, 2016; Acemoglu, 2015). This facilitates the second benchmark detailed in the next sub-section.

4.4.2 Identify performance enablers for each business process variable

The subsequent step in the development of the BPV database is defining sets of performance enablers for evaluating and comparing the BPV against each other. The performance enablers segregated into business states enable a quantification structure for varying the BPV impacts. The performance enablers detailed are defined from an extensive literature review and industrial experience of the researcher.

Human resource resolution time

Human resource resolution time is an important BPV with significant impacts on multinationals (Collings and Wood, 2009). This thesis defines six active roles associated with human resource resolution time. The roles are a combination of “Executive”; “Manager”; “Supervisor”; “Operations”; “Administrator” and “Manual” (Chelladurai and Kerwin, 2018; Yeoh and Popovič, 2016; Collings and Wood, 2009). The responsive roles defined are considered sufficient for investigating human resource resolution time as a BPV. A synopsis of each human resource resolution time business states selected is detailed.

(a) Executive refers to BP steps executed by an executive workforce directly or indirectly.
(b) Manager refers to BP steps executed by a manager workforce directly or indirectly.
(c) Supervisor refers to BP steps executed by a supervisor workforce directly or indirectly.
(d) Operations refer to BP steps executed by an operations workforce directly or indirectly.
(e) Administrator refers to BP steps executed by an administrative workforce directly or indirectly.
(f) Manual refers to BP steps executed by a manual workforce directly or indirectly.

Escalation rate

Escalation rate optimises business turn-around time and an important BPV with significant impacts on a large global business (Castellanos, et al., 2009). This thesis defines four responsive states considered sufficient for investigating the escalation rate BPV. This thesis prepositions BP steps can be escalated either one or two-level(s) up. The states selected are a combination of “Manual-tier 1 ER”; “Auto-tier 1 ER”; “Manual-tier 2 ER”; and Auto-tier 2 ER”. A synopsis of each escalation rate states selected is detailed.

(a) Manual tier 1 ER refers to BP steps unattended to or not resolved escalated manually to an immediate alternate workforce.
(b) Manual tier 2 ER refers to BP steps unattended to or not resolved escalated manually to a superior workforce.
(c) Auto-tier 1 ER refers to BP steps unattended to or not resolved escalated automatically to an immediate alternate workforce.
(d) Auto-tier 2 ER refers to BP steps unattended to or not resolved escalated automatically to a superior workforce.

System maturity index

System maturity index is an important BPV with significant impacts on multinationals (Gove and Uzdzinski, 2013). This thesis defines eight system maturity states considered sufficient for investigating the system maturity index BPV. This thesis considers options for manual or automation enablement across each maturity system level in defining the states. The states defined are collected from the Purdue enterprise reference architecture. The model details three system maturity levels which include "strategic (ERP)", "Operational (MES)" and "control (PCN)". The states selected for this thesis are a combination of "Fully enabled MES & ERP"; "connected PCN"; "Module-specific MES & ERP"; and "Manual PCN, MES & ERP (Gove and Uzdzinski, 2013). A synopsis of each system maturity index states selected is detailed.

(a) Fully enabled MES & ERP"; "connected PCN refers to multinationals fully integrated and operational with the MES, ERP, and PCN implementations.
(b) Module-specific MES & ERP" refers to multinationals partially integrated and operational driven by the MES, ERP, and PCN implementations.
(c) Manual PCN, MES & ERP refers to multinationals manually integrated, and operational premised on the MES, ERP, and PCN implementations.

Business state index

Business state index is an important BPV with significant impacts on multinationals (Shafiei, 2014). This thesis defines the responsiveness of business state index on the proposition that contemporary multinationals require two years to adapt to a change. This thesis defines three business states considered sufficient for investigating the business state index BPV. The states selected are a combination of "Greater Than 2yrs BP Last changed"; "Less Than 2yrs BP Last Changed"; and "Less Than 1yr BP Last Changed" (Shafiei, 2014 and Subramanyam, 2012). A synopsis of each business state index selected is detailed.

(a) Greater Than 2yrs BP Last changed refers to multinationals measuring the maturity of business operations more than two years after implementations.
(b) Less Than 2yrs BP Last changed refers to multinationals measuring the maturity of business operations less than two years after implementations.
(c) Less Than 1yr BP Last changed refers to multinationals measuring the maturity of business operations less than one year after implementations.

System resolution time

System resolution time is an important BPV with significant impacts on multinationals (Shafiei, 2014). This thesis defines three system resolution states considered sufficient for investigating the system resolution time BPV. The states defined are collected via publications from the Information Technology Infrastructure Library (ITIL). The publication details system resolution time levels relating to ERP, MES, and PCN. The system resolution time states selected for this thesis are a combination of "Full-Service Level Agreement (SLA) Less Than 2hrs"; "Full SLA Less Than 4hrs" and "Partial SLA Less Than 6hrs" (Subramanyam, 2012). A synopsis of each system resolution time states selected is detailed.

(a) Full-SLA less than 2hrs refers to present-day multinationals integrated with a full-service level agreement of the defined business operations less than two hours.
(b) Full-SLA less than 4hrs refers to contemporary multinationals integrated with a full-service level agreement of the defined business operations less than four hours.
(c) Partial-SLA less than 6hrs refers to multinationals integrated with a partial service level agreement of the defined business operations less than six hours.

Critical factor

Critical factor optimises business turn-around time and an important BPV with significant impacts on multinationals (Yeoh and Popovič, 2016). This thesis defines five critical factor states considered sufficient for investigating the critical factor BPV. The states defined emphasises on the process theory concepts detailed in (Best and Holmes, 2010). The critical factor states selected for this thesis are a combination of "Very High Priority (VHP)"; "Very Important Factor (VIF)"; "Standard (STD)"; Not Critical (NC)" and BASIC (Goyal, 2012). A synopsis of each critical factor states selected is detailed.

(a) VHP refers to BP steps with significant impact on multinationals. These sets of BP steps require urgent attention, hence a high escalation potential.
(b) VIF comprises BP steps requiring expedited attention with medium escalation potential.
(c) STD refers to BP steps requiring urgent attention with the least escalation potential.
(d) NC consists of BP steps multinationals must attend but not very critical.
(e) Basic refers to none essential BP steps in multinationals that can proceed normally.

Cost

Cost is an important BPV with significant impacts on multinationals (Baharudin and Jusoh, 2015). This thesis defines three cost enablers considered sufficient for investigating cost as a BPV. The cost enablers selected for this thesis are a combination of “Low”; “Medium” and “High” (KPMG, 2008). A synopsis of each cost states selected is detailed.

(a) Low refers to multinationals operating with an ideal combination of all monetary valuation of business infrastructures and processes.
(b) Medium refers to multinationals operating on an average combination of all monetary valuation of business infrastructures and processes.
(c) High refers to multinationals operating on an unacceptable combination of all monetary valuation of business infrastructures and processes.

Value chain design

Value chain design is an important BPV with significant impacts on multinationals (Felea and Albastroiu, 2013). This thesis defines three value chain design enablers considered sufficient for investigating value chain design BPV. The value chain states selected for this thesis are a combination of “Very high”, “Fairly high” and “Fairly low” (Felea and Albastroiu, 2013; Stevenson and Spring, 2007; KPMG, 2008). A synopsis of each value chain design states selected is detailed.

(a) Very high refers to multinationals integrated with an ideal structure for incorporating, monitoring and optimising a defined supply chain.
(b) Fairly low refers to multinationals integrated with an average structure for incorporating, monitoring and optimising a defined supply chain.
(c) Fairly low refers to multinationals integrated with a poor structure for incorporating, monitoring and optimising a defined supply chain.

Monitor

This is an important BPV with significant impacts on multinationals (Lukkari, 2011). This thesis defines three monitor enablers considered sufficient for investigating monitor as a BPV. The monitor states selected for this thesis are a combination of “Excellent”, “Good” and “Poor”. A synopsis of each monitor states selected is detailed.

(a) Excellent refers to multinationals integrated with an ideal structure for monitoring working capital and unlocking cash flows.
(b) Good refers to multinationals integrated with an average structure for monitoring working capital and unlocking cash flows.
(c) Poor refers to multinationals integrated with an unacceptable structure for monitoring working capital and unlocking cash flows.

Completeness of processes

Completeness of processes is an important BPV with significant impacts on multinationals (Rajaniemi, 2012). This thesis defines three completeness of process enablers considered sufficient for investigating the completeness of processes as a BPV. The completeness of process states selected for this thesis is a combination of "Excellent, "Good" and "Poor". A synopsis of each completeness of processes states selected is detailed.

(a) Excellent refers to multinationals operating on a minimal summation time expended from initiating and completing a business function.
(b) Good refers to multinationals operating on an average summation time expended from initiating and completing a business function.
(c) Poor refers to multinationals operating on unacceptable summation time expended from initiating and completing a business function.

Integration

Integration is an important BPV with significant impacts on multinationals (Guo, et al., 2015). This thesis defines three integration enablers considered sufficient for investigating integration as a BPV. The integration enablers selected for this thesis are a combination of "Fully integrated", "Not integrated" and "Partially integrated" (Karande and Kalbande, 2015). A synopsis of each integration states selected is detailed.

(a) Fully integrated refers to multinationals incorporated with an ideal structure for aligning management system with complex business processes and IT systems.
(b) Partially integrated refers to multinationals incorporated with an average structure for aligning management system with complex business processes and IT systems.
(c) Not integrated refers to multinationals incorporated with an unacceptable structure for aligning management system with complex business processes and IT systems.

Data/Inventory

Data/inventory is an important BPV with significant impacts on multinationals (Jin and Luo, 2017). This thesis defines three data/inventory enablers considered sufficient for investigating data/inventory as a BPV. The data/inventory enablers selected for this thesis are a combination of “Fairly low”, “Fairly high” and “Very high” (Amrani and Khmelnitsky, 2017). A synopsis of each data/inventory states selected is detailed.

(a) Very high refers to multinationals integrated with an ideal structure for investigating how multinationals manage, position and track inventory orders, sales, and deliveries.
(b) Fairly high refers to multinationals integrated with an average structure for investigating how multinationals manage, position and track inventory orders, sales, and deliveries.
(c) Fairly low refers to multinationals integrated with a poor structure for investigating how multinationals manage, position and track inventory orders, sales, and deliveries.

Automation

Automation is an important BPV with significant impacts on multinationals (Papajorgji, 2015). This thesis defines three automation states considered sufficient for investigating automation as a BPV. The automation states selected for this thesis are a combination of “No Automation”; “Partially Enabled Automation” and “Fully Enabled Automation”. A synopsis of each automation states selected is detailed.

(a) Fully enabled automation refers to multinationals integrated with an ideal structure for employing machinery and software in digitally executing business operations.
(b) Partially enabled automation refers to multinationals integrated with an average structure for employing machinery and software in digitally executing business operations.
(c) No automation refers to multinationals integrated with an unacceptable structure for employing machinery and software in digitally executing business operations.

Efficiency/Energy

Efficiency/energy is an important BPV with significant impacts on multinationals (Petro and Gardiner, 2015). This thesis defines three efficiency enablers considered sufficient for investigating efficiency/energy as a BPV. The efficiency enablers selected for this thesis are a combination of “High”, “Medium” and “Low”. A synopsis of each efficiency/energy states selected is detailed.

(a) High refers to multinationals integrated with an ideal structure for the effective management of operational platforms and internal processes.
(b) Medium refers to multinationals integrated with an average structure for the effective management of operational platforms and internal processes.
(c) Low refers to multinationals integrated with an unacceptable structure for the effective management of operational platforms and internal processes.

Skills

Skills are an important BPV with significant impacts on multinationals (Ighelogbo, 2016). This thesis defines three skill states considered sufficient for investigating skills as a BPV. The skill states selected for this thesis are a combination of "Fully-skilled", "Semi-skilled" and "No-skill". A synopsis of each skills management states selected is detailed.

(a) Fully-skilled applies to multinationals operating with an ideal combination of the workforce.
(b) Semi-skilled applies to multinationals operating with an average combination of the workforce.
(c) No-skill applies to multinationals operating with an unacceptable mix of workforce.

Standard and Non- Standard

Standard and non-standard is an important BPV with significant impacts on multinationals (Xie, et al., 2016). This thesis defines three states considered sufficient for investigating standard/non-standard as a BPV. The standard/non-standard states selected for this thesis are a combination of "Non-standard", "Neutral" and "Standard". A synopsis of each standard and non-standard states selected is detailed.

(a) Standard refers to multinationals integrated with an ideal structure to stimulate and implement best practice opportunities.
(b) Neutral refers to multinationals integrated with an average structure to stimulate and implement best practice opportunities.
(c) Non-standard refers to multinationals integrated with an unacceptable structure to stimulate and implement best practice opportunities.

Change

Change is an important BPV with significant impacts on multinationals (Goyal, 2012). This thesis defines three change enablers considered sufficient for investigating change as a BPV. The change states selected for this thesis are a combination of “Poor”, “Good” and “Excellent”. A synopsis of each change states selected is detailed.

(a) Excellent refers to multinationals integrated with an ideal structure for constantly employing new technologies, implementations, and policies.
(b) Good refers to multinationals integrated with an acceptable structure for constantly employing new technologies, implementations, and policies.
(c) Poor refers to multinationals integrated with an unacceptable structure for constantly employing new technologies, implementations, and policies.

Environmental Technologies

Environmental technology is an important BPV with significant impacts on multinationals (Acemoglu, 2015). This thesis defines three environmental technology states considered sufficient for investigating environmental technologies as a BPV. The environmental technologies states selected for this thesis are a combination of “Medium”, “High” and “Extremely high”. A synopsis of each environmental technologies states selected is detailed.

(a) Extremely high refers to multinationals integrated with an ideal structure for the development of a business system effective to stimulate sustainable management of resources and waste.
(b) Medium refers to multinationals integrated with an average structure for the development of a business system effective to stimulate sustainable management of resources and waste.
(c) High refers to multinationals integrated with an acceptable structure for the development of a business system effective to stimulate sustainable management of resources and waste.

The third benchmark constituent related to BPV database development steps defines experimental metrics to quantify each performance enabler. Several limitations exist when selecting intermediate states of numeric metrics effective for quantification. This is detailed in the next sub-section.

4.4.3 Configure experimental values for business process variables

The importance of experiments in business modelling designs cannot be overstated. Experiments are for testing theories providing a quantification basis for business research and knowledge (Bloom, et

al., 2018). The theoretical framework highlights the DOE (statistical) and simulation (stochastic) optimisation methods. Functionalities and effectiveness of the DOE and simulation optimisation methods are extensively detailed in chapters two and three. This thesis employs the DOE and simulation optimisation methods for statistically defining a range of numeric metrics.

The statistical investigations result in treatment combinations from defined random settings and simulation trials. To deliver the random settings, dummy numeric metrics detailed in the literature (Grotenhius and Thijs, 2015) are investigated. The dummy numeric metrics investigations are standardized for reliability employing the DOE techniques. This is based on repeated and random simulation runs. A reliability testing of the intermediate-range of options selected from the numerous simulation run trials limits the subjectiveness of the numeric metrics.

To undertake the DOE validation of numeric metrics, BPV investigated are spread across the defined performance enablers. Results of the DOE validation, which constitutes the numeric metrics considered for investigation is discussed during model implementations. The standardized numeric metrics are presumed potentially effective and strategically positioned for investigations.

The three benchmark constituents related to BPV development steps detailed results in a comprehensive database of BPV to predict impacts of change on a complex business. The BPV database is applicable irrespective of the business sector.

The complex developments of the model (CPS) require the right BPMT for configuration, testing, and analysis. The next section considers the extensive list of BPMTs comprehensively reviewed in chapter two to detail step-by-step BPMT selection effective for developing the model (CPS).

4.5 **Business process modelling tool selection**

A comprehensive list of BPMT often utilised for unique modelling objectives is collected from literature and investigated. This is driven by benchmark constituents related to BPMT selection steps captured in Figure 38.

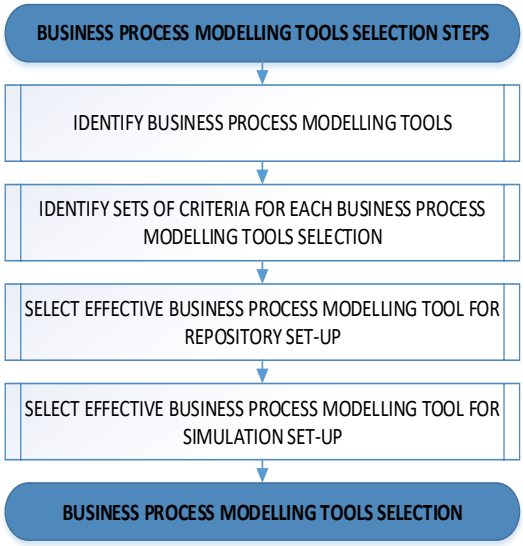


Figure 38: BPMT selection steps

Source: (Authors own compilation)

The BPMTs investigated in this thesis is a fundamental and selection input related to developing the conceptual BPOM. The next sub-sections details a synopsis of each benchmark element significant to BPMTs selection steps.

4.5.1 Identify BPMT

The initial step is identifying diverse sets of BPMTs effective for unique modelling objectives. The literature review detailed in chapter two extensively discusses a detailed set of BPMT. The BPMTs reviewed includes: Metastorm provision BPA, Accuprocess Modeler, iGrafx process, Enterprise Architect, ARIS business architect, Holocentric Modeler, Savvion process Modeler, System architect, Mega modelling suite, Casewise corporate Modeler suite, Lombardi blueprint, Microsoft Visio, Process maker, Visual paradigm, Insight Maker, Mavim, FlexSim simulation tool, Anylogic simulation tool, Lucidchart, Bonitasoft, Adonis and Bizagi.

The identified BPMTs are collected from the literature (Medoh and Telukdarie, 2017b; Murali, 2013; Islay, et al., 2007). The identified BPMTs are integrated with varying functionalities. The second benchmark element in the BPMT selection steps is defining sets of criteria for each BPMT identified. This is detailed in the next sub-section.

4.5.2 Identify sets of criteria for each BPMT selection

The subsequent constituent related to BPMT selection steps is defining sets of criteria effective to facilitate a framework for quality quantitative evaluations, and ranking of each BPMT identified. The

sets of criteria guide this thesis in selecting an effective BPMT. A synopsis of each criterion defined, and selected adapted from literature (Murali, 2013; Gupta, et al., 2010; Islay, et al., 2007; Vesna, 2007) is detailed in Table 4. The sets of criteria are serve as a decision-support in selecting an effective BPMT.

Table 4: Sets of criteria related to BPMT selection

Source: (Murali, 2013; Gupta, et al., 2010; Islay, et al., 2007; Vesna, 2007)

CRITERIA	DEFINITIONS
Cost	Cost-effectiveness
Availability	Easily accessible.
Support & Maintenance	Vendors providing regular users support.
Functional requirements	Visual quality and types of graphical objects.
Active content	Analysis competence.
General features	User-friendliness.
Training	Vendors providing training.
Technological requirements	Checking for reliability and performance-related specifications.
Version control	Controlling limitations to specific versions in the future.
Integration	Comprehensiveness.
Reference sites	Easy linkage with multiple applications.
User interface	Easy user-interactions.

Based on the BPMT aligned with associated sets of criteria defined, the next sub-section demonstrate the selection of an effective BPMT for developing a repository of BP.

4.5.3 Select an effective tool for business process repository set-up

As a result of the diverse sets of BPMTs identified, which are effective for unique modelling objectives. The AHP multi-objective (mathematical) optimisation approach is employed to demonstrate the selection of an effective BPMT for developing a repository of BP. The effectiveness of the AHP multi-objective optimisation approach for pre-decision-support is extensively discussed in previous chapters with emphasis from the literature (Awasthi, et al., 2018; Vargas-Ricardo, 2010; Saaty, 2009; Saaty, 2008).

The applicability of the proposed BPMT selection for developing a repository of BP is demonstrated, presented and published in an international conference “Industrial Engineering and Engineering

Management (IEEM)" (Medoh and Telukdarie, 2017b). The title of the publication is "Business Process Modelling Tool selection: A Review".

A synopsis of the selection process executed through the AHP steps captured in Figure 29 is detailed.

Define the objective: Select an effective BPMT for developing a repository of BP from the detailed list identified in chapter two. This thesis streamlines BPMTs from an extensive list discussed to three with an emphasis on the attributes of each BPMT collected from the vendor sites. This thesis streamlines the sets of criteria from an extensive list defined to four with an emphasis on the defined BP repository development objectives detailed.

Structure a hierarchy: A hierarchical arrangement of the three BPMT is configured aligned with the four sets of criteria selected.

Construct a pairwise comparison: Numeric values collected from Saaty rating scales is assigned to judgements, which details the importance of each set of criteria selected. The results are detailed in Table 5 with the following scenario prepositions.

(a) Functionality is strongly more significant compared with reference sites. This is allotted a measurable scale of 5. The reverse comparison results in a reciprocal and assigned a measurable scale of 1/5.
(b) Both functionality and support & maintenance are of equal importance. There is a compromise between both criteria as a preferred criterion. Hence, a measurable scale of 4 and 1/4 is allotted.
(c) Functionality is slightly more significant compared with cost. This is allotted a measurable scale of 2. The reverse comparison results in a reciprocal and assigned a measurable scale of 1/2.
(d) Sets of criteria are of equal importance along the main diagonal when compared to itself. This is assigned a measurable scale of 1.

Table 5: Pairwise comparison for sets of criteria selected

Business variables	Functionality	Reference sites	Cost	Support & Maintenance
Functionality	1.00	5.00	2.00	4.00
Reference sites	0.20	1.00	0.50	0.50
Cost	0.50	2.00	1.00	2.00
Support & Maintenance	0.25	2.00	0.50	1.00

Determine weights of the multi-criteria selected: The pairwise comparison developed in Table 5 is normalised to obtain weights for each multi-criterion selected. Functionality business criterion is normalised as an illustration. [Normalised measurable scale = 1 / (1.00 + 0.20 + 0.50 + 0.25) = 0.51].

A similar scenario is employed for obtaining normalised measurable scale for the other multi-criteria selected. The results obtained include: "Reference sites = 0.50", "Cost = 0.50" and "Support & maintenance = 0.53". , The weight for each criterion is calculated with outputs collected from the normalised measurable scale obtained for each criterion. Functionality business criterion is calculated as an illustration. [Criteria weight = 0.51 + 0.50 + 0.50 + 0.53) / (4.00) = 0.51]. A similar scenario is employed for obtaining weights of the other multi-criteria selected. The results obtained include: "Reference sites = 0.10", "Cost = 0.24" and "Support & maintenance = 0.15".

Determine the weights of BPMT alternatives selected: The same approach presented in the previous step is repeated to calculate the criteria weights of BPMT alternatives selected. The results obtained are detailed in Table 6.

Table 6: Criteria weights for BPMN tool alternatives selected

	Functionality	Reference sites	Cost	Support & Maintenance
Process Maker	0.57	0.16	0.09	0.08
Microsoft Visio	0.29	0.54	0.67	0.32
Savvion Process Modeler	0.14	0.30	0.24	0.60

Check the consistency ratio: The consistency of comparison is calculated by obtaining a product of the pairwise comparison matrix employing vector of priority technique. [Largest eigenvalue = (2.08/0.51 + 0.40/0.10 + 0.99/0.24 + 0.59/0.15) / 4.00 = 4.05] and [Comparison Index (C.I) = (λ-N)/(N-1) "(4.05 – 4.00) / (4 - 1) = 0.02"].

The value computed from the (C.I.) is then compared with Random Index (R.I) values detailed by Saaty in a previous publication. [C.R. = C.I. /R.I. = 0.02/0.90 = 0.02 = 2% < 10%]. Saaty establishes a C.I: R.I < 10 % as an acceptable matrix and C.I: R.I up to 20 % as a tolerable matrix. The results calculated indicates C.R. = 2% which is less than 10%. This affirms the comparison as consistent and the matrix is acceptable for evaluation.

Rank selected BPMT alternatives: The weights of the BPMT alternatives calculated is multiplied by the criteria weights obtained. Process Maker business process modelling tool is calculated to present an illustration. [Process Maker (overall weight) = 0.57 (0.51) + 0.16 (0.10) + 0.09 (0.24) + 0.08 (0.15) = 0.34]. A similar scenario is employed for obtaining the overall weights of the other BPMT alternative selected. The results obtained from calculating the overall weights are detailed in Table 7.

Table 7: Rank for BPMT alternatives selected

Business process modelling tool alternatives	Overall Weights	Rank
Process Maker	0.34	2nd
Microsoft Visio	0.41	1st
Savvion Process Modeler	0.25	3rd

The results obtained from the AHP demonstration indicates that the Microsoft Visio tool is a high priority and selected for developing a repository of BP. An extensive assessment of the Microsoft Visio tool is discussed in the literature review detailed in chapter two.

The next sub-section demonstrates the selection of an effective BPMT related to developing a simulation model.

4.5.4 Select an effective tool for simulation set-up

The literature review and theoretical framework discussed extensively in previous chapters' details the importance of simulation (stochastic) optimisation method relative to developing the BPOM. The attributes of each simulation approach comprehensively reviewed inspires the selection of the discrete event simulation approach.

This thesis streamlines BPMTs from a detailed list to four with emphasis on the attributes of each BPMT collected from the vendor sites. A fundamental consideration is segregating BPMTs with simulation competence, which supports the discrete event simulation approach. Based on BPMTs set aside and simulation competence criteria defined. A similar AHP scenario demonstrated in the previous section relative to selecting an effective BPMT for developing a repository of BP is employed.

The AHP results indicate and rank the Accuprocess Modeler as a high priority. The results are captured in Appendix A. The Accuprocess Modeler is selected for developing a simulation model related to

developing the BPOM. A detailed assessment of the Accuprocess Modeler is discussed in the literature review presented in chapter two.

4.6 **Summary and conclusions**

Chapter four progress from the research method and design chapter to detail a step-by-step discussion related to developing a conceptual BPOM framework. This chapter discusses the steps, applications, and justifies the selection of the integrated business constituents for developing the business model. The selection of an effective tool for the model developments is demonstrated in this chapter. The results indicate Microsoft Visio tool and Accuprocess Model as effective for developing the business model. The BPOM framework is developed with an emphasis on the 4IR CPS protocols extensively discussed in the literature review. The 4IR CPS benchmarks seek for a collaborative structure of all business constituents selected for developing the business model. The next chapter expands on the step-by-step conceptual BPOM developments to present detailed discussions on the business model implementations. The applications of each BPMT selected is demonstrated.

Chapter 5: Model Implementations

5.1 Chapter overview

The data on model specifications, performance metrics, and input variables are required to measure a model for strategic decisions. Chapter five proceeds from concept and developments to discuss implementations of the model (CPS). The database of each sub-system related to the conceptual BPOM framework is validated. This chapter is structured in four sections captured in Figure 39.

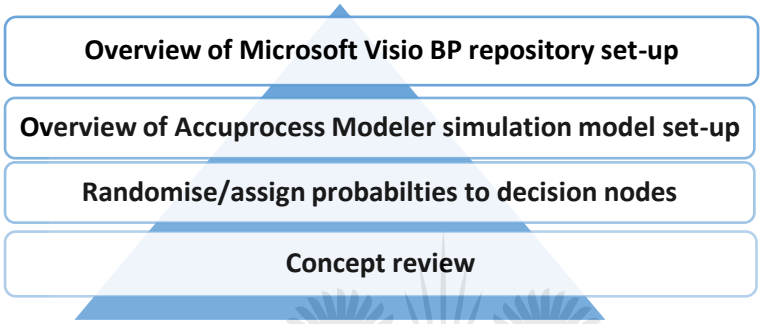


Figure 39: Scope of the Model implementations

Source: (Authors own compilation)

The initial section details and captures an overview of the Microsoft Visio tool selected in chapter four for developing a repository of business processes.

5.2 Overview of the Microsoft Visio tool for BP repository set-up

Chapter four demonstrates the effective selection of the Microsoft Visio tool for developing a repository database of BP. This is accomplished by employing the AHP multi-criteria approach. Based on information collected from the vendor website, Microsoft Visio tool is useful for modelling repository structure of business functions via diagrams, layouts, and charts. The graphics are standardised and configured employing decision blocks, flowcharts, process mapping, and network charts.

The techniques integrated into the Microsoft Visio tool includes process mapping (swim-lane) and flowcharts. Process mapping involves the effective capturing of business processes (Bradford and Gregory, 2015) related to:

(a) What business process steps are executed?

(b) Who executes the business process steps?

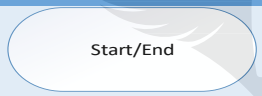
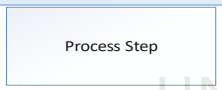
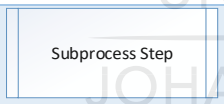
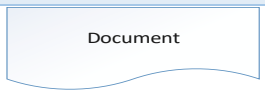
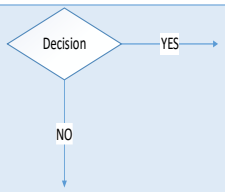
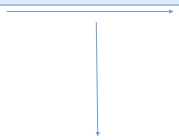
(c) How these business process steps are executed (standards)?

(d) Where each business step is executed (Successes)?

Process mapping use arrows combined with process shapes for capturing business processes. This enables a framework for business process modification and improvements (Beuth, et al., 2018). Swimlane is a process mapping technique for developing a cross-functional sequence of business process steps. The cross-functional sequence segregates business process steps across multiple functional domains of responsibilities.

Flowcharts enable a framework for graphically modelling, assessing, and re-designing business process steps (Laguna, and Johan, 2018). Table 8 captures a brief description of some important Microsoft Visio tool resources.

Table 8: Microsoft Visio tool resources and techniques

S/N	NAME	PROCESS BLOCK	FUNCTION
1	Start/Stop		Employed to initiate the commencement and completion of defined business processes steps.
2	Activity		This Microsoft Visio resource is used to represent and define each business process step.
3	Sub-activity		Employed to represent and define the sub-processes of each business processes step.
4	Document		This Microsoft Visio resource represents documents in a configured business processes steps.
5	Decision-point		The diamond-like Microsoft Visio resource appears with two divisions effective for representing business process decisions. A division defines a no response while the second division indicates a yes response.
6	Connectors		This Microsoft Visio resource business process block is used to link each business process step. The connectors also represent the direction of business process activities.

The step-by-step BP repository development extensively discussed in chapter four is accessed across several benchmarks. As the hierarchy expands from level 0 to 3 the number of business process steps increases. The lower functional levels are dependent on the preceding functional levels. A thin slice overview related to developing the BP repository via the Microsoft Visio tool is discussed in the next sub-sections.

5.2.1 Level 0 (Business area)

The initial step is identifying the level 0 (business area) functional domain. This sub-section presents a thin slice level 0 (business area) from the collaborative BP repository developed. The customer service relationship management, sales & marketing and research & development of new products level 0 (business area) are selected to present demonstrations. The customer service relationship management level 0 (business area) is captured in Figure 40, while Appendix B and C illustrate the sales & marketing and research & development of new products level 0 (business area).

5.2.2 Level 1 (Process group)

The second step is identifying the level 1 (process group) linked to level 0 (business area). This sub-section presents a thin slice level 1 (process group) connected with level 0 (business areas) selected. Figure 40 captures the customer service relationship management level 1 (process group), while Appendix B and C illustrate the sales & marketing and research & development of new products level 1 (process group).

5.2.3 Level 2 (Business process)

The third step is identifying the level 2 (business process) associated with level 0 (business areas) and level 1 (process groups). This sub-section presents a thin slice level 2 (business process) linked with level 0 (business areas) and level 1 (process groups) selected. Figure 40 captures the customer service relationship management level 2 (business process), while Appendix B and C illustrate the sales & marketing and research & development of new products level 2 (business process).

5.2.4 Level 3 (Process Variant)

The fourth step is identifying the level 3 (process variant) aligned with the levels “0 (business area)”, “1 (process group)” and “2 (business process)”. This sub-section presents a thin slice level 3 (process variant) linked with levels “0 (business area)”, “1 (process group)” and “2 (business process)” selected. Figure 41 captures the manage customer service problems inquires, & request subset of the customer

service relationship management level 3 (process variant), while Appendix D and E illustrate the sales & marketing and research & development of new products level 3 (process variant).

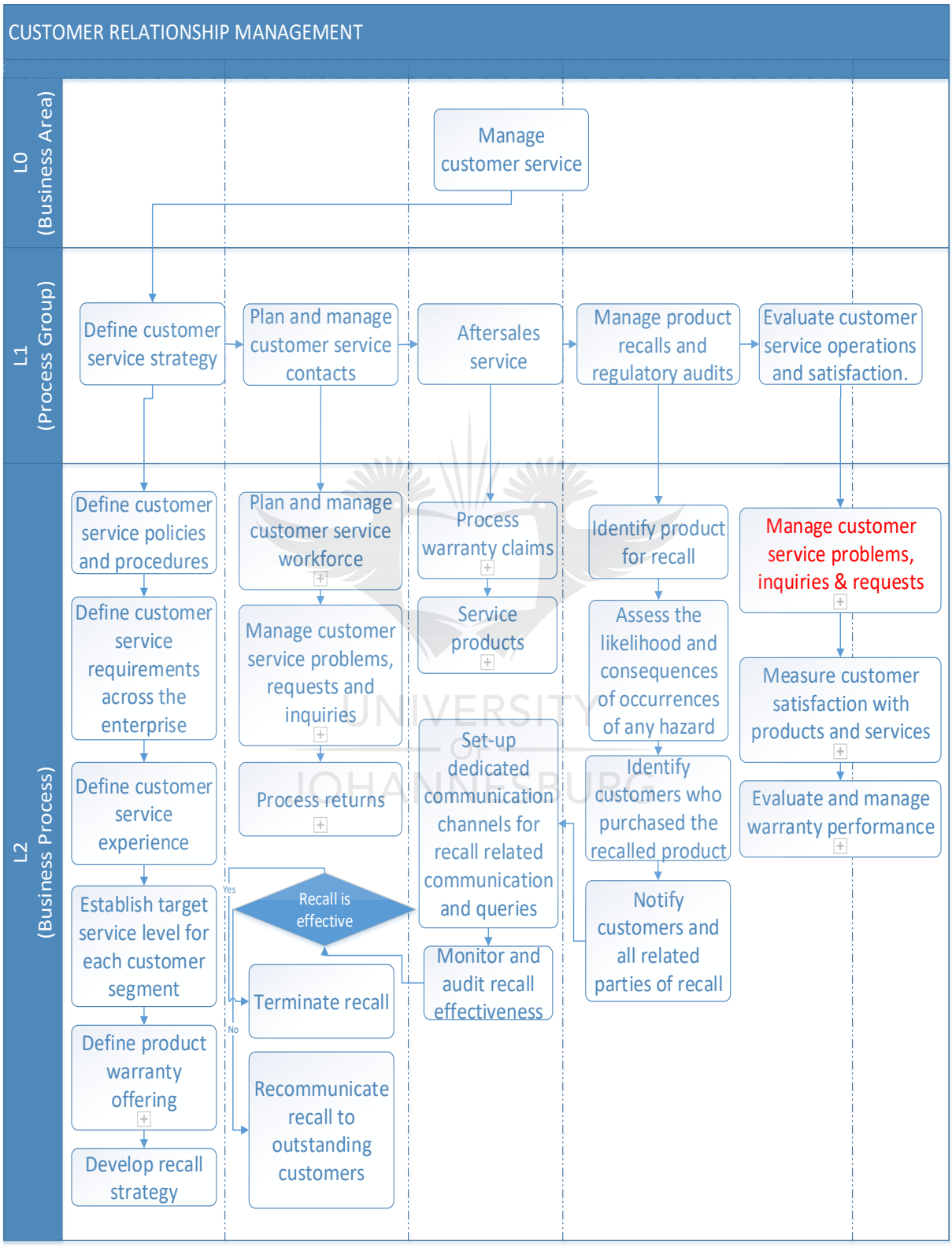


Figure 40: Thin slice customer relationship management levels 0, 1 and 2

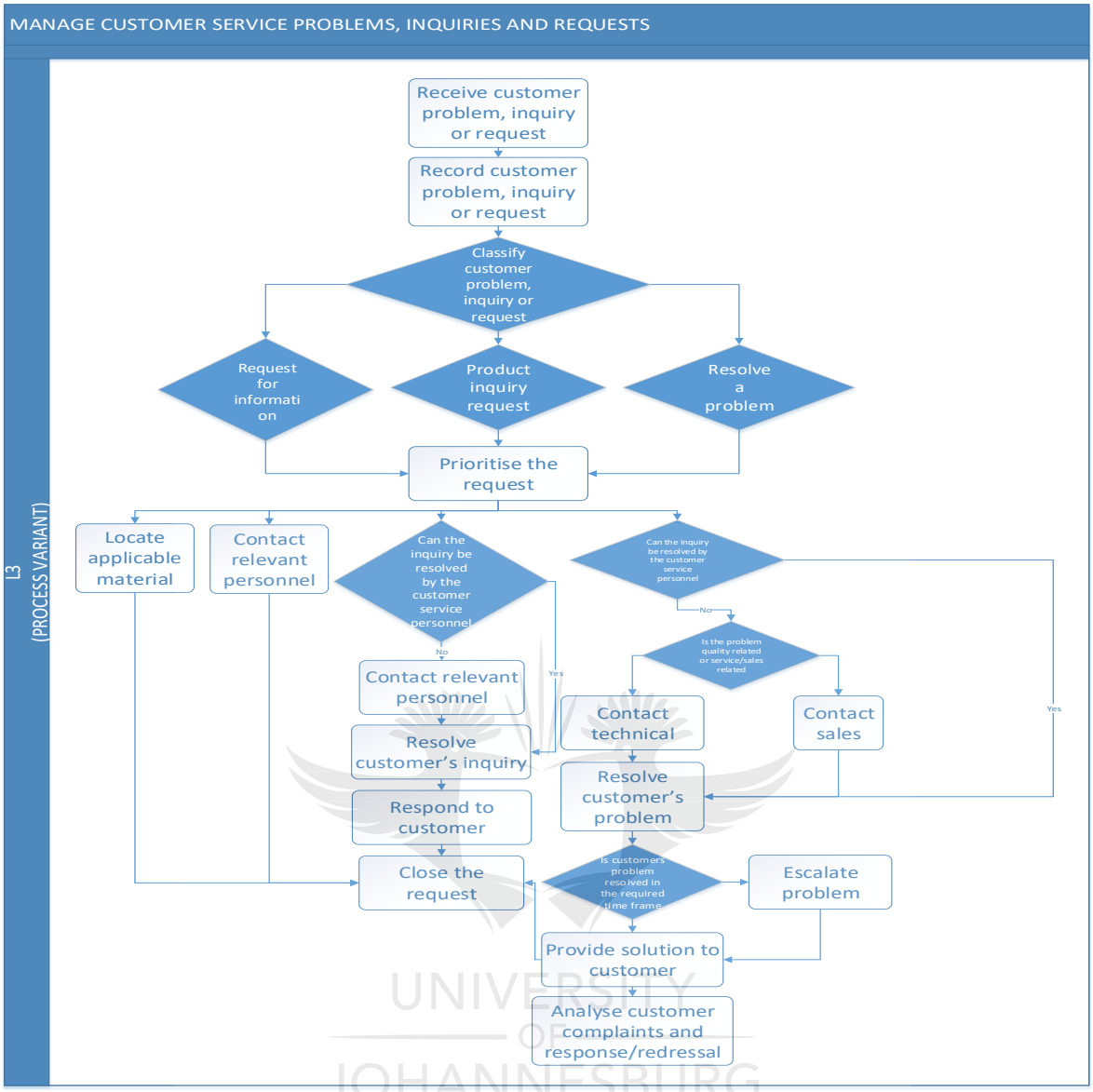


Figure 41: Manage customer service problems, inquiries and requests (level 3)

This thesis develops a collaborative BP repository related to a large global business via the Microsoft Visio tool. The collaborative BP which serve as an effective representation of contemporary multinationals includes customer service relationship management, sales & marketing, research & development of new products, dispatching production units' document control, data collection/acquisition, labour management, quality management, process management, maintenance management, production tracking & genealogy, production analysis, financial accounting, management accounting, human resources, manufacturing, order processing, supply chain management, project management, data services, monitoring & sensing, operations/detail scheduling, marketing, production operations, logistics, security, HSE, inventory management, resource allocation and status.

The collaborative BP repository configured comprises thousands of contemporary multinational BP steps stored in one of the University of Johannesburg servers. A thin slice integrated structure illustrating the collaborative multinational BP repository is captured in Figure 42.

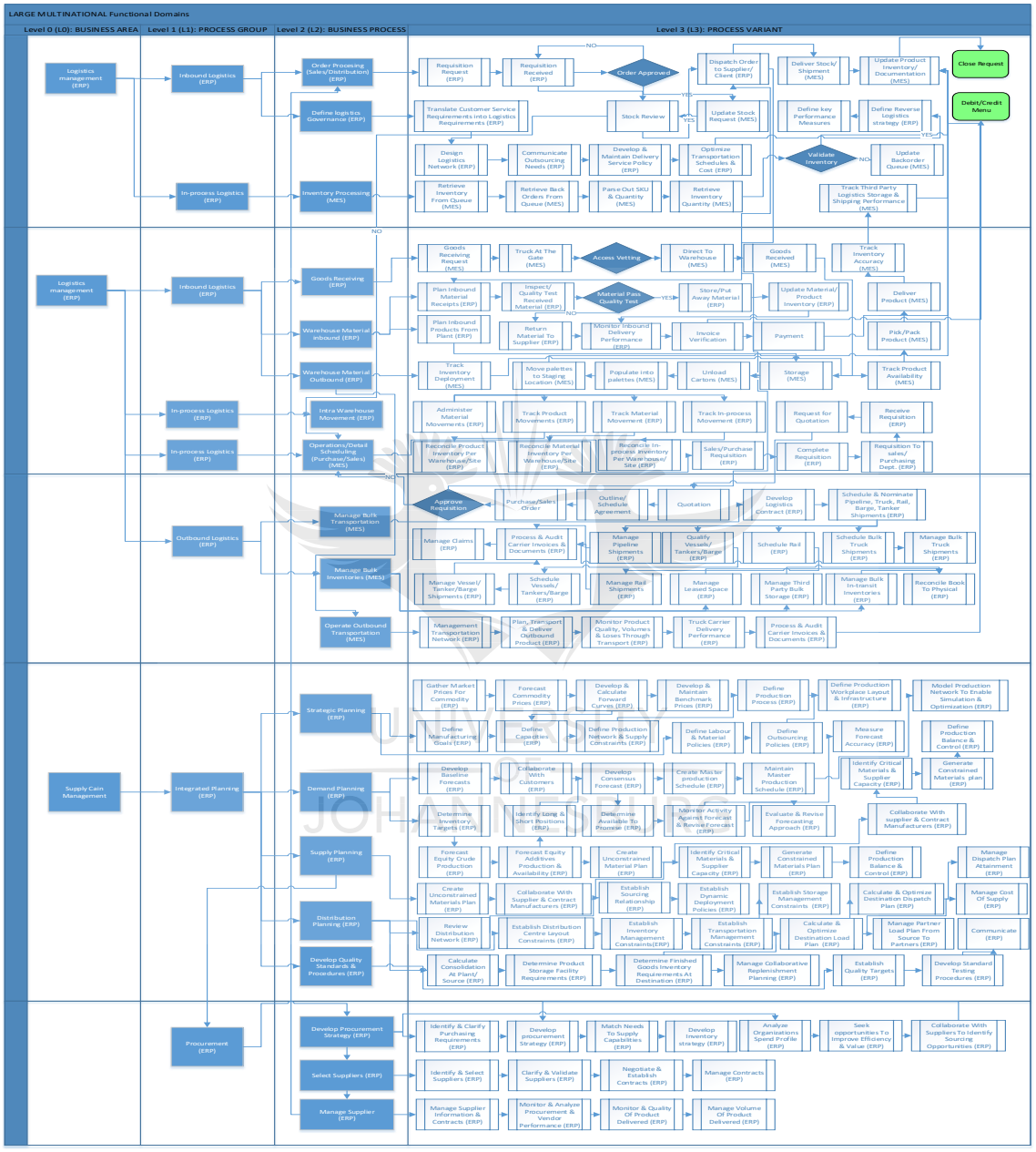


Figure 42: Thin slice collaborative multinational process repository

Appendix F details the collaborative BP repository developed. The collaborative BP repository facilitates a structure for investigating how a variety of BP steps fundamental to business enhancements are modelled, managed, and optimised.

The next section presents discussions related to constituting a simulation model with an overview of the Accuprocess Modeler selected in chapter four.

5.3 **Overview of the Accuprocess Modeler for Simulation model set-up**

Chapter four demonstrates the effective selection of the Accuprocess Modeler accomplished by employing the AHP multi-objective approach. The Accuprocess Modeler is an effective easy-to-use tool deployed by business managers for BP modelling, simulation, and optimisation functions. Accuprocess Modeler is effective for developing, documenting, observing, analysing and simulating business constituents (Papademetriou, and Karras, 2016; Gorevaya, and Khayrullina, 2015; Dwivedi, and Bharti, 2014). The Accuprocess modeler supports the discrete event simulation approach and cost-effective with efficient customer service packages.

Simulation tools are incapable of modelling, simulating, and optimising BP independently (Klee and Allen, 2018). Simulation tools function with mathematical computations, logical specifications, constraints, and business states estimating the final output (Garwood, et al., 2018). The simulation competencies of the Accuprocess Modeler offers analysis resources captured in Figure 43 for investigating the business constituents configured in the model.

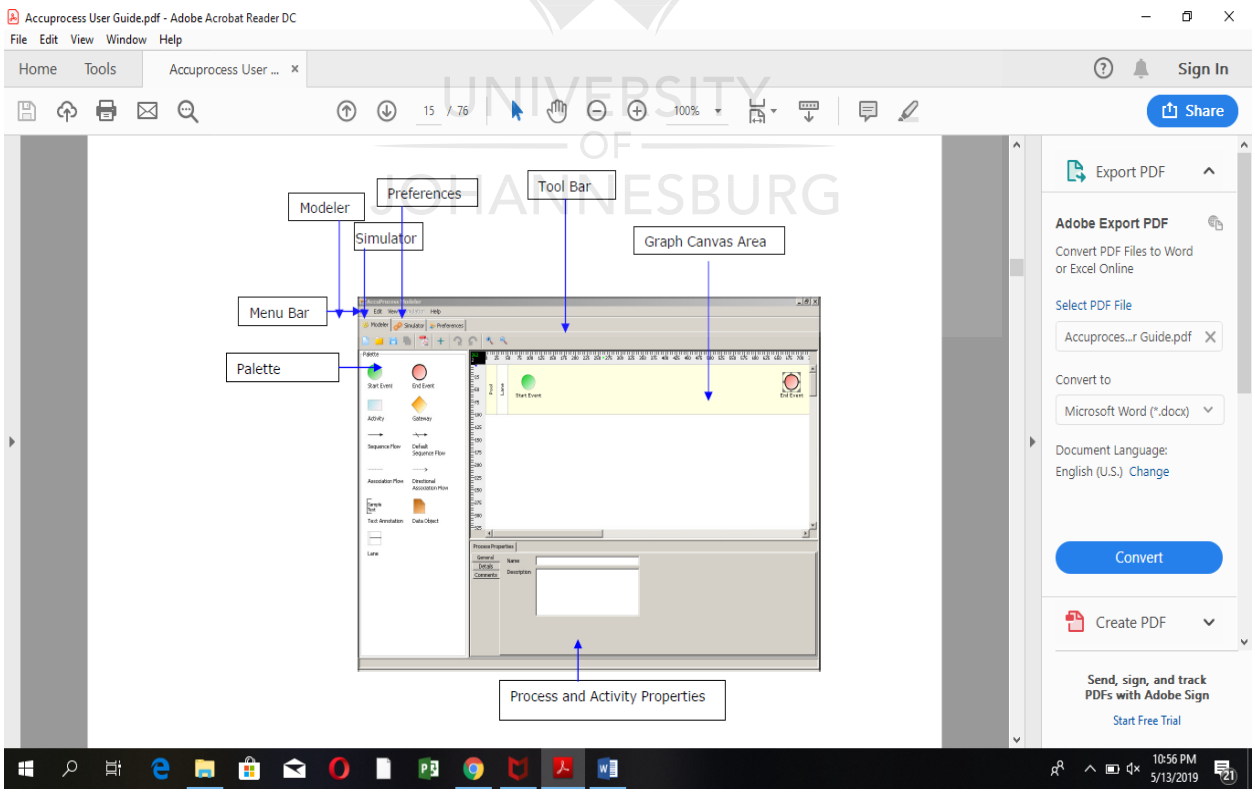


Figure 43: Parameters and resources adapted from Accuprocess user guide

The Accuprocess Modeler is integrated with parameters and resources for defining mathematical computations, logical specifications, constraints and business states. The parameters and resources illustrated in Figure 43 include menu bar; palette; toolbar; graph canvas; simulator; bottom pane; preferences; and Modeler. A brief description of the functionalities related to the parameters and resources integrated with the Accuprocess Modeler is detailed.

(a) Menu bar: The elements of the menu bar include file, edit, help, and view employed for opening a new model application, saving a model, viewing properties of the model, zooming a model application, maximise graph canvas, and exit a model application.

(b) Toolbar: The elements of the toolbar include new, open, save, restore/maximise flow canvas, and zoom used for opening a new model, open an existing model, save currently open process model, restore/maximise graph canvas, and zooming of the graph canvas platform.

(c) Palette: This Accuprocess Modeler resource contains sets of BPMN graphical elements integrated into six panels defined as events, activities, gateways, flows, artefacts, and lanes. The BPMN of each available palette in the Accuprocess Modeler is captured in Figure 44.

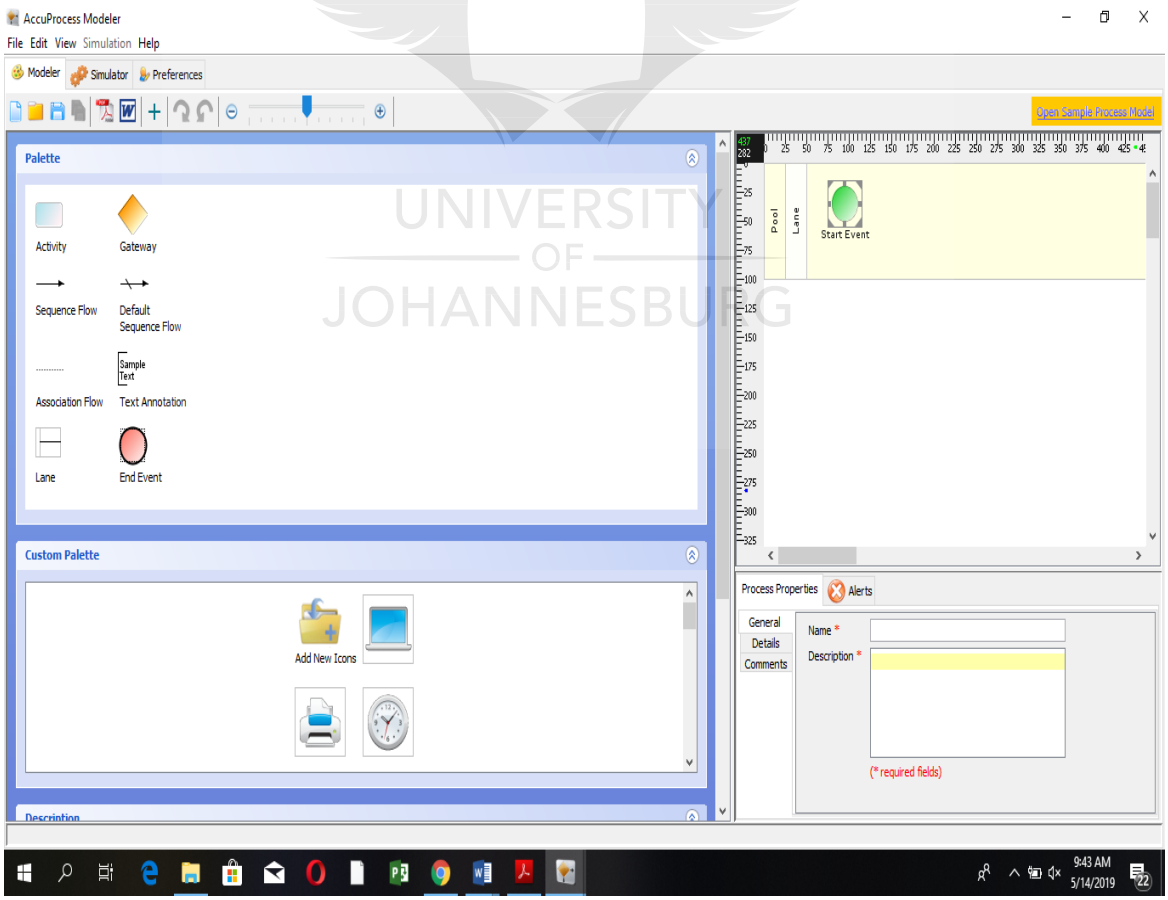


Figure 44: BPMN of each available palette in the Accuprocess Modeler

A synopsis of each palette resource is detailed.

- Events: Consists of incidents that occur during business process executions.
- Activities: Comprises the efforts accomplished within business process executions.
- Gateways: Used to control the convergence and divergence of business process sequence flow.
- Flows: Effective to indicate the order of business process executions. The palette flow notation consists of the sequence flow, association flow, default sequence flow, and directional association flow.
- Artefacts: Used to provide information for the users with no direct effect on business process sequence flow.
- Lanes: Effective to indicate divisions in the pool, which further organise and classify business process activities. The Accuprocess Modeler notations are dragged and arranged in each lane when developing a BPOM flowchart.

(d) Graph canvas: This Accuprocess Modeler constituent facilitates a platform for modelling the business process sequence flow. The platform is effective to model comprehensive business processes related to multinationals. The graph canvas facilitates a framework for assessing which, how, and why each business process is executed, resulting in an output. This Accuprocess Modeler constituent includes a pool integrated with multiple swim lanes for differentiating business process flowchart belonging to a distinct functional level.

(e) Bottom pane: This Accuprocess Modeler constituent is found below the graph canvas platform for documenting and viewing the business process flowchart properties.

(f) Process properties: This Accuprocess Modeler constituent facilitates a framework for integrating and defining a comprehensive list of business process variables investigated in the simulation model.

(g) Activity properties: This Accuprocess Modeler constituent facilitates a framework for describing each activity block in the business process flowchart. This includes but not limited to priority activities, expected time duration, and due time for each activity.

(h) Simulator: This Accuprocess Modeler constituent enables a window displaying tools useful for simulating the developed business processes. These tools are effective to capture, analyse and optimise a modelled business process flowchart. Constituents of the simulator window are captured in Figure 45.

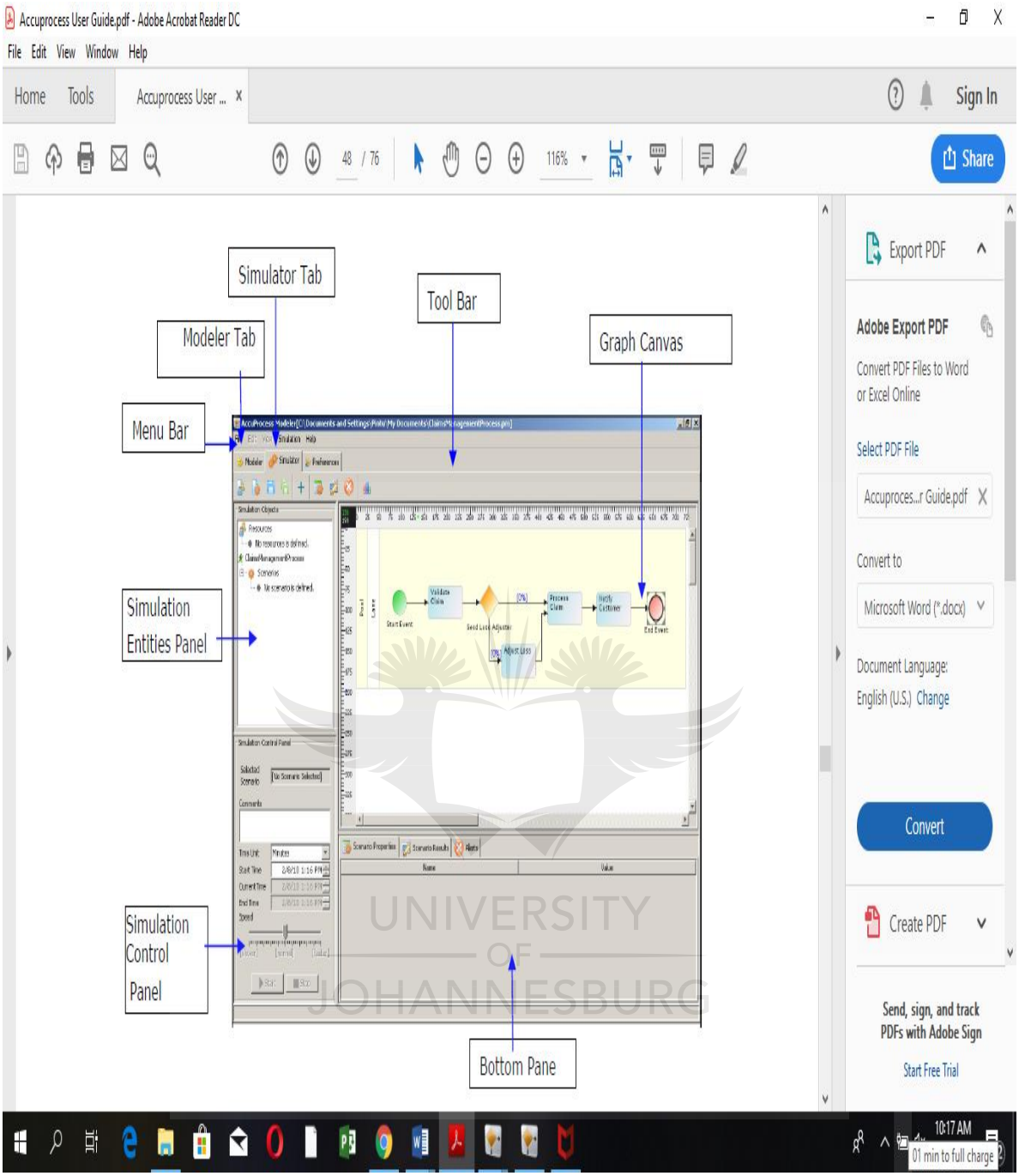


Figure 45: Constituents of the simulator window adapted from Accuprocess user guide

A synopsis of each simulator window constituent is detailed.

- Simulation entities panel: Enables a framework for viewing a defined list of scenarios and resources.
- Simulation control: Facilitates a framework for executing and defining simulation runs conditions inclusive but not limited to start time, current time, end time, and time units.

- Menu bar: Effective to define new scenarios/resources, illustrate scenario properties of the selected activity, demonstrate results of the running scenarios, and generate reports of the executed simulation scenario.
- Graph canvas: Enables a platform where the modelled and selected business process flowcharts are demonstrated during simulation runs.
- Bottom pane: This simulator window resource is integrated with three support panels. The first panel facilitate a framework for viewing scenario properties of the modelled business process flowcharts selected for simulation runs. The second panel facilitate a framework for viewing scenario results obtained from the simulation runs. The third panel display notifications of errors and alerts encountered during simulation runs.

(i) Preferences: This Accuprocess Modeler resource facilitates a platform for users to select and edit the model background, palette, and pool colours. Preferences enable options to select and edit background colours for graphical results obtained from the simulation runs.

Based on constituents of the Accuprocess Modeler detailed, the steps considered in configuring a simulation model for this thesis is captured in Figure 46.

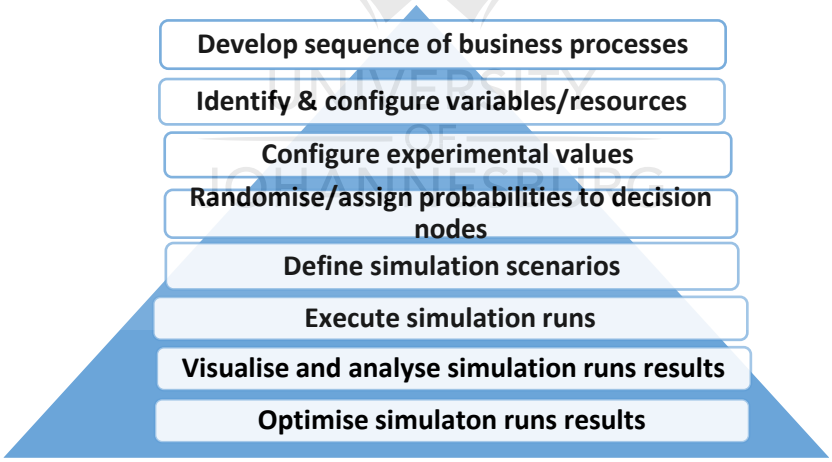


Figure 46: Conceptual steps for configuring and executing the simulation model

The simulation model developed for this thesis centred on steps captured in Figure 46 enables:

- Graphically drag and drop palette tool effective for modelling, assessing, and optimising BP flowcharts.
- Wizard-driven approach for documenting singular and comprehensive activities of a BPOM.

- Sharing, review and archival competence in different best practice formats.
- Wizard-driven tool for defining and developing BPOM variables, scenarios, and resource sets fundamental for executing simulation runs.

A thin slice integrated structure which details the simulation model configured via the Accuprocess Modeler is captured in Figure 47.

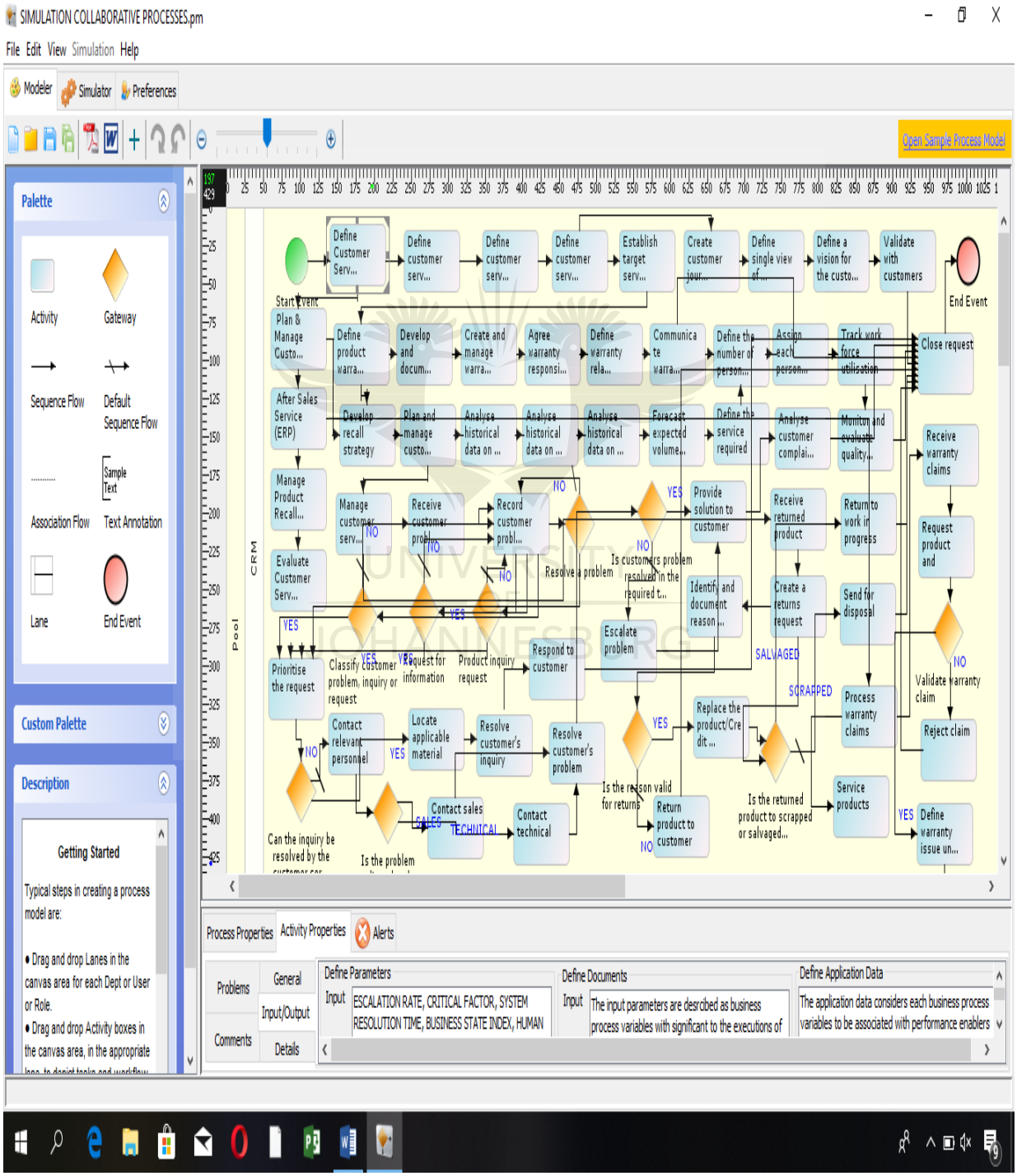


Figure 47: Thin slice simulation collaborative business processes architecture

The detailed simulation model is stored in one of the University of Johannesburg servers. The detailed simulation model developed are captured in Appendix G. The simulation model is configured with BP decision nodes, which determines BP flow based on probabilities. The next section extensively discusses the processes involved in randomising and assigning probabilities to each decision node.

5.4 **Randomise/assign probabilities to decision nodes**

The decision nodes are fundamental in determining the sequence of flow for the configured BP. Probability of an option occurring in a decision node is dependent on precise business conditions at an exact time resulting in complexities in decision-making. Randomising each decision node simplify the complexities in delivering an effective representation of real-world business scenarios and executions.

The decision nodes are randomised via a random number generator comprising different distribution probabilities or algorithm metrics such as Normal, Poisson and exponential distribution algorithm. Applications of the random number generator are driven by two simulation methods which include Monte Carlo and Discrete event simulation approaches.

- **Monte Carlo:** The Monte Carlo simulation approach is employed for repetitive investigations in a deterministic model. This simulation approach is applicable when the model is non-linear, complex, or comprises sets of uncertain parameters. The uncertainty parameters of the Monte Carlo approach results in uncertainty of the model outputs.
- **Discrete event:** The discrete event simulation approach is time-based and applicable when the model is linear. This simulation approach investigates dynamic scenarios of the model executed over time to generate outputs. The outputs present insights and clarity related to each configured decision node.

The selection and justification of the discrete event approach as a fundamental simulation method related to addressing objectives defined in this thesis are extensively discussed in previous chapters. To evaluate the randomness of each decision node configured in the simulation model. The discrete event simulation approach is considered for executing a large number of simulation runs. This results in sets of probabilities (random numbers).

To determine final sets of baseline probabilities used for the BPOM implementations, the standard deviation (**σ**) statistical approach via Excel is considered. The (**σ**) statistical approach is effective to regulate a suitable number of simulation runs suitable to decide final sets of baseline random numbers. This thesis considers ten discrete-event simulation runs set at a "2**σ**" (95%) statistical significance sufficient for evaluating final sets of baseline probabilities.

The ten discrete event simulation runs is considered appropriate after undertaking incremental iterations, with mean analysis of business response time (hours) calculated at each run. Each run is executed from the collaborated BP flow configured in the simulation model. The results collected from the mean and standard deviation of the simulation runs are captured in Appendix H. Figure 48 capture the bell curve of mean response times (hours) set at "2**σ**" (95%) statistical significance delivering the final sets of baseline random numbers input into the decision nodes.

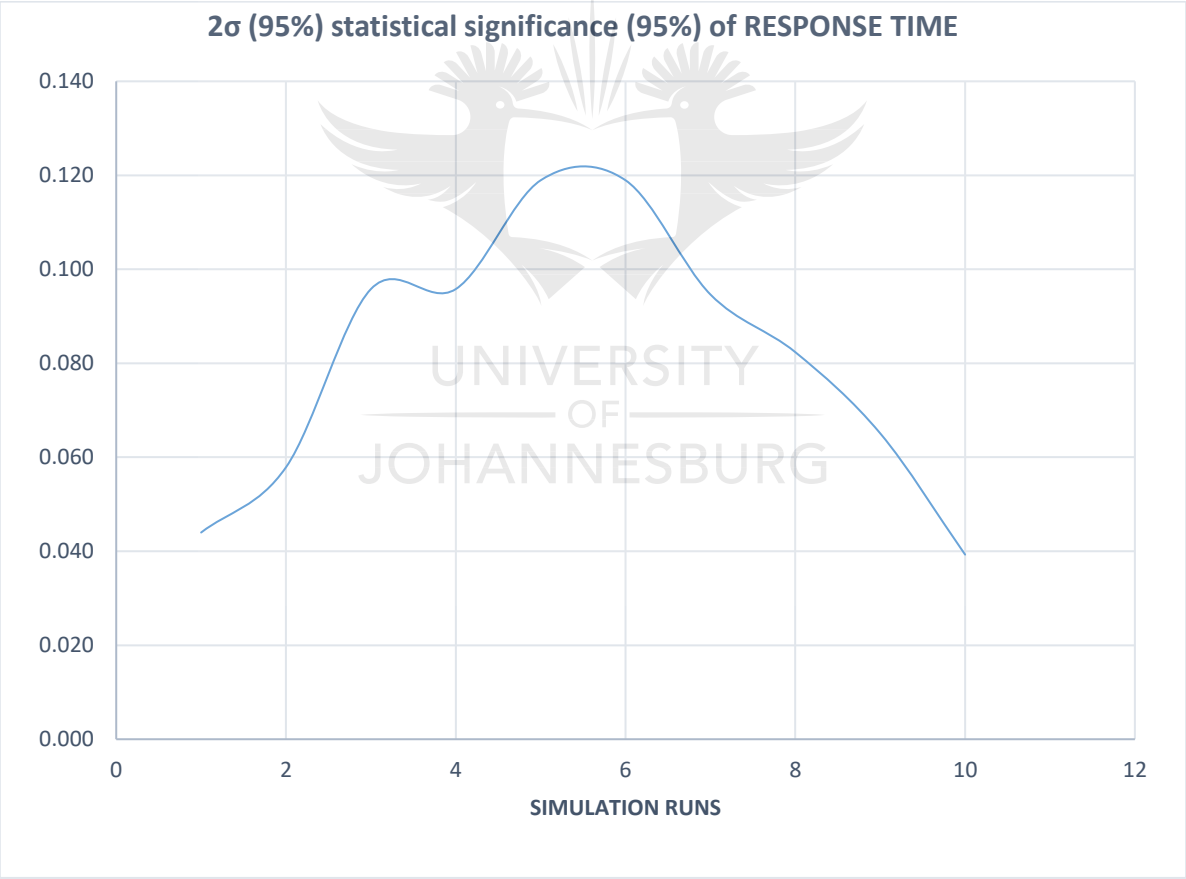


Figure 48: Bell curve for total business response time measured in hours

The next section details a conceptual review of the underlying DOE and simulation experimental conditions.

5.5 Concept review

The DOE and simulation model is effective and functional but is incapable of delivering the desired output at a defined performance level independently (Lawler, 2018 and Grigoryev, 2015). This section details a concept review to expatiate on the experimental conditions and numeric values associated with applications of the DOE and simulation optimisation approaches. The justification for selecting both optimisation approaches is comprehensively discussed in previous chapters. The concept review initiates with a discussion on defined experimental conditions detailed in the next sub-section.

5.5.1 Define experimental conditions

The experimental conditions related to applications of the DOE and simulation optimisation approaches are detailed.

(a) The experimental scenarios are tested set at the least number of experimental runs essential to result in an output.

(b) The experimental runs seek statistical confidence of (95% ≤ V ≤ 100%) for BPV effects and interactions.

(c) The simulation output for all experimental scenarios is investigated at a 30 days' execution period. The collaborative BP flow consists of thousands of process steps executed in order of magnitude, sequence, and requires multiple simulations runs. This thesis considers a daily estimation (24hours) in executing the complex BP sequence steps as insufficient. A yearly estimation (8760hours) seems extreme as it becomes rather accumulated with intense hours. This thesis settles in-between a daily and yearly estimations, considering a 30 days' execution period to accomplish each BP sequence steps cycle. A 30 days' execution period is prepositioned appropriate when configuring the simulation model after reliability testing of numerous intermediate range of options.

(d) Three-factor business states (+0.1, 0, -0.1) set at "maximum", "normal" and "minimum" is defined. The normal values represent the standard state and used for comparison between the maximum and minimum intermediate range of options. At the initiation of each simulation run, the business state is set at normal. The scenario building parameter a constituent in the simulation model is adjusted to a defined business state (maximum or minimum) for each experimental scenario investigated.

(e) Each simulation run results in total business turnaround time output (hours) for distinct BP sequence steps cycle set at a defined experimental scenario condition. This is considered as a collective response for the DOE and simulation model.

The subsequent concept review defines ranges of experimental values after reliability testing of numerous intermediate range of options. This is detailed in the next sub-section.

5.5.2 Experimental values

The experimental values related to applications of the DOE and simulation optimisation approaches are detailed. To select and standardize the reliability testing of numerous intermediate range of options, a reliability testing is accomplished with emphasis on the fundamentals of the DOE techniques and numerous simulation trials. The results collected from the reliability testing of numerous intermediate range of options is captured in Appendix I. The results illustrate each BPV associated with defined performance enablers and numeric metrics.

5.6 Summary and conclusion

Chapter five detail applications of the BPOM (CPS). The database of each sub-system in the business model is validated with thin-slice demonstrations of the BP repository (Microsoft Visio tool), and the simulation model (Accuprocess Modeler). This chapter successfully details steps undertaken to randomise and assign probabilities relative to decision nodes configured in the simulation model. This chapter concludes with a concept review which expatiates on the experimental conditions and values associated with the DOE and simulation optimisation approaches. The next chapter advances to test, optimise and validate the developed BPOM (CPS).

Chapter 6: Model Optimisation

6.1 Chapter overview

Optimisation is a crucial factor for model developments to validate the intended functions of the tool. This is accomplished with real data for comparative statistical analysis of the outputs in comparison with historical strategic alternatives identified. The optimisation scenarios assess, analyse and visualise strategy variations to ease uncertainties on how a change can impact the behaviour of the model. Chapter six details the model (CPS) validation through experimental protocol testing effective for conducting a comparative statistical analysis. This chapter aims to extract outputs from the optimisation scenario to develop a singular equation effectively representing the business response for variables impacting operations. Chapter six is structured in three sections captured in Figure 49.

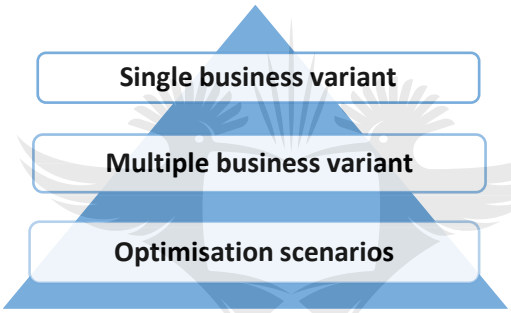


Figure 49: Scope of the Model optimisation

Source: (Authors own compilation)

This chapter details the quantification baseline demand for operations of a multinational. This is accomplished from a singular full set combination equation of BPV delivering optimum business demand on single and combined impacts of BPV. The optimal state enables minimal operational business implementations. The DOE and simulation optimisation approaches comprehensively discussed in previous chapters is applied for validating the BPOM (CPS).

The DOE and simulation optimisation methods are employed to test, simulate, and optimise the levels of importance of each BPV (factor) in the BPOM (CPS). The DOE experimental investigations are defined with either or both the full and fractional factorial techniques. An assessment of steps used in the full and fractional factorial techniques is extensively discussed in chapter two.

Selecting either or both factorial technique is dependent on the number of BPV associated with experimental conditions and numeric metrics constituted in the DOE, and simulation model.

Considering the number of BPV, a full factorial investigation for individual factor results in (6.40E+15) number of experimental runs. This thesis initiates the next section proposing the fractional factorial techniques as potentially effective to streamline the number of experimental runs.

6.2 Single business variant (λ_1)

The single business variant experimental scenario develops a predictive DOE factorial model for investigating BPV effects in single associations. The potential effectiveness of the DOE fractional factorial method to screen a segment of the total combinations, resulting in minimal experimental runs is detailed in chapter two. The discussions establish the applicability of the Taguchi fractional factorial DOE methods.

The effectiveness of the Taguchi fractional factorial DOE method for screening a segment of the total combinations is well-established in emerging publications relative to manufacturing, industrial experiments, biotechnology and engineering (Jaharah, et al., 2013; Romero-Villafranca, et al., 2007; Sorana and Lorentz, 2007). The viability of the Taguchi fractional factorial DOE method is supported by the Minitab statistical software (Kumar, 2017). This thesis undertakes the single business variant investigations with an emphasis on the Taguchi fractional factorial steps captured in Figure 28.

6.2.1 Define factors (input & response) and select a fixed number of trial levels

Factor levels result in n1 levels of factor 1, n2 levels of factor 2 and so on. The factorial design is thus n1 * n2 * … * ni (where i = infinity). Eighteen business process variables are constituted in the DOE, and simulation model. This thesis segregates the eighteen business process variables to fifteen uncontrolled factors and two controlled factors for investigation.

(a) Escalation rate and critical factor BPV are combined as a unit for investigation. Critical factor BPV states have a significant impact in determining the escalation potential of each BP steps.
(b) Human resource resolution time and skills BPV are configured as controlled factors for developing the simulation model. Skills BPV specific to this thesis operationalises the varying level of time responsiveness of the human resource resolution time BPV.

The conditions detailed results in modified experimental values captured in Table 9 with emphasis on the three business states (-0.1, 0, +0.1) and two-factor levels.

Table 9: Experimental values for investigation

Source: (Authors own compilation)

ACRONYM	FACTORS	LOW LEVEL (-)	NORMAL (N)	HIGH LEVEL (+)
A	Environmental Technologies	0.20	0.50	0.80
B	Data/Inventory	0.35	0.68	1.00
C	Escalation Rate/Critical Factor	1.50	0	5.10
D	Change	0.50	0.75	1.00
E	Integration	0.80	1.00	1.20
F	Efficiency/Energy	1.00	1.20	1.40
G	Business State Index	1.00	1.20	1.40
H	Value Chain Design	0.35	0.68	1.00
I	Completeness of Process	0.50	0.75	1.00
J	System Maturity Index	0.80	1.00	1.20
K	Cost	1.00	1.20	1.40
L	Monitor	0.50	0.75	1.00
M	System Resolution Time	1.00	1.05	1.10
N	Standard & Non-standard	0.80	1.00	1.20
O	Automation	0.80	1.00	1.20

6.2.2 Select an effective orthogonal array and assign treatment combinations

Taguchi established eighteen standard orthogonal arrays dependent on the number of factors levels defined. The eighteen standard orthogonal arrays can be modified when developing a complicated design. The columns in an orthogonal array represent the maximum number of factors while the rows define the number of experiments. The Minitab statistical software supports fractional factorial designs related to defining and selecting an optimal orthogonal array for investigations (Kumar, 2017). Based on three business states and two-factor levels defined, the **L16 2^15** Taguchi orthogonal array is selected. The **L16 2^15** Taguchi orthogonal array indicates a total of fifteen BPV (uncontrolled factors) and two BPV (controlled factors) at two-factor level settings with sixteen experimental rows

The full-set combination of business process variables might not have been investigated in the selected orthogonal array. The orthogonality of the Taguchi fractional factorial method limits these complexities. The columns of any defined orthogonal array are mutually orthogonal supporting detailed combinations of factor levels for any pair of the column, which occurs simultaneously. The **L16 2^15** Taguchi orthogonal array selected adapted from (Sorana and Lorentz, 2007) is captured in

Table 10. The "+" and "-" sign indicated in the orthogonal array corresponds to the level and treatment combinations each BPV investigated is held for a distinct experimental run.

6.2.3 Conduct experiments (simulation runs) based on factor levels

The experimental input values for each treatment combinations level are obtained from experimental values captured in Table 9. The simulation responses (Ω) measured in hours obtained via the Accuprocess Modeler defined for each level are captured in Table 10.

Table 10: Taguchi L16 orthogonal array and simulation responses for each level

LEVEL	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Simulation responses (Hrs)
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	650.00
2	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	634.10
3	-	-	-	+	+	+	+	-	-	-	-	+	+	+	+	644.50
4	-	-	-	+	+	+	+	+	+	+	+	-	-	-	-	627.90
5	-	+	+	-	-	+	+	-	-	+	+	-	-	+	+	539.90
6	-	+	+	-	-	+	+	+	+	-	-	+	+	-	-	582.80
7	-	+	+	+	+	-	-	-	-	+	+	+	+	-	-	573.90
8	-	+	+	+	+	-	-	+	+	-	-	-	-	+	+	577.90
9	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	569.90
10	+	-	+	-	+	-	+	+	-	+	-	+	-	+	-	568.10
11	+	-	+	+	-	+	-	-	+	-	+	+	-	+	-	583.50
12	+	-	+	+	-	+	-	+	-	+	-	-	+	-	+	567.50
13	+	+	-	-	+	+	-	-	+	+	-	-	+	+	-	635.20
14	+	+	-	-	+	+	-	+	-	-	+	+	-	-	+	631.80
15	+	+	-	+	-	-	+	-	+	+	-	+	-	-	+	634.10
16	+	+	-	+	-	-	+	+	-	-	+	-	+	+	-	643.50

6.2.4 Determine the full-set combinations of BPV

This step quantifies the main effects of individual BPV focus on simulation responses captured in Table 10. Based on data obtained from the Minitab statistical software, the minimal full-set combination related to BPV mean effects is **[$A_{L2}B_{L1}C_{L2}D_{L2}E_{L1}F_{L1}G_{L1}H_{L1}I_{L2}J_{L1}K_{L1}L_{L2}M_{L2}N_{L1}O_{L1}$].** This does not constitute one of the rows in the Taguchi L16 orthogonal array captured in Table 10. The orthogonality of the Taguchi fractional factorial method indicates this combination as yielding the minimal full-set mean effects combinations.

The Minitab statistical software supports confirmatory testing and analysis for the minimal full-set mean effects combinations. A confirmatory assessment is essential when the minimal full-set mean effects combinations do not constitute one of the rows in the selected orthogonal array. The two confirmatory tests supported is detailed.

(a) A theoretical calculation ($\Omega_{optimum}$) can be undertaken for the minimal full-set mean effects combinations based on the equation: $(\Omega_{optimum})^2 = 10^{-Xopt/10}$.
(b) Validity calculations from the range within which the optimum combination response is established. This is defined at the end of the Taguchi fractional factorial DOE experiment.

6.2.5 Calculate analysis of variance

An Analysis of Variance (ANOVA) table is developed to estimate the Sum of Squares (SS), Degree of Freedom (DOF), variance, p-values, and f-ratio set at a 95% statistical significance confidence for the main effects. The ANOVA analysis can, however, be calculated manually with the formulae adapted from the literature (Rees, 2018).

- Sum of squares due to factor A = $3(M_{A1} - M)^2 + 3(M_{A2} - M)^2 + 3(M_{A3} - M)^2$. This applies to every detailed BPV investigated.
- Variance = (Sum of Squares due to a factor) / (DOF of that factor).
- F-value for a factor = (Variance of that factor) / (Error variance).
- % contribution of a factor = (Sum of squares due to that factor) / (Total sum of squares) * 100.

This thesis incrementally varies the percentage contribution of individual BPV effects set at 80% model response for the ANOVA calculations. Based on the incremental scenario trials set at 80% model response. This thesis limits the optimum significant level at P ≥ 4%. A P ≥ 4% optimum level limit is considered appropriate for investigation with the potential to effectively represent comprehensive sets of business process variables.

The points aligning with statistically control limits delivers a representative model for the investigation. The DOF of a two-factor level is obtained by subtracting one from the number of levels of each factor. If the actual F-value (calculated) exceeds the critical F-value (statistical table) at an acceptable risk value, the null hypothesis is insignificant. The results obtained from the ANOVA calculations are captured in Table 11 indicated as significant (✓) and insignificant (**X**) for BPV effects.

Table 11: Analysis of variance data

BPV	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
P	2.4	1.4	17.8	0.5	13.8	4.6	5.8	0.3	2.5	16.9	4.5	1.2	3.3	1.5	17.4
P ≥ 3%	X	X	✓	X	✓	✓	✓	X	X	✓	✓	X	X	X	✓

6.2.6 Interpret results

This step interprets the results collected from the mean effects and ANOVA data of responses. This is accomplished via a Pareto chart, an integral constituent of the Minitab statistical software. The inferences established ranks the BPV investigated at either maximum or minimum relative to the mean effects. The results are captured in Figure 50 and Table 12.

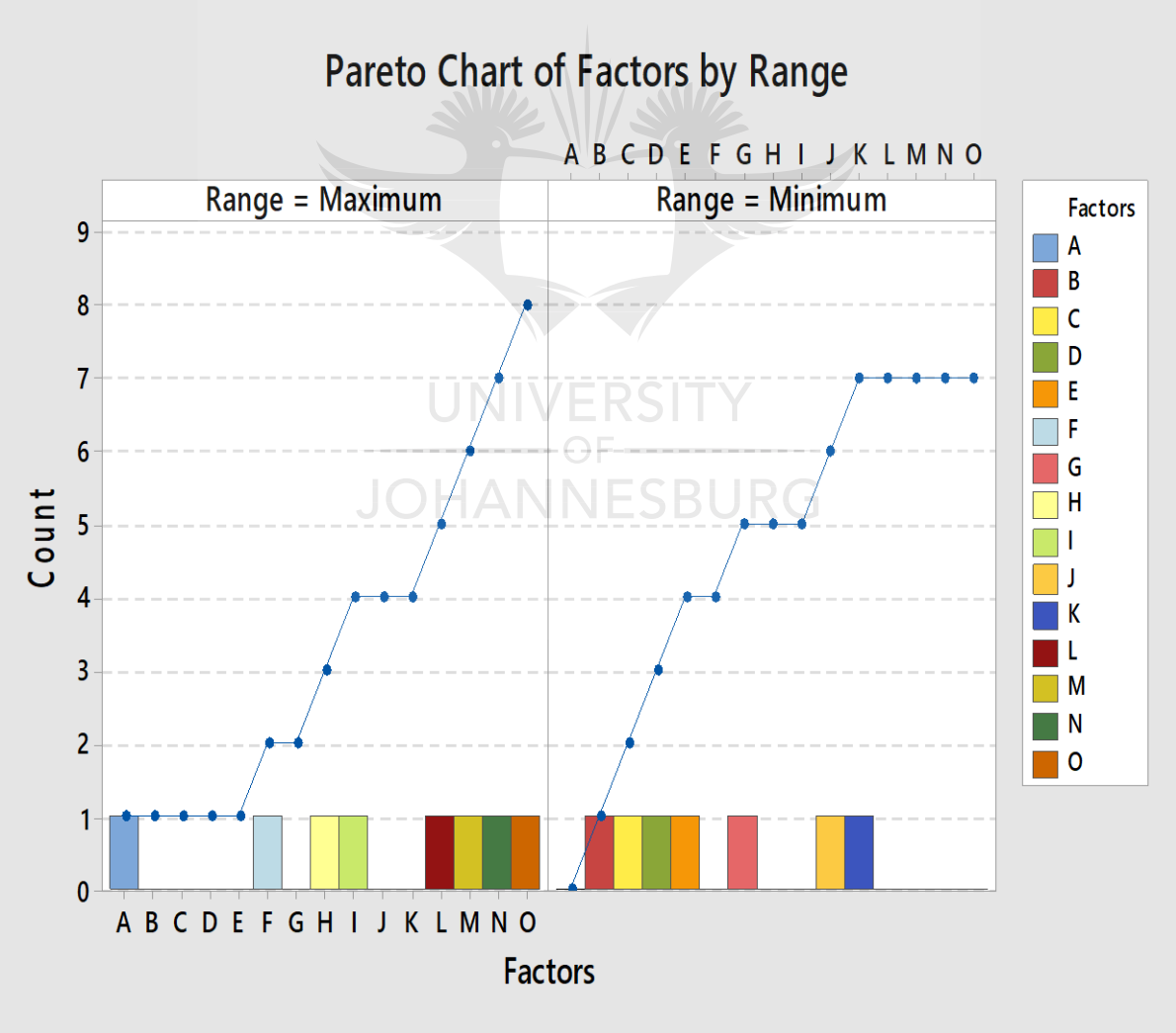


Figure 50: Pareto chart of factors by range (λ_1)

Table 12: Single business process variable ranking (λ_1)

ACRONYM	BUSINESS PROCESS VARIABLES	RANK
C	Escalation/Critical Factor	1
O	Automation	2
J	System Maturity Index	3
E	Integration	4
G	System Resolution Time	5
F	Efficiency/Energy	6
K	Cost	7
M	Business State Index	8
I	Completeness of Process	9
A	Environmental Technologies	10
N	Standard & Non-Standard	11
B	Data/Inventory	12
L	Monitor	13
D	Change	14
H	Value Chain Design	15

A representative business model response (μ_1) for the (λ_1) investigations set at ($P \geq 4\%$) is obtained from the Minitab statistical software and detailed.

$[(\mu_1) = 604.16 - 13.80C - 12.18E - 7.05F - 7.91G - 13.47J - 6.96K - 13.66O]$.

A validity testing of the single representative model outputs is undertaken. The validity testing involves comparing the simulation responses (Ω) and the model response (μ_1) at each iteration level defined. The validity results obtained are captured in Table 13.

Table 13: Validity testing of model outputs (λ_1)

LEVEL	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Ω (Hrs)	μ_1(Hrs)	Model Validity
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	650.00	518.17	**80%**
2	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	634.10	503.38	**79%**
3	-	-	-	+	+	+	+	-	-	-	-	+	+	+	+	644.50	517.08	**80%**
4	-	-	-	+	+	+	+	+	+	+	+	-	-	-	-	627.90	499.18	**79%**

5	-	+	+	-	-	+	+	-	-	+	+	-	-	+	+	539.90	426.28	**79%**
6	-	+	+	-	-	+	+	+	+	-	-	+	+	-	-	582.80	461.28	**79%**
7	-	+	+	+	+	-	-	-	-	+	+	+	+	-	-	573.90	454.28	**79%**
8	-	+	+	+	+	-	-	+	+	-	-	-	-	+	+	577.90	458.18	**79%**
9	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	569.90	450.98	**79%**
10	+	-	+	-	+	-	+	+	-	+	-	+	-	+	-	568.10	455.08	**80%**
11	+	-	+	+	-	+	-	-	+	-	+	+	-	+	-	583.50	462.88	**79%**
12	+	-	+	+	-	+	-	+	-	+	-	-	+	-	+	567.50	453.58	**80%**
13	+	+	-	-	+	+	-	-	+	+	-	-	+	+	-	635.20	503.88	**79%**
14	+	+	-	-	+	+	-	+	-	-	+	+	-	-	+	631.80	502.28	**79%**
15	+	+	-	+	-	-	+	-	+	+	-	+	-	-	+	634.10	504.18	**80%**
16	+	+	-	+	-	-	+	+	-	-	+	-	+	+	-	643.50	510.98	**79%**

This section employs the Taguchi fractional factorial DOE method for effectively screening the BPV configured in the DOE, and simulation model, resulting in a segment of the total combinations.

A validity testing of the results obtained from the single business variant (λ_1) investigations indicates **(79% ≤ V ≤ 80%)** validity output. This facilitates further investigations aimed at statistical confidence of **(95% ≤ V ≤ 100%)** for BPV effects and interactions. This is extensively discussed in the next section.

6.3 **Multiple business variant scenarios**

The multiple business variants experimental scenario develops a predictive DOE (statistical) factorial model for investigating BPV effects in multiple associations. The significant BPV set at a (P ≥ 4%) obtained from the (λ_1) investigations serve as an effective model representation of the BPV in single associations. Based on the number of significant BPV obtained from the (λ_1) investigations, the full factorial DOE method is considered potentially suitable for the multiple business variant instances.

The significant BPV include “C = Escalation/Critical Factor”, “E = Integration”, “F = Efficiency/Energy”, “G = Business State Index”, “J = System Maturity Index”, “K = Cost”, and “O = Automation”. The seven (7) significant BPV results in combinations of (λ_2), (λ_3), (λ_4), (λ_5), (λ_6), and (λ_7) Factor Interactions (FI). The next sub-section initiates with the (λ_2) FI investigations centred on the full factorial steps captured in Figure 27.

6.3.1 Multiple business variant: two at a time (λ_2)

Step 1: Twenty-one possible (λ_2) FI combinations are defined, which includes CE, CF, CG, CJ, CK, CO, EF, EG, EJ, EK, EO, FG, FJ, FK, FO, GJ, GK, GO, JK, JO, and KO. The full factorial approach is prepositioned as potentially effective as a result of the number of (λ_2) FI combinations of significant BPV.

Step 2: Calculate the effects of each (λ_2) FI centred on the treatment combinations and simulation response time (hours) obtained from the fractional factorial investigations. The effects of (λ_2) FI are captured in Appendix J.

Step 3: This step categorises the absolute value (data points) of the twenty-one (λ_2) effects. The cumulative probability values (Pi) is then calculated from a defined statistical formula. This involves dividing the 0 to 100% cumulative probability scale into twenty-one equal segments. Based on the data points and (λ_2) FI effects, each segment is estimated at (100/21), which equals 4.76%.

Step 4: This step evaluates if the absolute and cumulative probability values of (λ_2) FI effects obtained from the previous step vary normally. This is investigated via a half-normal plot and Pareto chart of effects. Both graphs facilitate a framework for comparing the relative magnitude of absolute and cumulative probability values of effects, evaluating for statistical significance. If the absolute and cumulative probability values of effects do not vary. The Lenth's method (Lenth's pseudo standard error) a statistical constituent integrated with the Minitab software is effective to determine and draw a reference line representing the statistical significance constituents.

The half-normal plot compares the magnitude of the main and interaction statistical significance effects. The fitted-line establishes the expected points if the absolute effects are zero, with the significant effects varying towards the right direction of the plot. The half-normal plot varies both positive and negative absolute effects. This motivates this thesis in selecting this approach in comparison with the normal plot. The normal plot varies negative absolute effects to the left and positive absolute effects to the right with all the significant effects tending towards the right.

The Pareto chart facilitates a framework for investigating the magnitude and relative importance of the absolute effects by drawing a reference line on the cumulative effects. This distinguishes the statistical and non-statistical effects. The effects **extending beyond the reference line** drawn is considered statistically significant. The Pareto chart outputs are captured in Figure 51.

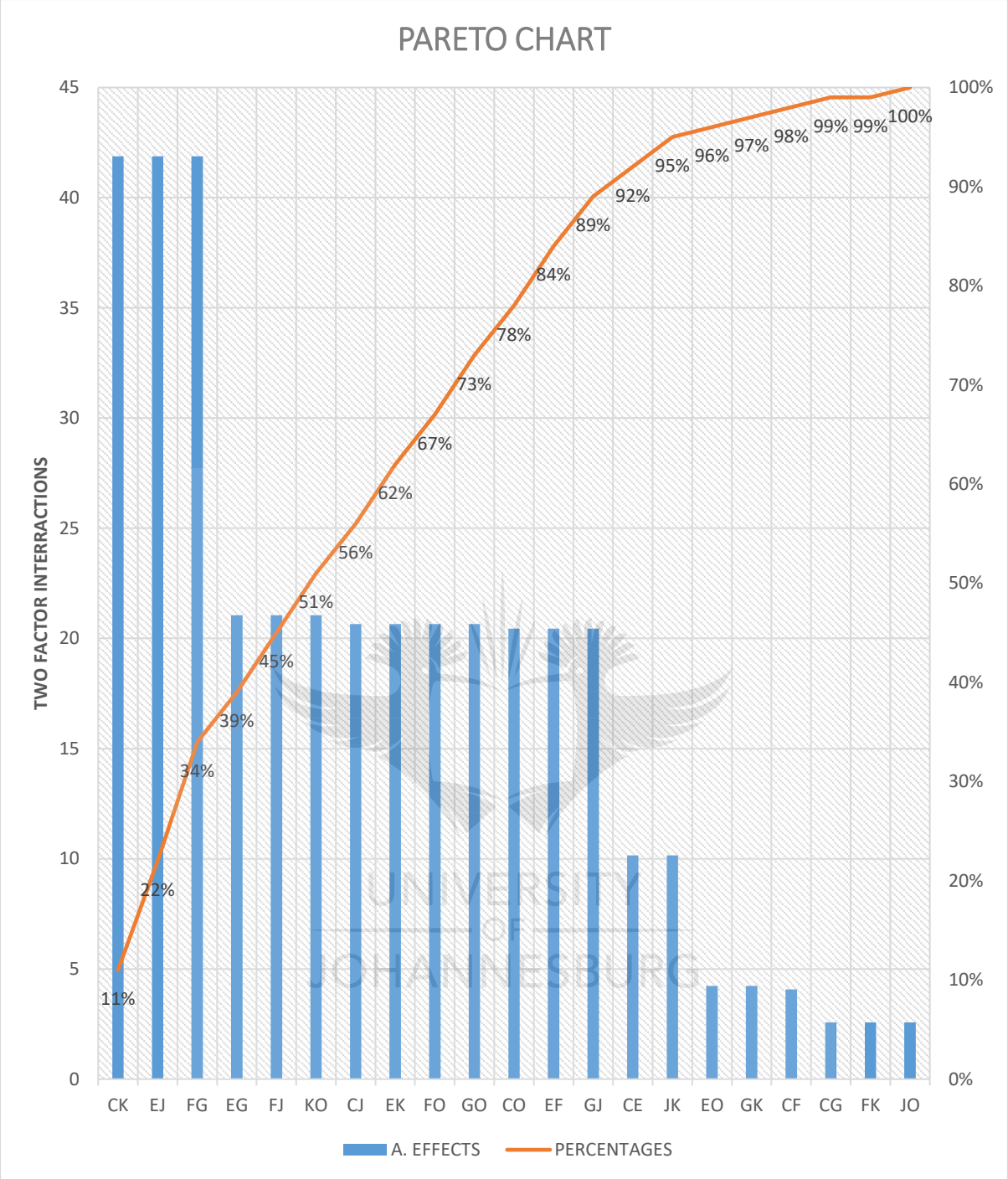


Figure 51: Pareto plot of (λ_2) FI effects

Extraction of data collected from the Pareto and half normal plot investigations indicate cumulative/mean statistically significance related to the (λ_2) FI is **"73.3375".** This is associated with (λ_2) FI **(CK, EJ, FG, and EG) extending beyond the reference line drawn.** A combined business model response (μ_2) related to the (λ_1), and (λ_2) investigations are detailed.

[(μ_2) = 604.16 – 13.80C – 12.18E – 7.05F – 7.91G – 13.47J – 6.96K – 13.66O + 20.90CK + 20.90EJ + 20.90FG + 10.50EG].

A validity testing of the new business model response outputs collected from the (λ_1) and (λ_2) effects is captured in Table 14.

Table 14: Validity testing of the model outputs (λ_2)

(Ω) Hrs	μ_1(Hrs) λ_1	Model Validity (λ_1)	μ_2(Hrs) λ_2	Model Validity (λ_2)
650.00	518.17	**80%**	591.51	**91%**
634.10	503.38	**79%**	576.72	**91%**
644.50	517.08	**80%**	590.42	**92%**
627.90	499.18	**79%**	572.52	**91%**
539.90	426.28	**79%**	499.62	**93%**
582.80	461.28	**79%**	534.62	**92%**
573.90	454.28	**79%**	527.62	**92%**
577.90	458.18	**79%**	531.52	**92%**
569.90	450.98	**79%**	524.32	**92%**
568.10	455.08	**80%**	528.42	**93%**
583.50	462.88	**79%**	536.22	**92%**
567.50	453.58	**80%**	526.92	**93%**
635.20	503.88	**79%**	577.22	**91%**
631.80	502.28	**79%**	575.62	**91%**
634.10	504.18	**80%**	577.52	**91%**
643.50	510.98	**79%**	584.32	**91%**

A validity testing of the results obtained from the (λ_2) investigations indicates **(91% ≤ V ≤ 93%)** validity output. This facilitates further investigations relative to (λ_3) FI aimed at statistical confidence of **(95% ≤ V ≤ 100%)** for BPV effects and interactions. This is extensively discussed in the next sub-section.

6.3.2 Multiple business variant: three at a time (λ_3)

Fifteen possible (λ_3) FI combinations are defined, which includes CEF, CEG, CEJ, CEK, CEO, EFG, EFJ, EFK, EFO, FGJ, FGK, FGO, GJK, GJO, and JKO. A similar scenario demonstrated with the (λ_2) FI investigations is adapted for the (λ_3) FI inquiries. The (λ_3) FI effects are captured in Appendix K, while the Pareto plot outputs are captured in Figure 52.

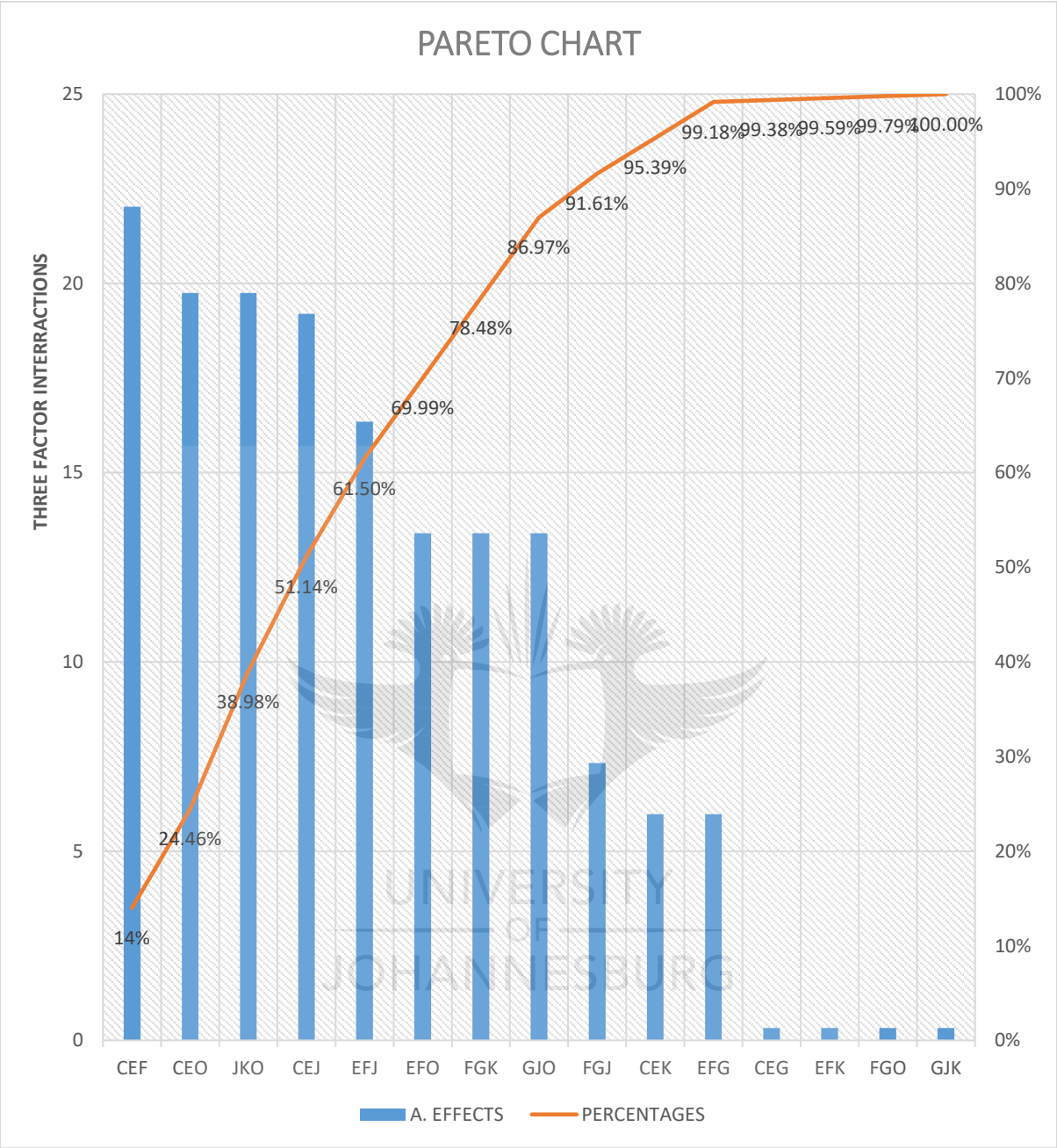


Figure 52: Pareto plot of (λ_3) FI combinations

Extraction of data collected from the Pareto and half normal plot investigations indicate cumulative/mean statistically significance related to the (λ_3) FI is **"48.5375"**. This is associated with (λ_3) FI **(CEF, CEO, JKO, CEJ, and EFJ) extending beyond the reference line drawn.**

A combined business model response (μ_3) related to the (λ_1), (λ_2), and (λ_3) investigations are detailed.

[(μ_3) = 604.16 – 13.80C – 12.18E – 7.05F – 7.91G – 13.47J – 6.96K – 13.66O + 20.90CK + 20.90EJ + 20.90FG + 10.50EG + 11.00CEF + 9.90CEO + 9.90JKO + 9.60CEJ + 8.20EFJ].

A validity testing of the new model outputs collected from the (λ_1), (λ_2), and (λ_3) effects are captured in Table 15.

Table 15: Validity testing of the model outputs (λ_3)

(Ω) Hrs	μ_1(Hrs) (λ_1)	Model Validity (λ_1)	μ_2(Hrs) λ_2	Model Validity (λ_2)	μ_3(Hrs) λ_3	Model Validity (λ_3)
650.00	518.17	**80%**	591.51	**91%**	617.29	**95%**
634.10	503.38	**79%**	576.72	**91%**	602.50	**95%**
644.50	517.08	**80%**	590.42	**92%**	616.20	**96%**
627.90	499.18	**79%**	572.52	**91%**	598.30	**95%**
539.90	426.28	**79%**	499.62	**93%**	525.40	**97%**
582.80	461.28	**79%**	534.62	**92%**	560.40	**96%**
573.90	454.28	**79%**	527.62	**92%**	553.40	**96%**
577.90	458.18	**79%**	531.52	**92%**	557.30	**96%**
569.90	450.98	**79%**	524.32	**92%**	550.10	**97%**
568.10	455.08	**80%**	528.42	**93%**	554.20	**98%**
583.50	462.88	**79%**	536.22	**92%**	562.00	**96%**
567.50	453.58	**80%**	526.92	**93%**	552.70	**97%**
635.20	503.88	**79%**	577.22	**91%**	603.00	**95%**
631.80	502.28	**79%**	575.62	**91%**	601.40	**95%**
634.10	504.18	**80%**	577.52	**91%**	603.30	**95%**
643.50	510.98	**79%**	584.32	**91%**	610.10	**95%**

A validity testing of the results obtained from the (λ_3) investigations indicates (**95% ≤ V ≤ 100%)** validity output. The validity outputs deliver a comprehensive singular (combined) predictive equation (μ_3) effective to represent the business response to variables impacting operations.

The next section focus on the singular predictive equation obtained to discuss and expatiate optimal scenarios of operational performances.

6.4 **Optimisation scenario**

The outputs collected from the DOE and simulation model indicate that modelling multinationals as a CPS for detailed business evaluation and sustainability is possible. The model responses provide technical and advanced business decision-support for total business optimisation. The following deductions are detailed with emphasis on the singular predictive equation (μ_3) obtained measured in hours.

(a) The intercept **604.16 (λ_0)** indicates the line gradient representing a rise in business turnaround time (effect) divided by corresponding factor level iterated. The value **604.16** consequently indicates the mean of total actual business turnaround time (hours).

(b) The single effect investigations (λ_1) at statistical confidence of (79% ≤ V ≤ 80%) indicates BPV [**C, E, F, G, J, K, O]** are statistically significant.

(c) The ranking of individual BPV in single associations is captured in Table 12. The minimal full-set combination obtained from the (λ_1) investigations effects is **[$A_{L2}B_{L1}C_{L2}D_{L2}E_{L1}F_{L1}G_{L1}H_{L1}I_{L2}J_{L1}K_{L1}L_{L2}M_{L2}N_{L1}O_{L1}$].**

(d) The (λ_2) FI investigations at statistical confidence of (91% ≤ V ≤ 93%) indicates BPV FI **[CK, EJ, FG, and EG]** are statistically significant and stimulates more substantial effects related to the comprehensive (λ_2) FI associations.

(e) The (λ_3) FI investigations at statistical confidence of (95% ≤ V ≤ 100%) indicates BPV FI **[CEF, CEO, JKO, CEJ, and EFJ]** are statistically significant and stimulates more substantial effects related to the comprehensive (λ_3) FI associations.

Figure 53 captures optimisation scenarios related to the comprehensive BPV associated with ranges of experimental values.

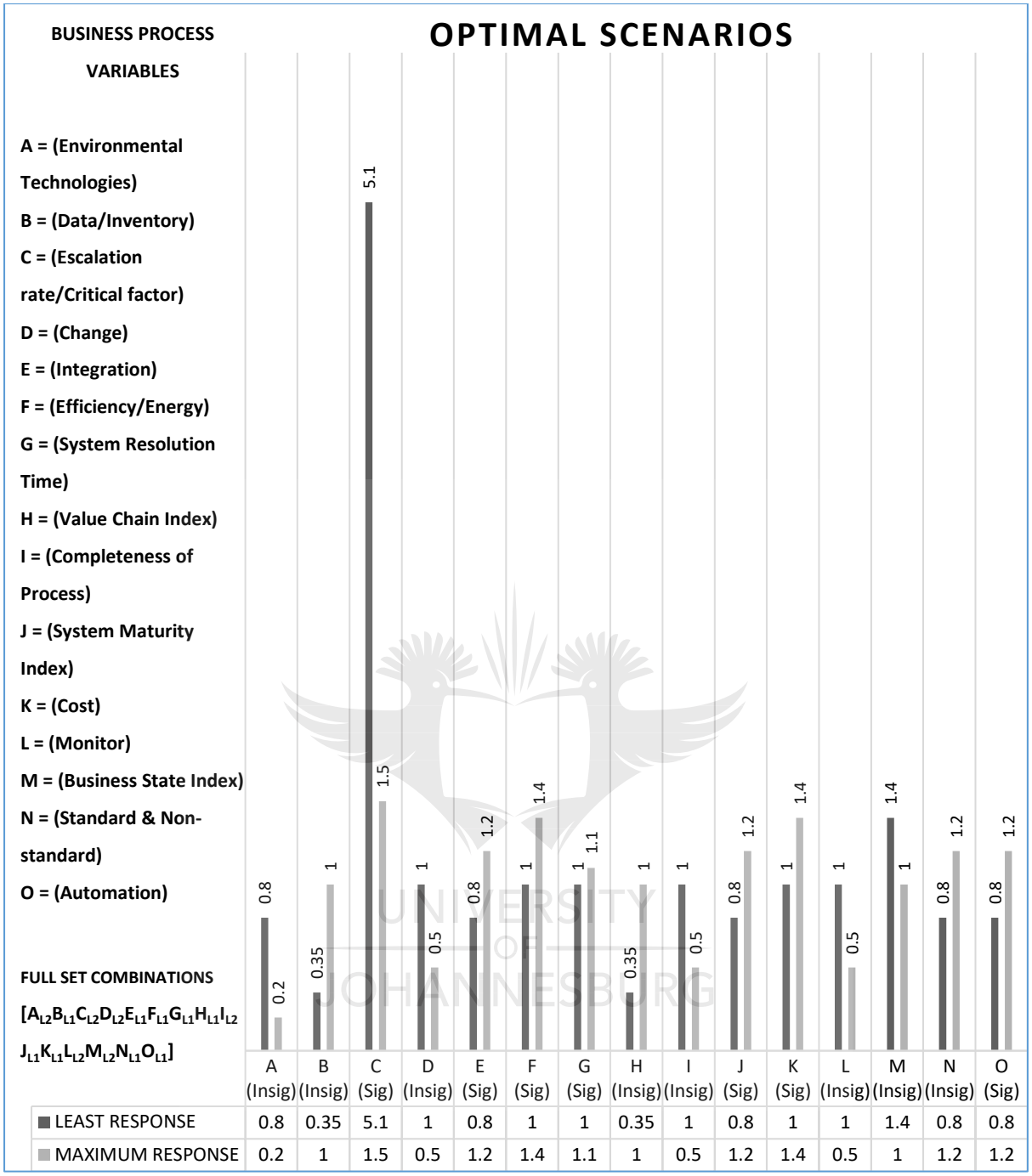


Figure 53: Optimal scenarios

The following deductions are defined with an emphasis on the outputs captured in Figure 53. The business turnaround time (responses) are measured in hours.

- Setting time BPV **Environmental Technologies "A"** at **maximum** relative to multinational process steps results to a significant **decrease** in business turnaround time and increases when setting at

a minimum. This indicates that maximum technologies must be deployed by multinationals for ensuring lesser effects of global warming resulting from environmental degradation and pollution. Maximum settings align with the **Extremely High**-performance enabler and numeric metric.

- Setting time BPV **Data/Inventory "B"** at **minimum** relating to multinational process steps results to a significant **decrease** in business turnaround time and increases when setting at a maximum. This indicates that multinationals must strive for the minimal amount of data sufficient for facilitating optimal execution of business processes. Minimum settings align with the **fairly low**-performance enabler and numeric metric.
- Setting time BPV **Escalation rate/Critical factor "C"** at **maximum** relative to multinational process steps results to a significant **decrease** in business turnaround time and increases when setting at a minimum. Maximum (tier-2) escalation rate indicates that a business escalates process steps at the least, minimal or swift delay time up to tier-2 escalation. Maximum settings align with the **Auto-tier 2 ER, Manual-tier 2 ER, and Very High Priority (VHP)** performance enabler and numeric metric.
- Setting time BPV **Change "D"** at **maximum** relating to multinational process steps results to a significant **decrease** in business turnaround time and increases when setting at a minimum. This indicates that multinationals must develop maximum strategies supporting the change culture. This facilitates continuous research and innovations relating to ensuring optimised executions of business processes. Maximum settings align with **excellent** performance enabler and numeric metric.
- Setting time BPV **Integration "E"** at **minimum** relative to multinational process steps results to a significant **decrease** in business turnaround time and increases when setting at a maximum. Integration seeks for a structure, which supports the swift collaboration of important business constituents facilitating minimal business turnaround time. Minimum setting aligns with **Fully Integrated** performance enabler and numeric metric.
- Setting time BPV **Efficiency/Energy "F"** at **minimum** relating to multinational process steps results to a significant **decrease** in business turnaround time and increases when setting at a maximum. Minimum energy seeks for a structure, which supports lesser usage of energy in executing business processes facilitating optimal outputs and efficiency. Minimum settings align with **High-**performance enabler and numeric metric.
- Setting time BPV **System Resolution Time "G"** at **minimum** relative to multinational process steps results to a significant **decrease** in business turnaround time and increases when setting at a maximum. Configuring system resolution time at a minimum (< 2hours) ensures a decrease in the

total time expended by a system from initiating an input to generating an output. Minimum settings align with **Full SLA Less Than 2HRS** performance enabler and numeric metric.

- Setting time BPV **Value Chain Index "H"** at **minimum** relating to multinational process steps results to a significant **decrease** in business turnaround time and increases when setting at a maximum. This indicates that present-day multinationals must support a structure facilitating swift supply chain delivery resulting in minimal response time (hours). Minimum setting aligns with **Very High**-performance enabler and numeric metric.
- Setting time BPV **Completeness of Process "I"** at **maximum** relative to multinational process steps results to a significant **decrease** in business turnaround time and increases when setting at a minimum. This indicates that multinationals must execute business processes at optimal completion. Maximum settings align with **excellent** performance enabler and numeric metric.
- Setting time BPV **System Maturity Index "J"** at **minimum** relating to multinational process steps results to a significant **decrease** in business turnaround time and increases when setting at a maximum. This indicates that multinationals must support a structure facilitating full ERP, MES and PCN enablement. Experimental values associated with the full enablement options are at minimal. Minimum settings align with **Fully Enabled ERP, Fully Enabled MES, and Connected PCN** performance enabler and numeric metrics.
- Setting time BPV **Cost "K"** at **minimum** relative to multinational process steps results to a significant **decrease** in business turnaround time and increases when setting at a maximum. This indicates that multinationals must support a structure facilitating the execution of business processes at a minimal or optimised cost. Minimum settings align with **Low-**performance enabler and numeric metrics.
- Setting time BPV **Monitor "L"** at **maximum** relating to multinational process steps results to a significant **decrease** in business turnaround time and increases when setting at a minimum. This indicates that multinationals must support a structure facilitating optimal or maximum monitoring of business processes executions. Maximum settings align with **excellent** performance enabler and numeric metrics.
- Setting time BPV **Business State Index "M"** at **maximum** relative to multinational process steps results to a significant **decrease** in business turnaround time and increases when setting at a minimum. Configuring business state index at maximum (> 2years) allows a business more time to adapt to business change and maturity. Maximum settings align with **Greater Than 2Yrs Last Changed** performance enabler and numeric metrics.
- Setting time BPV **Standard & Non-standard "N"** at **minimum** relating to multinational process

steps results to a significant **decrease** in business turnaround time and increases when setting at a maximum. This indicates that multinationals must adhere to the comprehensive regulations stipulated by relevant best practice organisation's ensuring benchmarks detailed to the minimum are strictly implemented. Minimum settings align with **standard**-performance enabler and numeric metrics.

- Setting time BPV **Automation "O"** at **minimum** relative to multinational process steps results to a significant **decrease** in business turnaround time and increases when setting at a maximum. This indicates that multinationals must develop strategies supporting the swift automation culture, which facilitates minimal business turnaround time. Minimum settings align with **Fully Enabled Automation** performance enabler and numeric metrics.
- The full set combinations [$\mathbf{A_{L2}B_{L1}C_{L2}D_{L2}E_{L1}F_{L1}G_{L1}H_{L1}I_{L2}J_{L1}K_{L1}L_{L2}M_{L2}N_{L1}O_{L1}}$] results in a simulation response of **"489.30"** (hours) and a representative model response of **"480.29"** (hours)**.** This simulation response time (hours) is minimal in comparison with simulation response time (hours) obtained from the single business variant investigations. The results validate the simulation and model response at approximately **98%** statistical confidence.

The deductions detailed indicates multinationals attain optimal scenarios of operations setting individual BPV responses at either minimum or maximum ranges of experimental values. This is driven by the full set combinations of [$\mathbf{A_{L2}B_{L1}C_{L2}D_{L2}E_{L1}F_{L1}G_{L1}H_{L1}I_{L2}J_{L1}K_{L1}L_{L2}M_{L2}N_{L1}O_{L1}}$] and singular equation (μ_3) representing the business response for variables impacting operations.

6.4.1 Deductions from the combined business response equation

Technological innovations driven by industry 4.0 implementations deliver a dynamic ecosystem requiring continuous ground-breaking business advancements. Business modelling present a risk-free investigative scenario for value thinking of business implementations. This thesis develops a representative model (CPS) of a present-day multinational. The model (CPS) captured with a singular equation effectively predict the collective challenges of a complex business for current and future business implementations. The singular (combined) predictive equation (μ_3) comprehensively captures and represents collaborative business constituents related to multinationals.

[(μ_3) = 604.16 – 13.80C – 12.18E – 7.05F – 7.91G – 13.47J – 6.96K – 13.66O + 20.90CK + 20.90EJ + 20.90FG + 10.50EG + 11.00CEF + 9.90CEO + 9.90JKO + 9.60CEJ + 8.20EFJ].

As operations in a large global business increases, the more complex analysing and predicting the business becomes. The singular predictive equation limits these complexities delivering a predictive decision-support tool effective for analysing operational performances. A discussion on the deductions of the combined business response equation is detailed.

(a) **Visualisation:** The singular equation replicates the structure of present-day multinationals limiting the complexities in holistically viewing and understanding the impact of multiple functional domains.

(b) Improvements in accuracy: The singular equation allows for complex interrelationships between vital business constituents over time. This is a limitation in present-day business analysing tools for analysing real-world systems and establish solutions.

(c) Generic: The singular equation indicates that multinationals irrespective of business sector can evaluate the impacts of change on the business. This implies that diverse multinationals without prepositioning distinct BP can substitute associated experimental values into the combined predictive equation.

(d) Measurability: The singular equation can evaluate, track and measure a mix of optimisation options providing the lowest operation abstraction with each factor (BPV) set at either maximum or minimum.

(e) Enhanced randomness: The singular equation is developed to signify real-world business scenarios which effectively considers uncertainty such as decision-nodes in unique business process step.

(f) User-friendly: The singular equation is easily accessible requiring less intellectual effort and data inputs. A user is only required to substitute unique business process variables into the equation for investigations.

(g) Reproducible: The singular equation allows for addition or subtraction of statistical analysis or measurements at any time.

The singular equation provides a solution to model the predicted impact of operations on present-day multinationals. The model (CPS) via the singular equation provide substantial/practical evidence that multinationals can be modelled, simulated, analysed and optimised in real-time for total business sustainability. This addresses issues of innovative research aimed at developing a structure effective to collaborate all business constituents and for predictive capabilities. The outputs are fundamental

for multinationals investigating technological business advances for detailed business evaluation and optimisation.

6.5 **Summary and conclusions**

Chapter six details the model (CPS) applications to a mix of optimisation options providing the ideal operation abstraction with each factor (BPV) set at either maximum or minimum. The optimisation scenario successfully establishes the baseline business demand relating to multinational implementations. This chapter demonstrates the comprehensiveness of the statistical comparative analysis of each business constituent in the model (CPS). The scenario optimisation approach successfully validates the developments, execution, and implementations of the model (CPS). To function as an advanced decision-support tool for current and future predictive analysis of operations. The next chapter accentuates on the comprehensive results collected from this thesis. The implications, validity, and reliability of the outputs combined with recommendations and future research directions are detailed.

Chapter 7: Summary, Conclusions, and Recommendations

7.1 Chapter overview

The literature study identified a research gap relating to the current business modelling status for total business evaluation and optimisation of a present-day multinational. This thesis aims to develop a model (CPS) driven by standards of industry 4.0 for application at multinationals to address this limitation. The interrelated model (CPS) development demand a mixed-method approach. Applications of the mixed-method approach are demonstrated through a theoretical framework to discuss the sequential development of the model (CPS) from concept to implementation. Crucial databases are defined and configured (Accuprocess), which initiates with developing a repository of business processes (Visio) to deliver a digital prototype of a real-world modern multinational. The databases are tested to determine simple correlations through the simulation and design of experiments statistical methods. Both approaches serve as decisive differentiators to validate the randomness of decision nodes and conduct comparative calculations via two business cases. The scenario analysis conducted through single and multiple investigations identifies an optimal mix of business factors and validates baseline business demand for ideal operational performances at a multinational. This chapter details the key outputs of this thesis and proposes recommendations for future investigations. This chapter aims to extract findings from developing the model (CPS) to establish inferences and discuss limitations to this thesis. Chapter seven is structured in five sections captured in Figure 54.

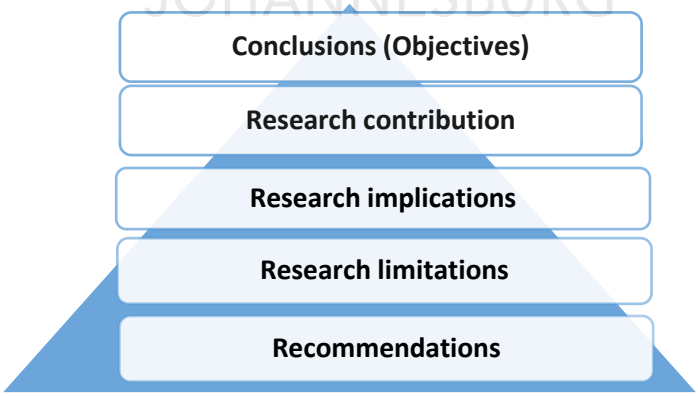


Figure 54: Scope of the concluding discussions

Source: (Authors own compilation)

The initial section summarises the conclusion of this thesis relating to the Research Objectives (RO) detailed.

7.2 Review of research objectives

(RO) 1: Conduct a comprehensive literature review to determine the status of various knowledge relevant to this research.

A systematic literature review is conducted to provide documents relevant for a detailed study of diverse approaches obtainable globally to model and analyse a present-day multinational. The SLR search focuses on keywords relevant to this research.

(RO) 2: To review existing business models and determine its applicability for effectively predicting impacts of change.

A detailed literature study is carried out on available business models. This identified a research gap relating to the competence of current business models for predictive analysis. The first and second research objectives provide insights to the first research question detailed which states "Referencing the current knowledge base and business modelling status, can a CPS model be developed to represent a large business?"

(RO3): To evaluate the effectiveness of the 4IR implementations for innovative business advancements and total business sustainability.

A detailed review of the technologies relating to the fourth industrial revolution implementations is conducted. This identified four 4IR enablers and the cyber-physical systems as suitable to investigate the research gap identified. This research objective provide insights to the second research question detailed which states "Are the 4IR technologies (CPS/Integration, Automation) practical to provide a comprehensive input and systems dynamic of a complex business?"

(RO4): To develop a comprehensive set of operations which serve as an effective representation of a present-day multinational.

Multinational operations are assessed as business processes to deliver the digital prototype of real-world business implementations. The business processes constitute comprehensive functional domains of a complex business. The high-level abstraction to distinct sub-processes is developed deploying the Microsoft Visio tool.

(RO5): To determine important business constituents essential for developing a comprehensive holistic model (CPS) for a complex business.

A detailed review of related work to gather information on all business constituents significant for developing the model (CPS) is conducted. This identified business processes, business process modelling tools, business process variables, analytical hierarchy process, simulation method and design of experiments statistical approach as crucial business subsets. This objective addresses the second model assumption and fourth research question respectively. Which states "Each constituent in the model (CPS) development is comprehensive and a fundamental subset within multinationals" and "Based in literature and best practice, what are the variables affecting a business, can these variables be integrated into the CPS and impacts determined?"

(RO6): To develop a comprehensive holistic model (CPS) which serve as a digital representation of multinationals for total business evaluation.

A mixed-method approach is applied integrating interrelated theoretical concepts of each business constituent fundamental in developing the model (CPS). The model (CPS) is developed in Accuprocess Modeler (simulation) and Minitab (DOE) architectures. This objective addresses the first model assumption detailed which states "The model (CPS) developments is a digital representation of a complex business focus on relevant theoretical perceptions and engineering management approach". This objective provide insights to the third research question which indicates "Can a validated CPS business model be tested for reliability enabling total business performance and sustainability?"

(RO7): To test, simulate and optimise the levels of importance, states, and interdependencies of each business constituent influencing the development of a practical model (CPS).

The Accuprocess Modeler through distinct simulation runs present the turnaround time of the comprehensive multinational functional domains. The DOE test for the priority states of business

process variables from a comparative statistical analysis resulting in representative model outputs. This objective provide insights to the fifth research question which states “Does the business model proposed, serve as a decision-support analysis tool for current and future business implementations relating to predicting multiple impacts of business demand and change?”

(RO8): To develop an experimental protocol through a representative model output effective for comparative statistical analysis.

The simulation and DOE methods are used to define together with test the reliability of the decision-nodes, business states, numeric constraints, and experimental metrics appropriate to quantify the investigations.

(RO9): To develop a simplified relationship obtainable from the comparative statistical analysis effectively representing the business response for variables impacting operations.

The comparative statistical investigations result in a single equation suitable to represent the business response of a multinational for detailed business evaluation and optimisation. The simplified relationship set at a 95% statistical-significance delivers an optimal mix of business process variables interactions. This objective addresses the fourth model assumption detailed which states “Applications of the model (CPS) require minimum operational time, technical proficiency and data inputs”.

(RO10): To critically evaluate the impact that can be determined from the model (CPS) and how multinationals can leverage the inferences for transforming the future of the corporate world.

Inferences are established through optimal scenarios to determine baseline business demand driven by the singular equation. Multinationals irrespective of process steps can substitute current operations into the equation to determine current and ideal business demand. This objective addresses the third model assumption detailed which states “The model (CPS) developments are imperative, generic, reproducible and applicable irrespective of the type of business sector”. This objective answers the fourth research question which indicates “What are the benefits of the business model prepositioned for positioning physical business systems in real-time?”

(RO11): To validate the individual models and collective results relating to developing the model (CPS) by providing recommendations for operational practice and implementations.

The model (CPS) present a viable alternative to traditional business models inadequate for predictive competencies. The collective results deliver significant value adds to present-day multinationals to predict the impacts of change. This objective provides insights and addresses the sixth research question detailed which state “Can advanced methods be adopted to determine relationships between variables and impact to business? What is the most significant impacting variables and can the variable impacts be reduced to simpler correlations?”

The second section of chapter seven detail the research contribution of the model (CPS).

7.3 Research contribution

The detailed literature study conducted indicates traditional analysis tools are inadequate to investigate collective business challenges and predict operational performances. The review establishes multinationals are struggling with implementing the recent inventions delivered by industry 4.0 technologies. This thesis seeks to address these limitations intended at enhancing the sustainability of multinationals and improving business demand.

The key contribution of this thesis is delivering a viable alternative to existing business models with reduced efforts and advancements to predicting ideal operational practice and business demands. This is a shift from traditional analysing methods incapable of self-predicting in real-time. The results provide a validated, generic and sustainable analysis tool for detailed business evaluation and optimisation. The advanced tool driven by the model (CPS) demonstrates unique implementations of industry 4.0 requiring moderate skill competencies, minimal technical inputs, and assessment timelines.

The analysis tool demonstrates enablement implementations of industry 4.0 expected to enhance the global impact of operations performance and demand in multinationals for detailed business evaluation and optimisation. The next section summarises the managerial, practical and theoretical implications driven by inferences established from the research contribution.

7.4 Research implications

The practical research impacts of the outputs collected are detailed.

Industry 4.0 implementations

This thesis integrates benchmark implementations of the fourth industrial revolution to investigate the research gaps identified. The technologies and protocols of industry 4.0 enable the holistic modelling of all business constituents for total business evaluation. A synopsis of some of the impacts driven by the 4IR implementations is detailed.

(a) 4IR implementations go beyond IT offering innovative protocols for configuring a digitalised business model.
(b) Supports for an effectively networked, intelligent and integrated business architecture for ease of data collection, analysis, and evaluating inter-relationships.
(c) Present an innovative direction and enhances technical competencies of the model (CPS) for detailed business evaluation in real-time.

Predictive architecture

The model (CPS) enables a large global business to conduct a rapid but detailed predictive analysis to assess crucial business constituents towards enhancing operational performance. A synopsis of some of the impacts resulting from the predictive architecture is detailed.

(a) Enables strategic business decisions and swift model outputs.
(b) Increased visibility and proactive competence.
(c) Delivers practical lead-times.

Modelling, simulation, process and systems orientation

Business constituents cannot be investigated as an independent detachment. The literature review indicates limitations in the holistic conceptualisation of traditional business models. A synopsis of some of the impacts obtained from the system positioning is detailed.

(a) Present a virtual prototype of a real-world multinational.
(b) Enables a holistic assessment of all business constituents stimulating a system-level output as a substitute to the outputs it delivers as an independent unit.

(c) Supports a framework for observing the interdependencies and data flow of comprehensive business constituents.
(d) Allows for greater transparency and potential approaches to address persistent and complex business challenges more effectively.

The comprehensiveness of important business constituents

Numerous business constituents are fundamental to the effective implementation of multinational operations. This thesis ensures a detailed literature review is conducted to identify the comprehensive business subsets. A synopsis of some of the impacts resulting from this benchmark theme is detailed.

(a) Presents a document comprehensively detailing all business constituents.
(b) Enables an integrated structure for effectively investigating detail multinational operations and for critical business decisions.
(c) Delivers a flexible and efficient condition monitoring business architecture for identifying critical areas for development.

Scenario selection and modification options

The model (CPS) introduces a new concept to quantify and analyse a business. The model (CPS) integrates knowledge areas of engineering management and beyond driven by relevant interrelated theories which can be refined for future applications. A synopsis of some of the impacts obtainable from this benchmark theme is detailed.

(a) The model (CPS) supports future research efforts in the short and long-term.
(b) The singular (combined) predictive equation is applicable and can be modified to address unique business requirements.

7.5 Research limitations

(a) This thesis aims for a comprehensive and accurate digital prototype of a present-day multinational through business processes. The literature review identified high-level abstraction to sub-processes functional domains from levels 0 to levels 4. The investigations are not exhaustive with limitations to the business processes developments from level 0 to level 3 (where required). The level 0 to level 3 business processes repository is however sufficient for demonstrating detailed business evaluation.

(b) The model (CPS) development is conducted with databases available from reliable enterprise architectures. The information might not be comprehensive in comparison with practical on-site implementations.
(c) The model (CPS) validation requires actual on-site applications. Practical implementations of the integrated decision-support tool via the developed BPOM (CPS) on-site across varying business sectors irrespective of BP executed is beyond the scope of this thesis.
(d) Simulation tools are quite expensive with very exhaustive functionalities which are not readily available and accessible.

7.6 **Research recommendations**

Total business evaluation, optimisation, and sustainability is a significant priority for any multinational. The results deliver constructive benefits to present-day multinationals with potential future research applications and investigations.

(a) This thesis recommends that future research prospects are directed to practical on-site executions of the model (CPS) results for predictive decision-support.
(b) Multinationals can direct attention to developing innovative systems or robots programmed based on comprehensive results collected from this thesis. This probes into the Artificial Intelligence learning paradigm delivering robots effective to automatically quantify current business demand and predict ideal operational performance driven by the singular equation established in this thesis.

7.7 **Concluding discussions**

The model (CPS) is a constitution of a set of databases that represent modern multinationals statistically assessed with simulation and DOE optimisation methods. This thesis elaborates on the benefits of developing a sustainable, comprehensive, holistic, and predictive business analysis tool. The proposed advanced business solution is a shift from the traditional analysis methods with limitations to self-predicting capabilities. The development of the model (CPS) delivers a self-predicting decision-support tool driven by protocols of the fourth industrial revolution. The model (CPS) is suitable to quantify current and future operational performances.

The enterprise architecture constituents integrated into the model (CPS) include business processes, business process variables, business process modelling tools, analytic hierarchy process, simulation

method and design of experiment statistical technique. Each enterprise operation incorporating comprehensive functional domains of a complex business is holistically captured as business processes. The model data is captured in Visio, validated and subsequently modelled in Accuprocess for comparative statistical analysis. The statistical investigations demonstrate and validate applications of the model (CPS) providing an optimal mix of factor interactions on the business response via a singular equation. The equation is applicable irrespective of the type of business sector and for addressing collective business challenges.

The singular equation effectively represents the business response for comprehensive factors impacting operations set at a statistical significance of 95%. This delivers a novel business analytic tool for strategic business decisions suitable to predict operational practices. The singular equation is a viable alternative to traditional business analysis tools requiring minimum operational time, technical proficiency and data inputs. The collective result substantiate that modelling a complex business as a CPS for predictive capability is possible with reduced efforts and advancements to evaluating business demand.

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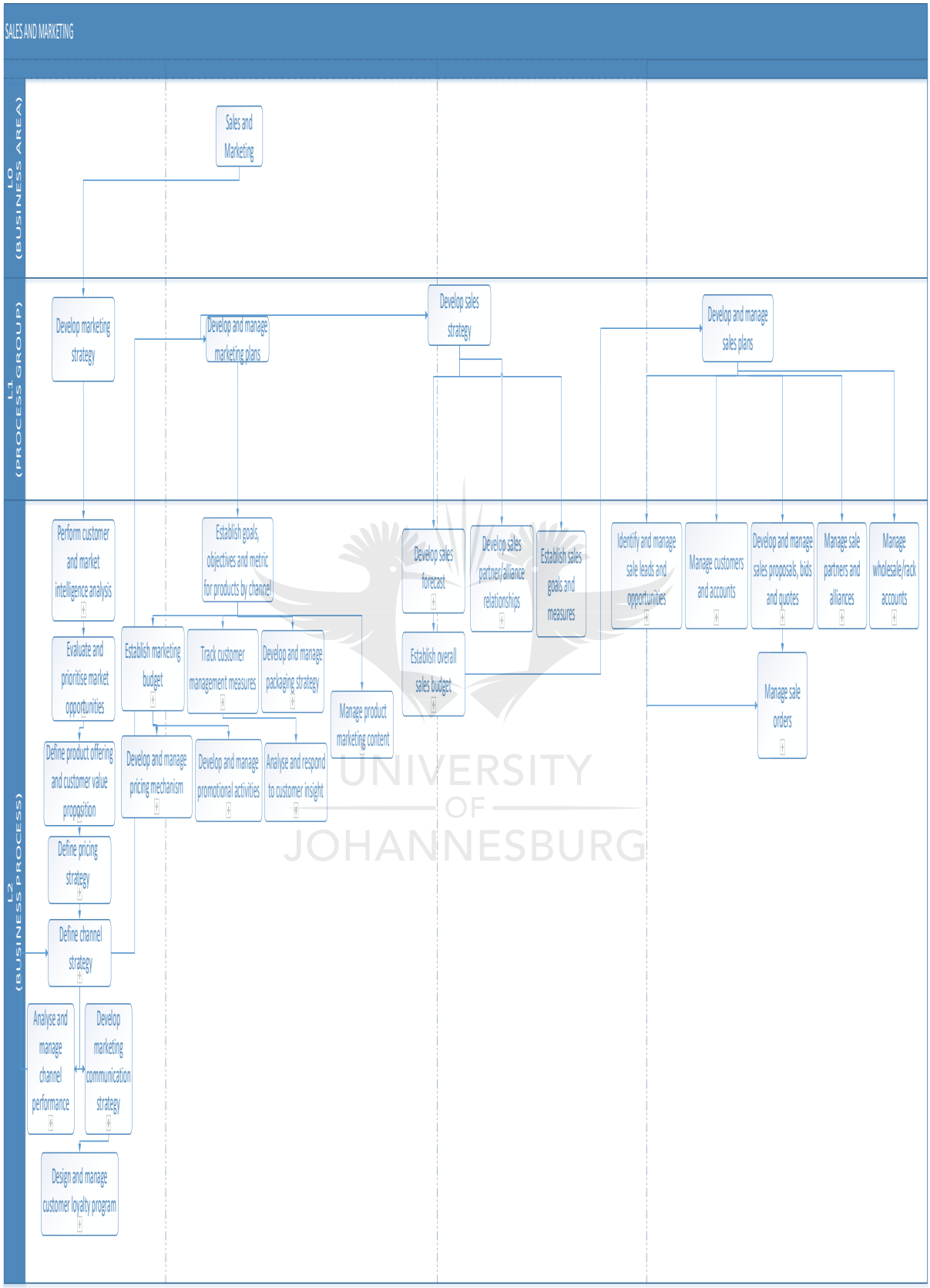
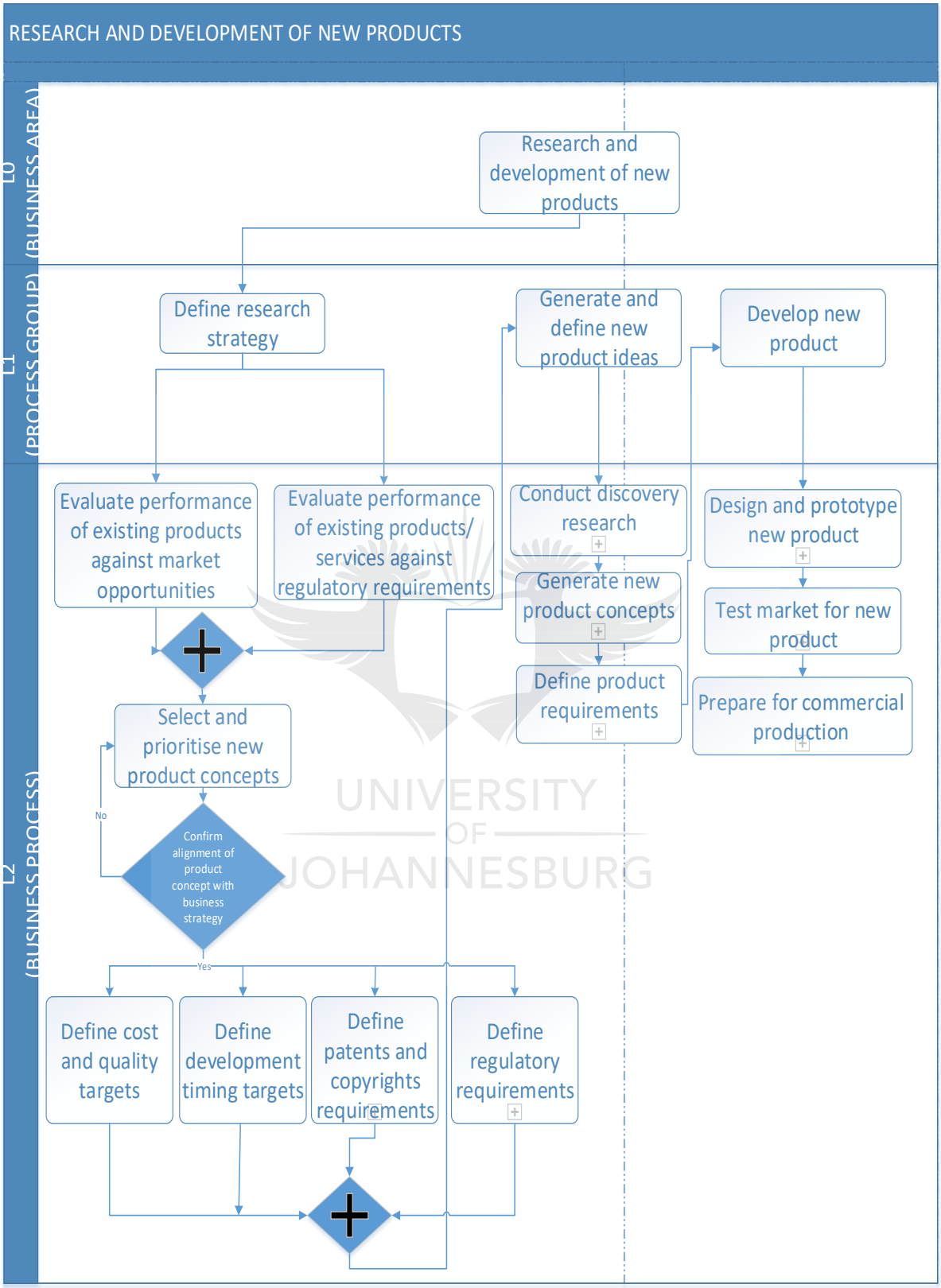
Appendix A: Rank for BPMT alternatives for developing a simulation model

Business process modelling tool alternatives	Overall Weights	Rank
Anylogic simulation tool	0.28	**2nd**
ARIS business architect	0.25	**3rd**
Accuprocess Modeler	0.34	**1st**
Enterprise architect	0.07	**4th**

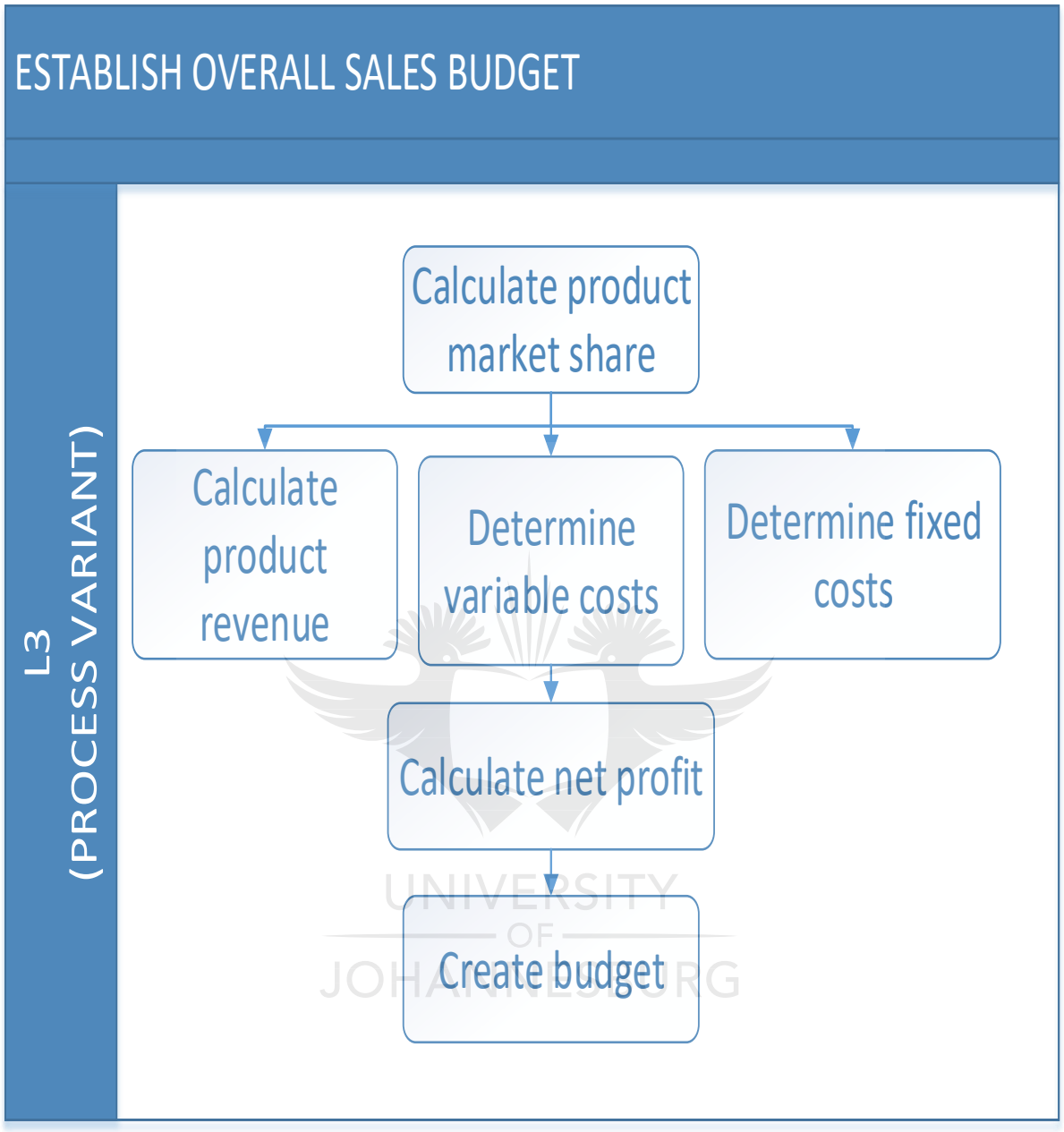
Appendix B: Thin slice sales and marketing (level 0 to level 2)



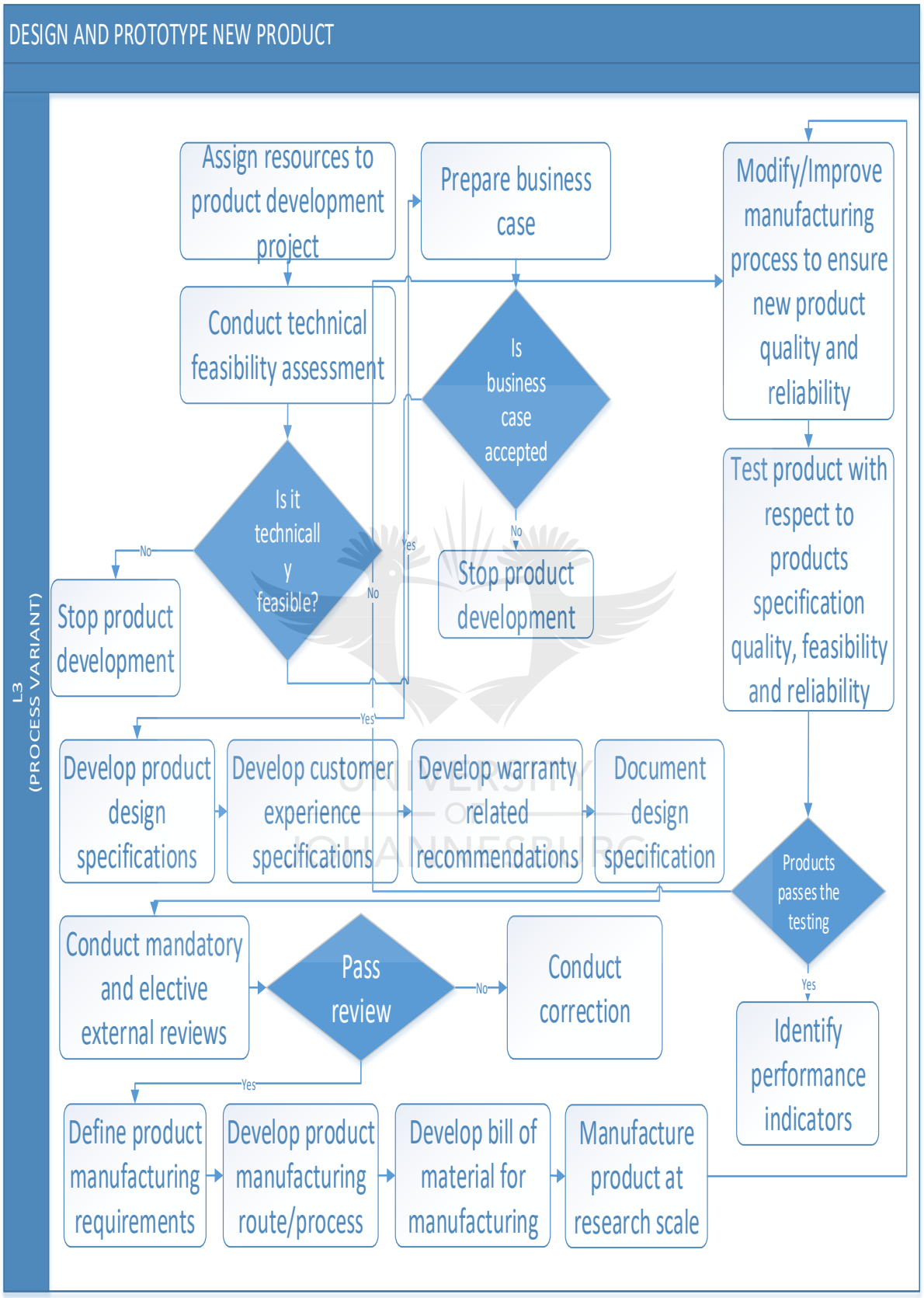
Appendix C: Thin slice research and development (level 0 to level 2)



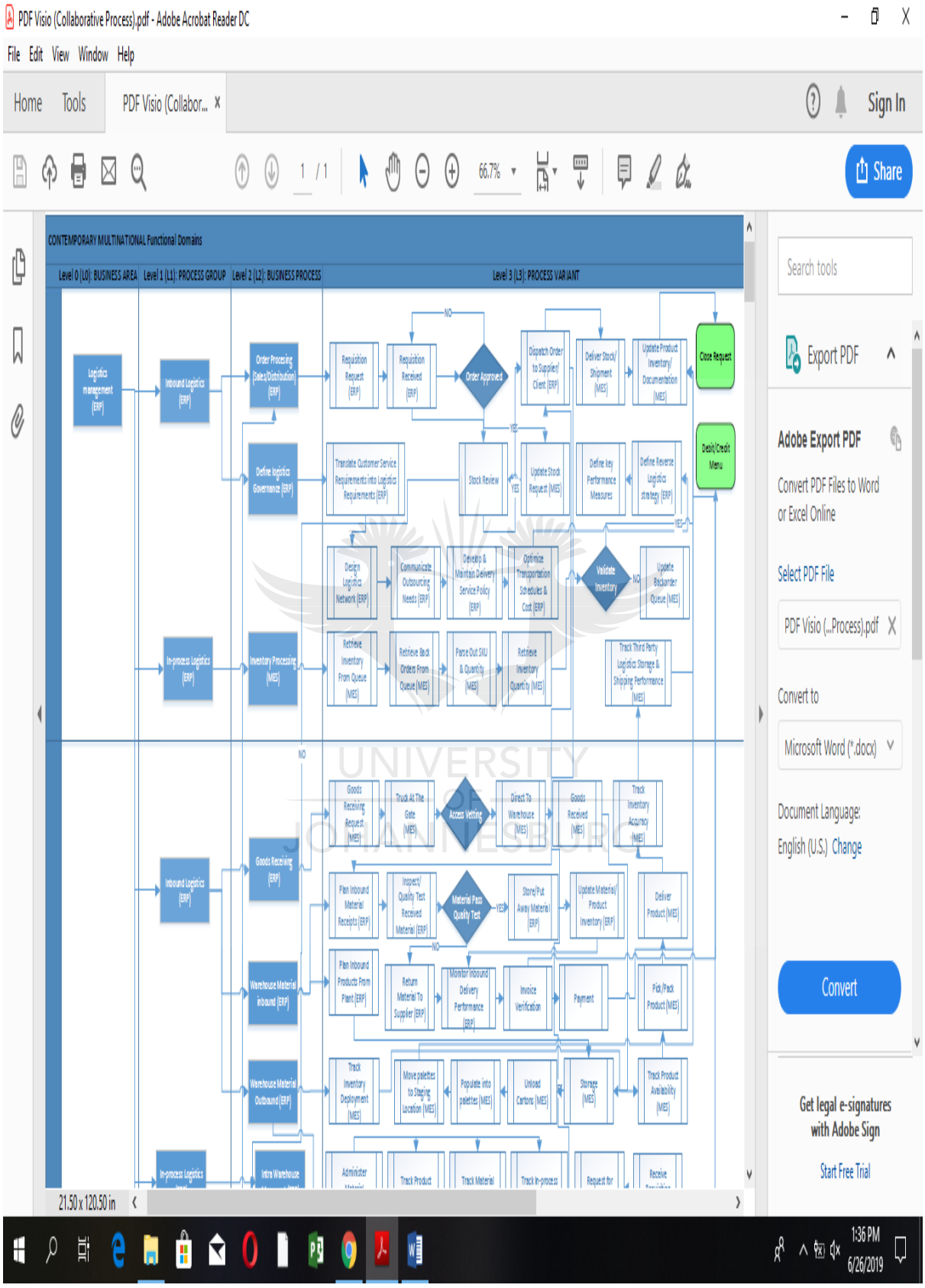
Appendix D: Establish overall sales budget (level 3)



Appendix E: Design and prototype a new product (level 3)



Appendix F: Business process repository configurations

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Convert to
Microsoft Word (*.docx)
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Convert
Get legal e-signatures with Adobe Sign
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Intra Warehouse Movement (ERP)
Administer Material Movements (ERP)
Track Product Movements (ERP)
Track Material Movement (ERP)
Track In-process Movement (ERP)
Request for Quotation
Receive Requisition (ERP)
Operations/Detail Scheduling (Purchase/Sales) (MES)
Reconcile Product Inventory Per Warehouse/Site (ERP)
Reconcile Material Inventory Per Warehouse/Site (ERP)
Reconcile In-process Inventory Per Warehouse/Site (ERP)
Sales/Purchase Requisition (ERP)
Complete Requisition (ERP)
Requisition To sales/ Purchasing Dept. (ERP)
Approve Requisition
Purchase/Sales Order
Outline/ Schedule Agreement
Quotation
Develop Logistics Contract (ERP)
Schedule & Nominate Pipeline, Truck, Rail, Barge, Tanker Shipments (ERP)
Outbound Logistics (ERP)
Manage Bulk Transportation (MES)
Manage Claims (ERP)
Process & Audit Carrier Invoices & Documents (ERP)
Manage Pipeline Shipments (ERP)
Qualify Vessels/ Tankers/Barge (ERP)
Schedule Rail (ERP)
Schedule Bulk Truck Shipments (ERP)
Manage Bulk Truck Shipments (ERP)
Manage Bulk Inventories (MES)
Manage Vessel/ Tanker/Barge Shipments (ERP)
Schedule Vessels/ Tankers/Barge (ERP)
Manage Rail Shipments (ERP)
Manage Leased Space (ERP)
Manage Third Party Bulk Storage (ERP)
Manage Bulk In-transit Inventories (ERP)
Reconcile Book To Physical (ERP)
Operate Outbound Transportation (MES)
Management Transportation Network (ERP)
Plan, Transport & Deliver Outbound Product (ERP)
Monitor Product Quality, Volumes & Losses Through Transport (ERP)
Truck Carrier Delivery Performance (ERP)
Process & Audit Carrier Invoices & Documents (ERP)
Strategic Planning (ERP)
Gather Market Prices For Commodity (ERP)
Forecast Commodity Prices (ERP)
Develop & Calculate Forward Curves (ERP)
Develop & Maintain Benchmark Prices (ERP)
Define Production Process (ERP)
Define Production Workplace Layout & Infrastructure (ERP)
Model Production Network To Enable Simulation & Optimization (ERP)
Define Manufacturing Goals (ERP)
Define Capacities (ERP)
Define Production Network & Supply Constraints (ERP)
Define Labour & Material Policies (ERP)
Define Outsourcing Policies (ERP)
Measure Forecast Accuracy (ERP)
Define Production Balance & Control (ERP)
Develop Baseline Forecasts (ERP)
Collaborate With Customers (ERP)
Develop Consensus Forecast (ERP)
Create Master production Schedule (ERP)
Maintain Master Production Schedule (ERP)
Identify Critical Materials & Supplier Capacity (ERP)
Materials plan (ERP)
CFF Container
Supply Chain
Integrated Planning
Demand Planning
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Supply Chain Management
Integrated Planning (ERP)
Demand Planning (ERP)
Develop Baseline Forecasts (ERP)
Collaborate With Customers (ERP)
Develop Consensus Forecast (ERP)
Create Master production Schedule (ERP)
Maintain Master Production Schedule (ERP)
Materials & Supplier Capacity (ERP)
Constrained Materials plan (ERP)
Determine Inventory Targets (ERP)
Identify Long & Short Positions (ERP)
Determine Available To Promise (ERP)
Monitor Activity Against Forecast & Revise Forecast (ERP)
Evaluate & Revise Forecasting Approach (ERP)
Collaborate With supplier & Contract Manufacturers (ERP)
Supply Planning (ERP)
Forecast Equity Crude Production (ERP)
Forecast Equity Additives Production & Availability (ERP)
Create Unconstrained Material Plan (ERP)
Identify Critical Materials & Supplier Capacity (ERP)
Generate Constrained Materials Plan (ERP)
Define Production Balance & Control (ERP)
Manage Dispatch Plan Attainment (ERP)
Distribution Planning (ERP)
Create Unconstrained Materials Plan (ERP)
Collaborate With Supplier & Contract Manufacturers (ERP)
Establish Sourcing Relationship (ERP)
Establish Dynamic Deployment Policies (ERP)
Establish Storage Management Constraints (ERP)
Calculate & Optimize Destination Dispatch Plan (ERP)
Manage Cost Of Supply (ERP)
Review Distribution Network (ERP)
Establish Distribution Centre Layout Constraints (ERP)
Establish Inventory Management Constraints (ERP)
Establish Transportation Management Constraints (ERP)
Calculate & Optimize Destination Load Plan (ERP)
Manage Partner Load Plan From Source To Partners (ERP)
Communicate (ERP)
Develop Quality Standards & Procedures (ERP)
Calculate Consolidation At Plant/ Source (ERP)
Determine Product Storage Facility Requirements (ERP)
Determine Finished Goods Inventory Requirements At Destination (ERP)
Manage Collaborative Replenishment Planning (ERP)
Establish Quality Targets (ERP)
Procedures (ERP)
CFF Container
Procurement (ERP)
Develop Procurement Strategy (ERP)
Identify & Clarify Purchasing Requirements (ERP)
Develop procurement Strategy (ERP)
Match Needs To Supply Capabilities (ERP)
Develop inventory strategy (ERP)
Analyze Organizations Spend Profile (ERP)
Seek opportunities To Improve Efficiency & Value (ERP)
Collaborate With Suppliers To Identify Sourcing Opportunities (ERP)
Select Suppliers (ERP)
Identify & Select Suppliers (ERP)
Clarify & Validate Suppliers (ERP)
Negotiate & Establish Contracts (ERP)
Manage Contracts (ERP)
Generate line level plan
Schedule planned and preventive maintenance
Manage Supplier (ERP)
Manage Supplier Information & Contracts (ERP)
Monitor & Analyze Procurement & Vendor Performance (ERP)
Monitor & Quality Of Product Delivered (ERP)
Manage Volume Of Product Delivered (ERP)
Release productions
Schedule requested maintenance
Manufacture (ERP)
Production Scheduling (ERP)
Model and simulate plant
Generate detailed schedule
Schedule production orders and create lots
Select vendor quote
Check if vendor in system
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Manufacture (ERP)
Production Scheduling (ERP)
Model and simulate plant
Generate detailed schedule
Schedule production orders and create lots
Select vendor quote
Check if vendor in system
Order Material (ERP)
Process requisitions
Approve requisitions
Solicit vendor quotes
Verify vendor quotes
Create and issue purchase order to vendor
Clarify and validate suppliers
Perform Quality Testing (ERP)
Resolve order exceptions
Record receipt of goods
Record test results
Track and analyse non-conformance trends
Perform root cause analysis
Maintain Production Records & Manage Lot Traceability (ERP)
Calibrate test equipment
Perform quality testing as per testing procedures
Determine lot numbering system
Determine lot use
Close request
Customer Relationship Management
Define Customer Service Strategy (ERP)
Define customer service policies and procedures
Create customer journey maps
Define single view of the customer for the organization
Define a vision for the customer experience
Validate with customers
Communicate warranty policies and offerings
Assign each personnel specific customer service contract/s
Plan & Manage Customer Service Contracts (ERP)
Define customer service requirements across the enterprise
Develop and document warranty policies
Create and manage warranty rules/claim codes for products
Agree warranty responsibilities with suppliers
Define warranty related offering for customers
Define the number of personnel required specifically for customer service
Track work force utilization
After Sales Service (ERP)
Define customer service experience
Analyze historical data on the number of service contracts
Analyze historical data on the frequency of enquiries
Analyze historical data on the servicing capability per head of the employees
Forecast expected volume of customer service contracts
Define the service required
Monitor and evaluate quality of customer interactions with service representatives
Manage Product Recalls & Regulatory Audits (ERP)
Establish target service level for each customer segment
Receive customer problem, inquiry or request
Record customer problem, inquiry or request
Classify customer problem, inquiry or request
Request for information
Product inquiry request
Resolve a problem
Prioritize the request
Evaluate Customer Service Operations
Define product warranty offering
Contact
Resolve
Contact
Locate
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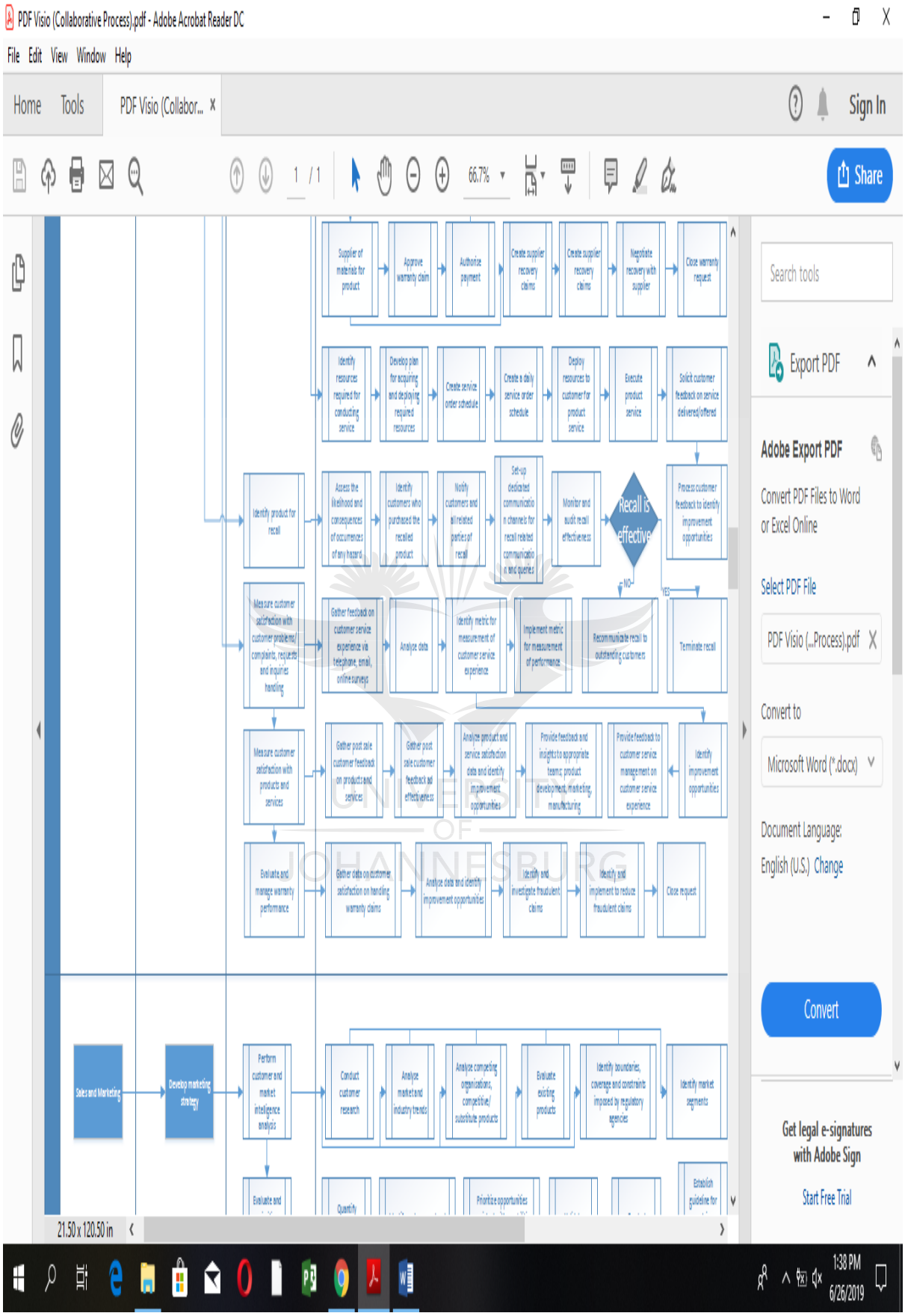

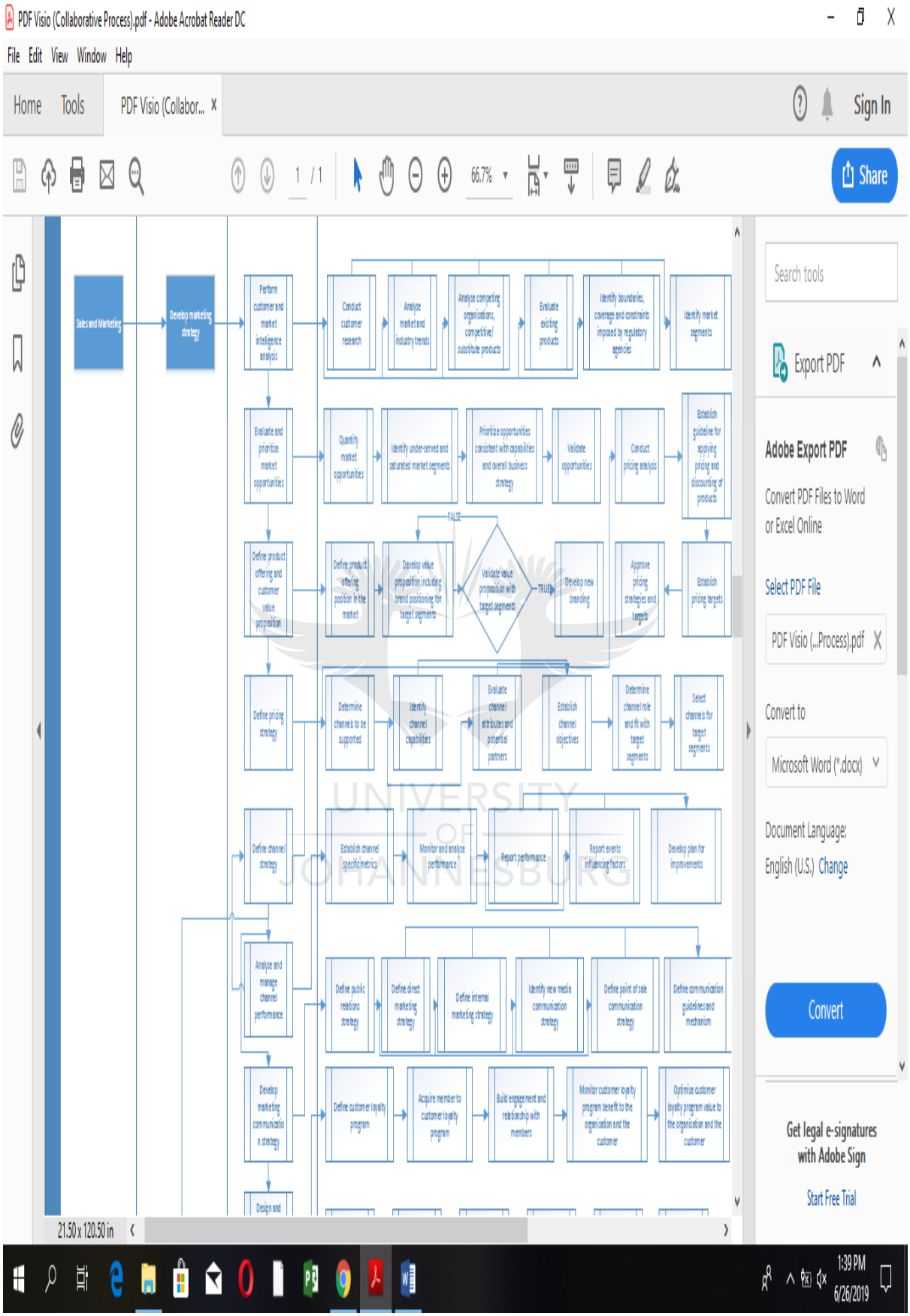

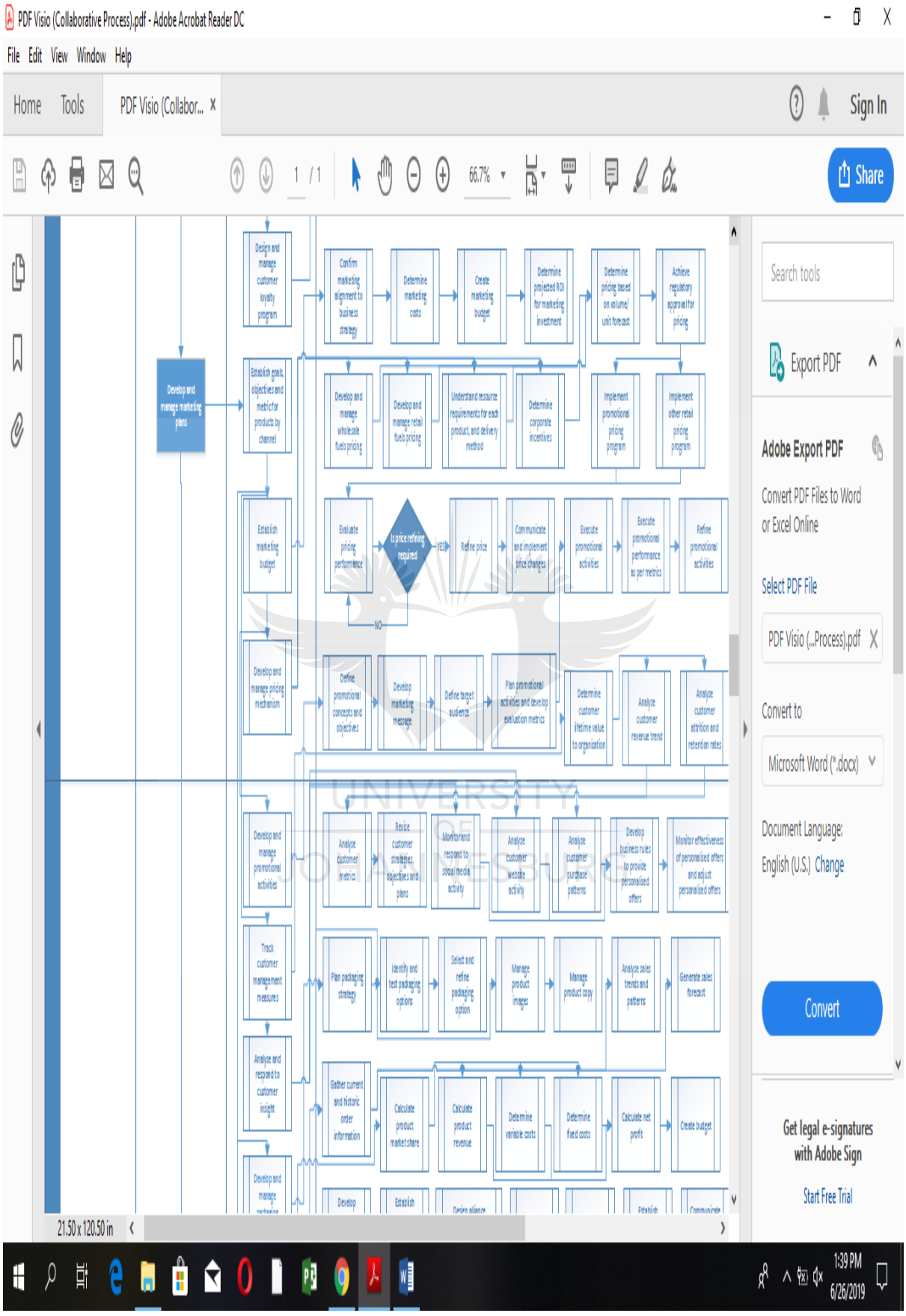
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Develop and manage marketing plans
Design and manage customer loyalty program
Confirm marketing alignment to business strategy
Determine marketing costs
Create marketing budget
Determine projected ROI for marketing investment
Determine pricing based on volume/ unit forecast
Achieve regulatory approval for pricing
Establish goals, objectives and metrics for products by channel
Develop and manage wholesale fuels pricing
Develop and manage retail fuels pricing
Understand resource requirements for each product, and delivery method
Determine corporate incentives
Implement promotional pricing program
Implement other retail pricing program
Establish marketing budget
Evaluate pricing performance
Is price refining required
YES
NO
Refine price
Communicate and implement price changes
Execute promotional activities
Execute promotional performance as per metrics
Refine promotional activities
Develop and manage pricing mechanism
Define promotional concepts and objectives
Develop marketing message
Define target audience
Plan promotional activities and develop evaluation metrics
Determine customer lifetime value to organization
Analyze customer revenue trend
Analyze customer attrition and retention rates
Develop and manage promotional activities
Analyze customer metrics
Revise customer strategies, objectives and plans
Monitor and respond to social media activity
Analyze customer website activity
Analyze customer purchase patterns
Develop business rules to provide personalized offers
Monitor effectiveness of personalized offers and adjust personalized offers
Track customer management measures
Plan packaging strategy
Identify and test packaging options
Select and refine packaging option
Manage product images
Manage product copy
Analyze sales trends and patterns
Generate sales forecast
Analyze and respond to customer insight
Gather current and historic order information
Calculate product market share
Calculate product revenue
Determine variable costs
Determine fixed costs
Calculate net profit
Create budget
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Develop Employees (ERP)
Reward & Retain Employees (ERP)
Redeploy & Retire Employees (ERP)
Screen & Select Candidates (ERP)
Identify The Recruitments Methods (ERP)
Select The Recruitments Methods (ERP)
Head Hunting (ERP)
Job Postings (ERP)
External Third Part Sourcing (ERP)
Retrieve Candidates Application (ERP)
Review Results Of Assessment & Select Candidates For Interview (ERP)
Manage New Hire (ERP)
Review Applicants & Select Candidates Who Meet The Minimum Requirements (ERP)
Screening Of Applicants For Further Consideration (ERP)
Set Up Pre-testing With Approved Third Party Contractor (ERP)
Notify Potential Candidates (ERP)
Conduct Assessment(ERP)
Notify Candidates of Interview(ERP)
Manage Employee Orientation (ERP)
Arrange Logistics For Candidates if Required (ERP)
Prepare Documentation For Interview & Invite Required Personnel From The Organization (ERP)
Conduct Interview (ERP)
Select Candidate (ERP)
NO
YES
Sign Contracts Update Records (ERP)
Candidate Accepts The Offer
Manage Employee Performance (ERP)
Conduct Background Check On Selected Candidate (ERP)
Candidate Passed The Background Check
YES
NO
Draw Up Offer For The Selected Candidate (ERP)
Negotiate Offer With Candidate (ERP)
Update Records On HR System (ERP)
Develop & Train Employees (ERP)
Identify Methods For Conducting Induction (ERP)
Formal Lectures (ERP)
Videos (ERP)
Printed Materials (ERP)
Computer Based (ERP)
Online (ERP)
Print Material (ERP)
Face To Face (ERP)
Develop & Implement Employee Rewards Program (ERP)
Identify Methods For Evaluating Induction (ERP)
Develop Material For Each Of The Methods (ERP)
Conduct Induction Training For The employees (ERP)
Update Employee Records (ERP)
Evaluate The Effectiveness Of The Induction Program (ERP)
Update Induction Program As Identified (ERP)
Evaluate & Review The Performance Appraisal Program (ERP)
Manage & Administer Benefits (ERP)
Define Employee Performance Objectives & Measures (ERP)
Communicate Performance Objectives & Measures (ERP)
Create Employee Performance KPA's & KPI's (ERP)
Develop Generic Employee Performance Contract (ERP)
Employee & Manager Agree & Sign An Employee performance Contract (ERP)
Conduct Employee Performance Appraisal (ERP)
Administer Payroll (ERP)
Manage Employee promotion (ERP)
Develop Employee Career Paths (ERP)
Define Employee Competencies (ERP)
Identify Training Needs by Analysis Of Required & Available Skills (ERP)
Identify Which Training Will Be Offered In-house Externally (ERP)
Source & Review Training Material (ERP)
Identify External Consultants For Offering Training (ERP)
Manage Employee Retirement (ERP)
Review & Improve Training (ERP)
Conduct Training (ERP)
Communicate To Employees (ERP)
Develop Training Schedule (ERP)
Develop In-house Training Programs (ERP)
Select External Consultants (ERP)
Manage Employee Redeployment (ERP)
Develop Benefits & Rewards Program (ERP)
Benchmark Benefits & Rewards Program (ERP)
Is The Program Competitive
Administer Compensation & Rewards To Employees (ERP)
Send request to payroll
Perform benefit/
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Start Free Trial
Administer benefit enrolment
Process requests for benefit claims from employee
Receive Claims (ERP)
Have Claims Been Received Within Time
Store For Next Month Processing (ERP)
Verify Claims
Return Claims To Sender For Correction (ERP)
Update & Approve Employee Payroll (ERP)
Receive Employee Request For Promotion (ERP)
Validate Documents Received
Prepare Documents For Next Committee Meeting (ERP)
Get approval from Committee
Update Employee Details (ERP)
Notify Employee (ERP)
Evaluate performance of existing products against market opportunities
Receive Request From Employee For Early Retirement (ERP)
Receive Notification From System Of Employee Eligibility For Retirement (ERP)
Verify Eligibility For Retirement
Correct System Error (ERP)
Determine Payout/ Benefits Of Employee (ERP)
Prepare Documentation For Processing For Approval (ERP)
Evaluate performance of existing products/services against regulatory requirements
Receive Request From Employee For Redeployment (ERP)
Receive Request From Organization For Services Of Specific Employee (ERP)
Validate Request
Update HR Records (ERP)
Submit Payment Info To Payroll (ERP)
Get Approval
Define regulatory requirements
Are There Positions Available For The Requested Deployment
Contact Relevant Manager With Employee Details (ERP)
Set Up Interview Between Employee & Manager (ERP)
Get Approval From Manager
Submit Documents To The Relevant Committee (ERP)
Get Approval From Committee
Receive Request With Request To Redeployment Costs (ERP)
Verify Request
Approve Request
Notify/Submit Request To Payroll (ERP)
Research and development of new products
Define research strategy
Define patents and copyrights requirements
Select and prioritise new product concepts
Confirm alignment of product concept with business strategy
Identify regulatory requirements
Define regulatory requirements for the organization with respect to research
Define regulatory submission life cycle with respect to product development life cycle
Conduct
Review infringement
Define patent and
Assess feasibility of
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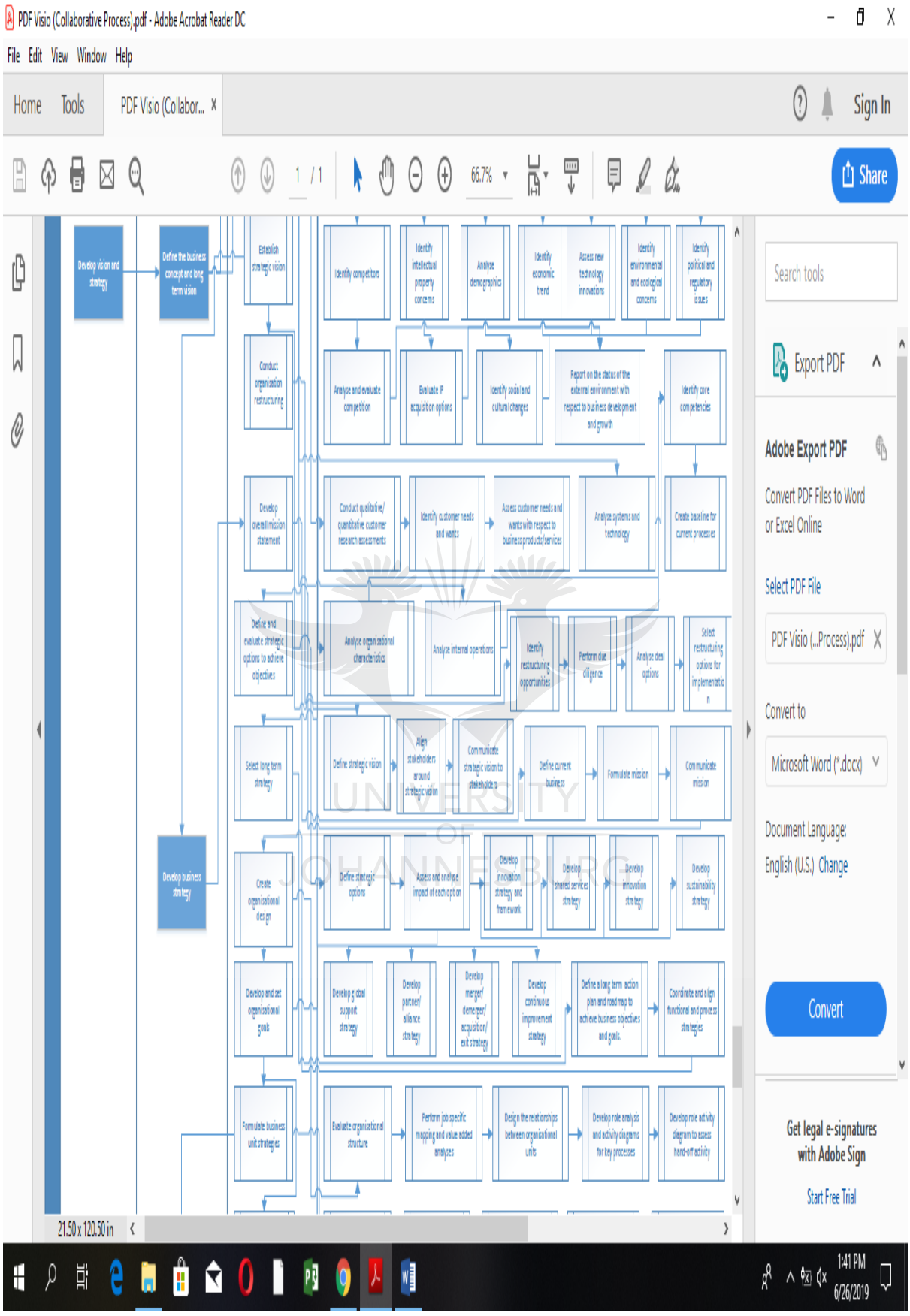
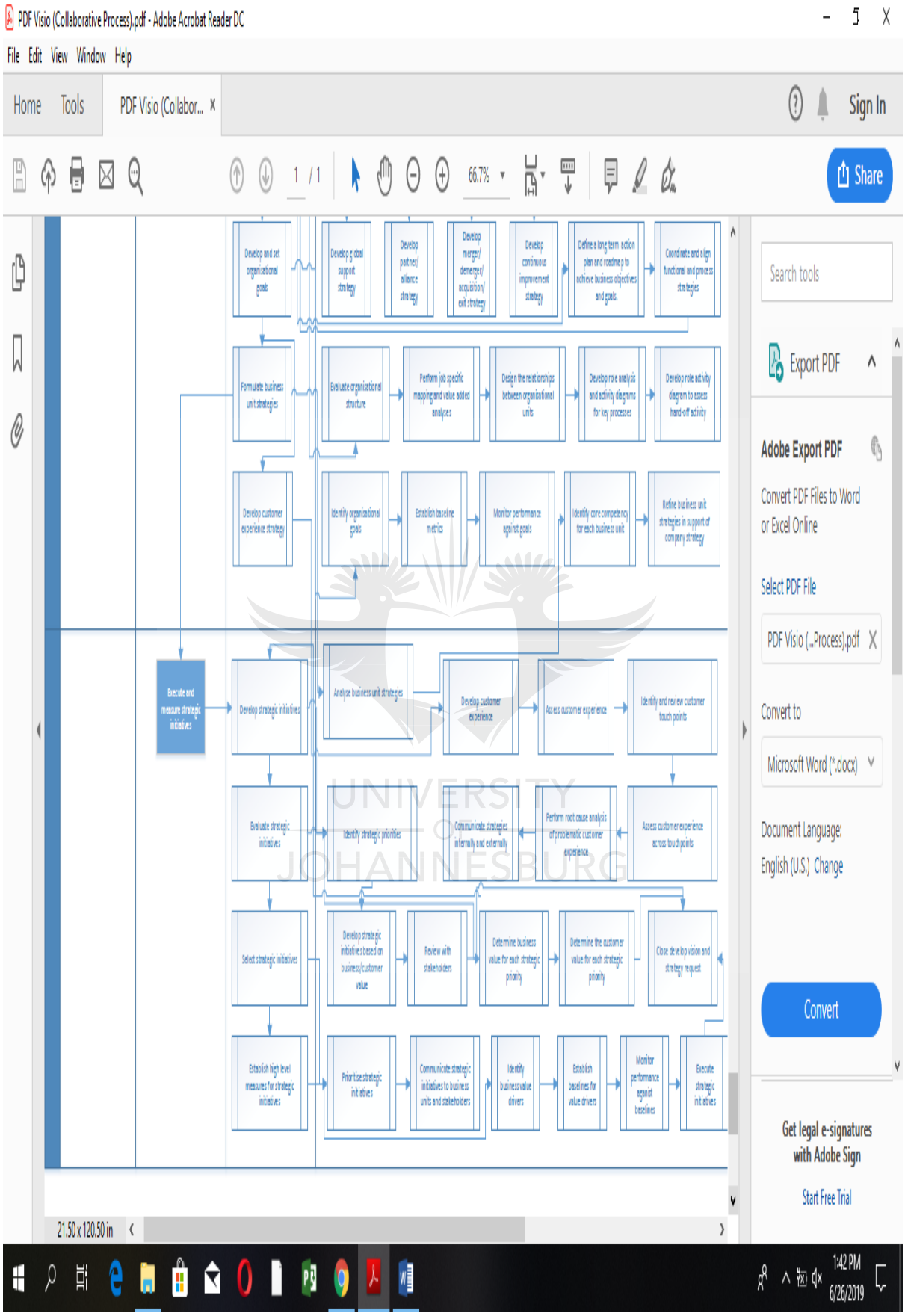
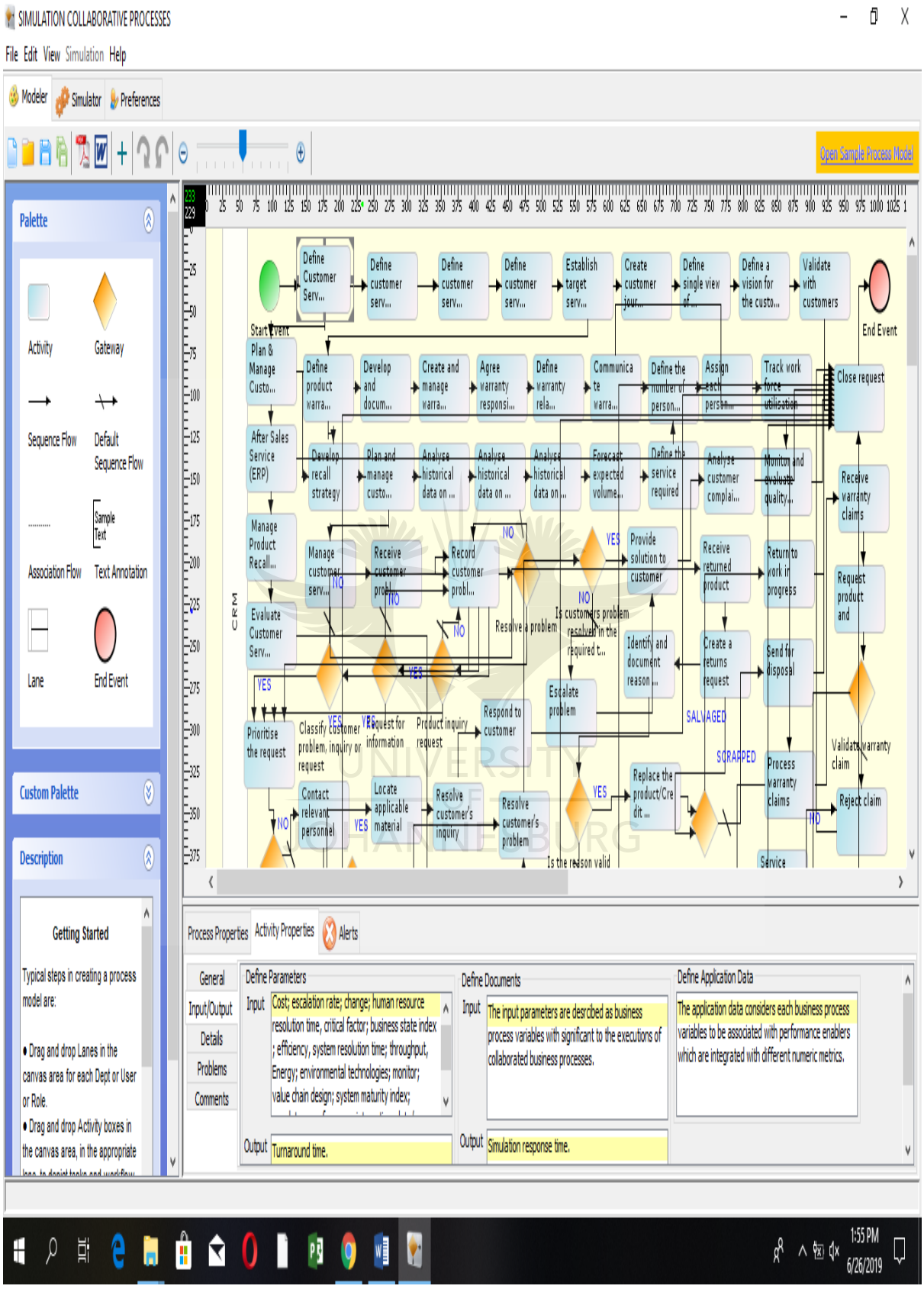
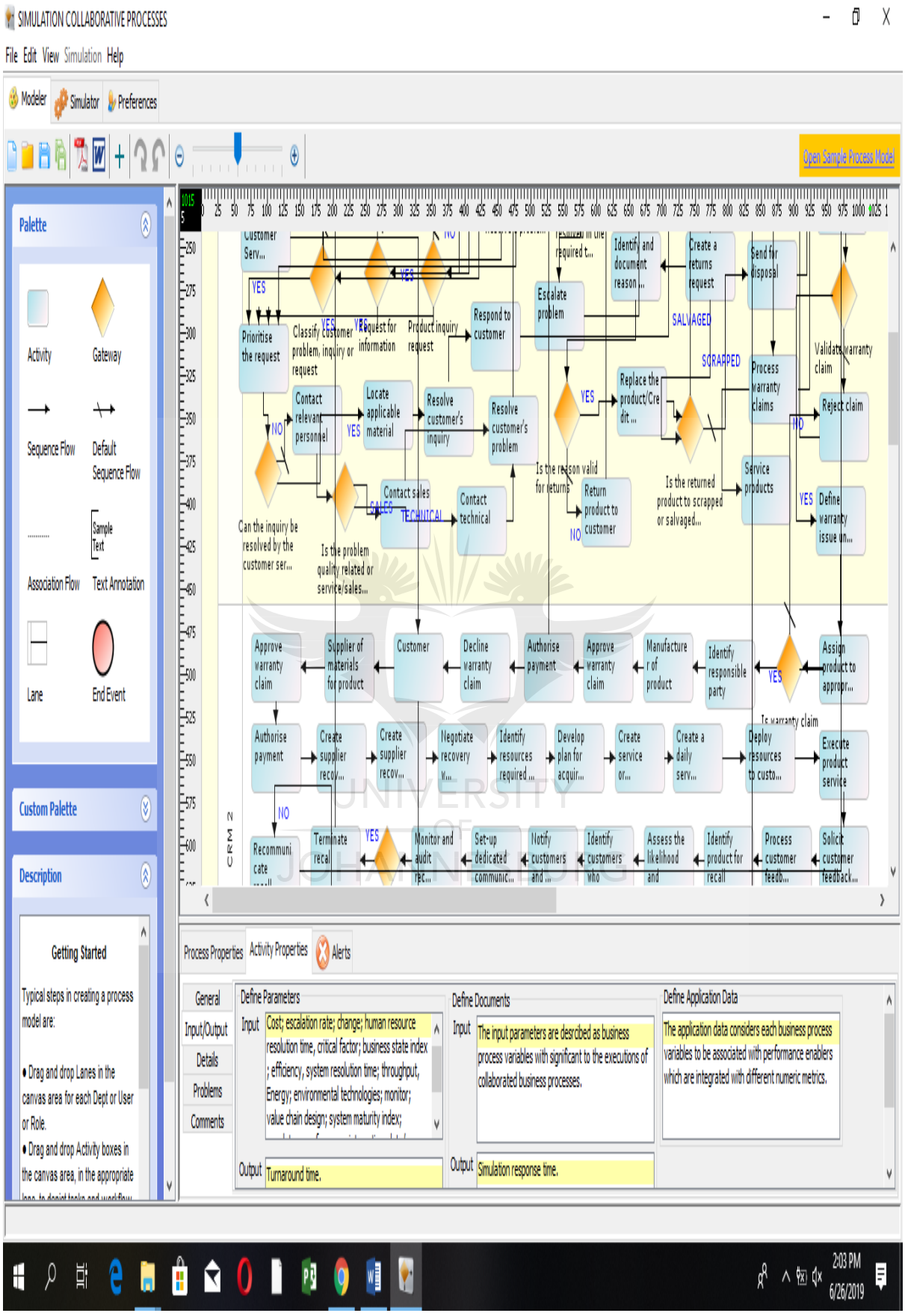




Appendix G: Simulation model configurations

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Palette
Activity
Gateway
Sequence Flow
Default Sequence Flow
Association Flow
Sample Text
Text Annotation
Lane
End Event
Custom Palette
Description
Getting Started
Typical steps in creating a process model are:
• Drag and drop Lanes in the canvas area for each Dept or User or Role.
• Drag and drop Activity boxes in the canvas area, in the appropriate
Prioritise the request
Classify customer problem, inquiry or request
Request for information
Product inquiry request
Respond to customer
Escalate problem
Identify and document reason ...
Create a returns request
Send for disposal
Contact relevant personnel
Locate applicable material
Resolve customer's inquiry
Resolve customer's problem
Replace the product/Credit ...
Process warranty claims
Validate warranty claim
Reject claim
Can the inquiry be resolved by the customer ser...
Is the problem quality related or service/sales...
Contact sales
Contact technical
Is the reason valid for returns
Return product to customer
Is the returned product to scrapped or salvaged...
Service products
Define warranty issue on...
Approve warranty claim
Supplier of materials for product
Customer
Decline warranty claim
Authorise payment
Approve warranty claim
Manufacturer of product
Identify responsible party
Assign product to appropr...
Authorise payment
Create supplier recov...
Create supplier recov...
Negotiate recovery v...
Identify resources required ...
Develop plan for acquir...
Create service or...
Create a daily serv...
Deploy resources to custo...
Execute product service
Is warranty claim
Recommunicate
Terminate recal
Monitor and audit rec...
Set-up dedicated communic...
Notify customers and ...
Identify customers who
Assess the likelihood and
Identify product for recall
Process customer feedb...
Solicit customer feedback...
CRM 2
Process Properties
Activity Properties
Alerts
General
Input/Output
Details
Problems
Comments
Define Parameters
Input
Cost; escalation rate; change; human resource resolution time, critical factor; business state index ; efficiency, system resolution time; throughput, Energy; environmental technologies; monitor; value chain design; system maturity index;
Output
Turnaround time.
Define Documents
Input
The input parameters are described as business process variables with significant to the executions of collaborated business processes.
Output
Simulation response time.
Define Application Data
The application data considers each business process variables to be associated with performance enablers which are integrated with different numeric metrics.
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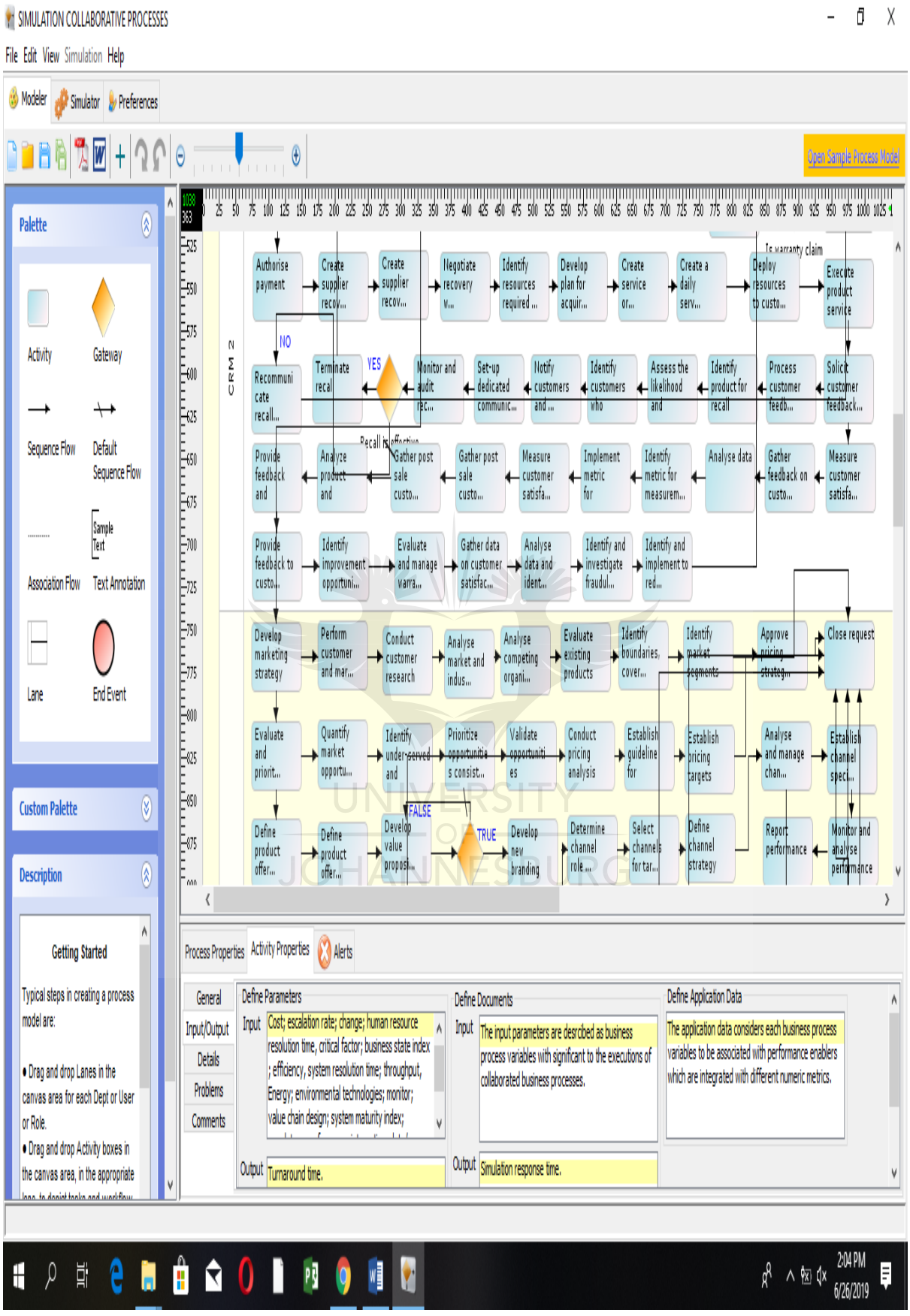
SIMULATION COLLABORATIVE PROCESSES
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Preferences
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Palette
Activity
Gateway
Sequence Flow
Default Sequence Flow
Association Flow
Sample Text
Text Annotation
Lane
End Event
Custom Palette
Description
Getting Started
Typical steps in creating a process model are:
• Drag and drop Lanes in the canvas area for each Dept or User or Role.
• Drag and drop Activity boxes in the canvas area, in the appropriate
CRM 2
Authorise payment
Create supplier recov...
Create supplier recov...
Negotiate recovery w...
Identify resources required ...
Develop plan for acquir...
Create service or...
Create a daily serv...
Deploy resources to custo...
Execute product service
Is warranty claim
NO
YES
Recommunicate recall...
Terminate recall
Monitor and audit rec...
Set-up dedicated communic...
Notify customers and ...
Identify customers who
Assess the likelihood and
Identify product for recall
Process customer feedb...
Solicit customer feedback...
Recall is effective
Provide feedback and
Analyze product and
Gather post sale custo...
Gather post sale custo...
Measure customer satisfa...
Implement metric for
Identify metric for measurem...
Analyse data
Gather feedback on custo...
Measure customer satisfa...
Provide feedback to custo...
Identify improvement opportuni...
Evaluate and manage warra...
Gather data on customer satisfac...
Analyse data and ident...
Identify and investigate fraudul...
Identify and implement to red...
Develop marketing strategy
Perform customer and mar...
Conduct customer research
Analyse market and indus...
Analyse competing organi...
Evaluate existing products
Identify boundaries, cover...
Identify market segments
Approve pricing strateg...
Close request
Evaluate and priorit...
Quantify market opportu...
Identify under-served and
Prioritize opportunities consist...
Validate opportuniti es
Conduct pricing analysis
Establish guideline for
Establish pricing targets
Analyse and manage chan...
Establish channel spec...
Define product offer...
Define product offer...
Develop value propost...
FALSE
TRUE
Develop new branding
Determine channel role ...
Select channels for tar...
Define channel strategy
Report performance
Monitor and analyse performance
Process Properties
Activity Properties
Alerts
General
Input/Output
Details
Problems
Comments
Define Parameters
Input
Cost; escalation rate; change; human resource resolution time, critical factor; business state index ; efficiency, system resolution time; throughput, Energy; environmental technologies; monitor; value chain design; system maturity index;
Output
Turnaround time.
Define Documents
Input
The input parameters are described as business process variables with significant to the executions of collaborated business processes.
Output
Simulation response time.
Define Application Data
The application data considers each business process variables to be associated with performance enablers which are integrated with different numeric metrics.
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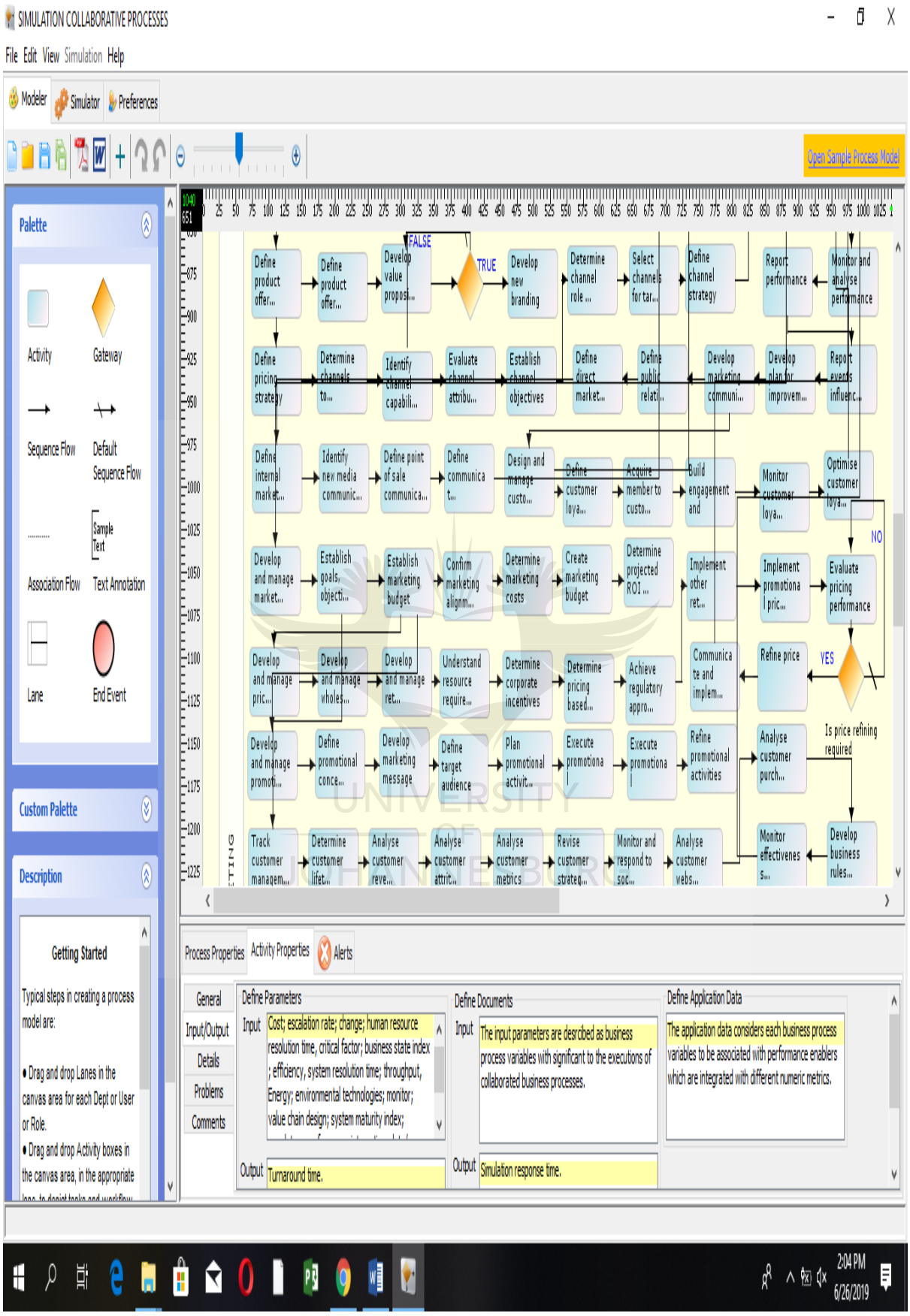
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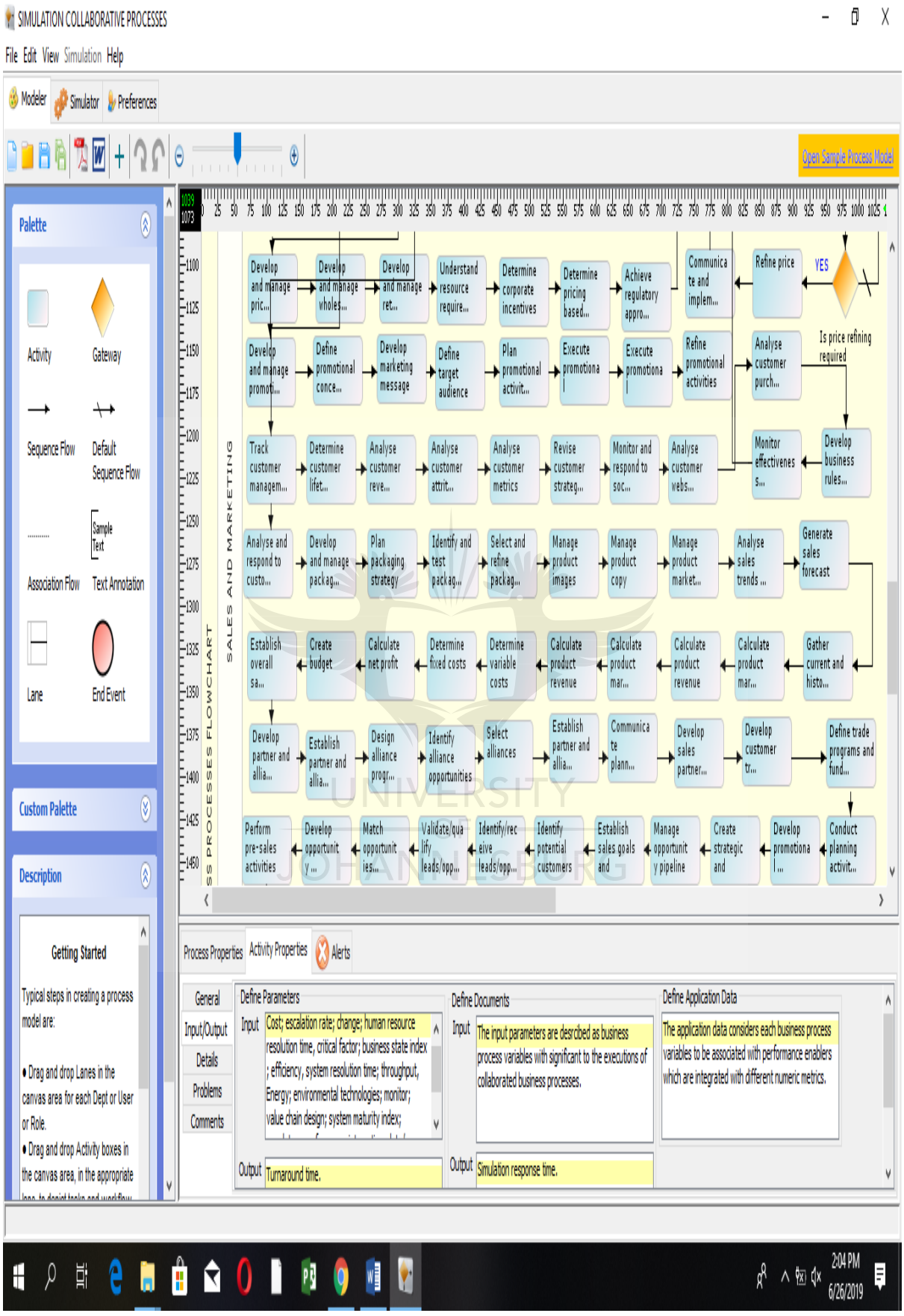
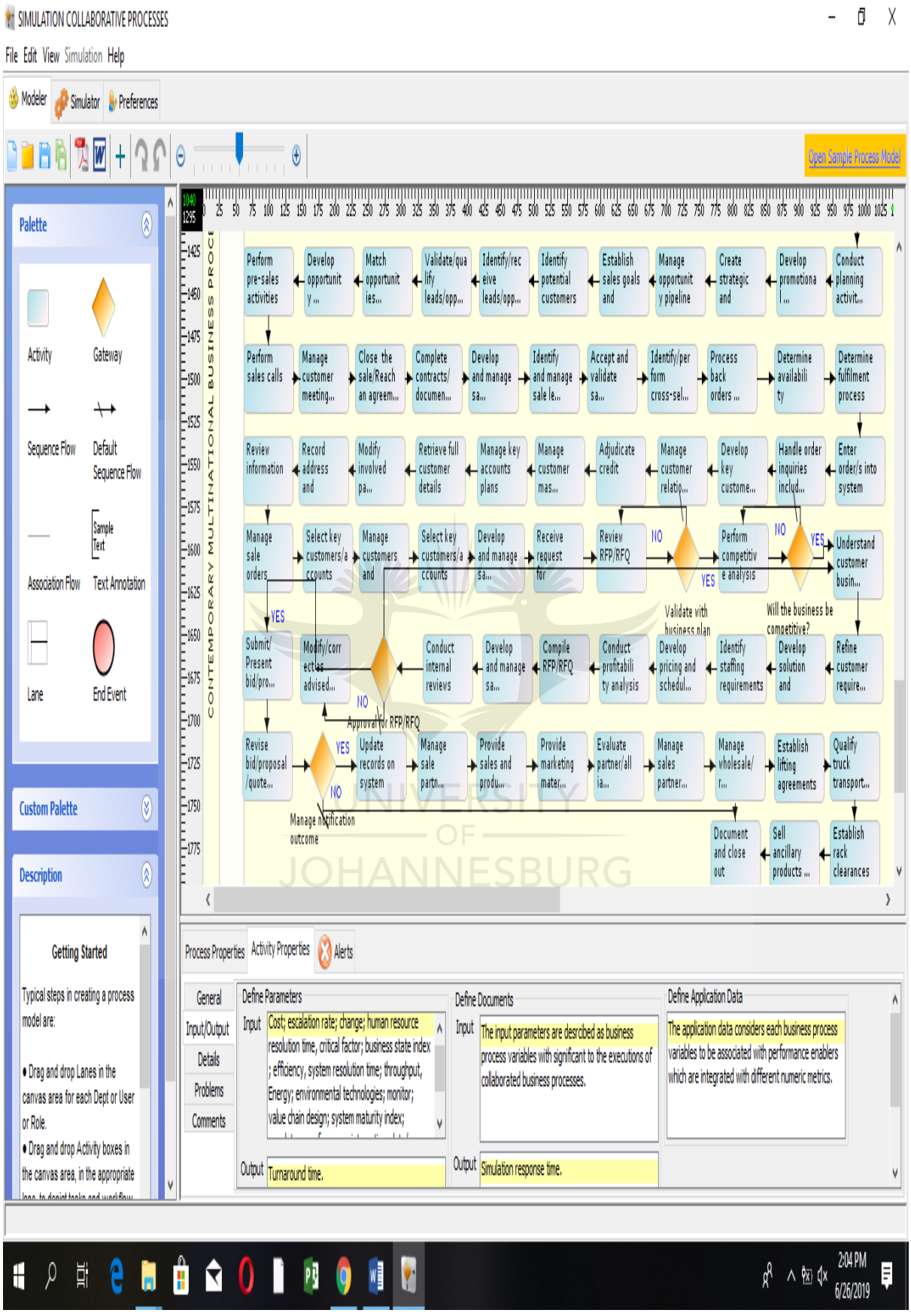
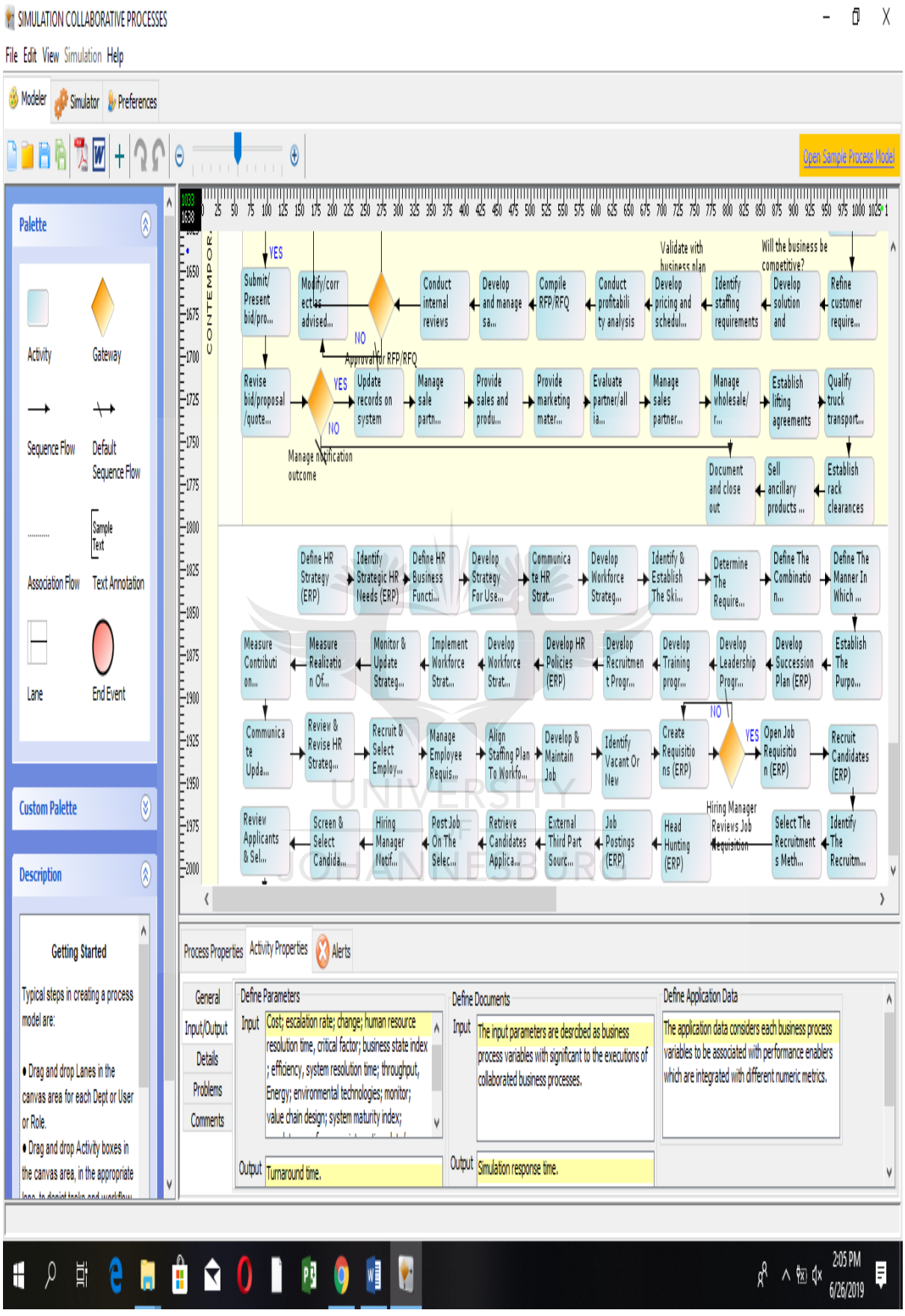
Simulator
Preferences
Open Sample Process Model
Palette
Activity
Gateway
Sequence Flow
Default Sequence Flow
Sample Text
Association Flow
Text Annotation
Lane
End Event
Custom Palette
Description
Getting Started
Typical steps in creating a process model are:
• Drag and drop Lanes in the canvas area for each Dept or User or Role.
• Drag and drop Activity boxes in the canvas area, in the appropriate
Define product offer...
Define product offer...
Develop value propos...
FALSE
TRUE
Develop new branding
Determine channel role ...
Select channels for tar...
Define channel strategy
Report performance
Monitor and analyse performance
Define pricing strategy
Determine channels to...
Identify channel capabili...
Evaluate channel attribu...
Establish channel objectives
Define direct market...
Define public relati...
Develop marketing communi...
Develop plan for improvem...
Report events influenc...
Define internal market...
Identify new media communic...
Define point of sale communica...
Define communica t...
Design and manage custo...
Define customer loya...
Acquire member to custo...
Build engagement and
Monitor customer loya...
Optimise customer loya...
NO
Develop and manage market...
Establish goals, objecti...
Establish marketing budget
Confirm marketing alignm...
Determine marketing costs
Create marketing budget
Determine projected ROI ...
Implement other ret...
Implement promotiona l pric...
Evaluate pricing performance
Develop and manage pric...
Develop and manage wholes...
Develop and manage ret...
Understand resource require...
Determine corporate incentives
Determine pricing based...
Achieve regulatory appro...
Communica te and implem...
Refine price
YES
Develop and manage promoti...
Define promotional conce...
Develop marketing message
Define target audience
Plan promotional activit...
Execute promotiona l
Execute promotiona l
Refine promotional activities
Analyse customer purch...
Is price refining required
Track customer managem...
Determine customer lifet...
Analyse customer reve...
Analyse customer attrit...
Analyse customer metrics
Revise customer strateg...
Monitor and respond to soc...
Analyse customer webs...
Monitor effectivenes s...
Develop business rules...
Process Properties
Activity Properties
Alerts
General
Input/Output
Details
Problems
Comments
Define Parameters
Input
Cost; escalation rate; change; human resource resolution time, critical factor; business state index ; efficiency, system resolution time; throughput, Energy; environmental technologies; monitor; value chain design; system maturity index;
Output
Turnaround time.
Define Documents
Input
The input parameters are described as business process variables with significant to the executions of collaborated business processes.
Output
Simulation response time.
Define Application Data
The application data considers each business process variables to be associated with performance enablers which are integrated with different numeric metrics.
2:04 PM
6/26/2019


SIMULATION COLLABORATIVE PROCESSES
File Edit View Simulation Help
Modeler
Simulator
Preferences
Open Sample Process Model
Palette
Activity
Gateway
Sequence Flow
Default Sequence Flow
Association Flow
Sample Text
Text Annotation
Lane
End Event
Custom Palette
Description
Getting Started
Typical steps in creating a process model are:
• Drag and drop Lanes in the canvas area for each Dept or User or Role.
• Drag and drop Activity boxes in the canvas area, in the appropriate
SALES AND MARKETING
Develop and manage pric...
Develop and manage wholes...
Develop and manage ret...
Understand resource require...
Determine corporate incentives
Determine pricing based...
Achieve regulatory appro...
Communica te and implem...
Refine price
YES
Is price refining required
Develop and manage promoti...
Define promotional conce...
Develop marketing message
Define target audience
Plan promotional activit...
Execute promotiona l
Execute promotiona l
Refine promotional activities
Analyse customer purch...
Track customer managem...
Determine customer lifet...
Analyse customer reve...
Analyse customer attrit...
Analyse customer metrics
Revise customer strateg...
Monitor and respond to soc...
Analyse customer webs...
Monitor effectivenes s...
Develop business rules...
Analyse and respond to custo...
Develop and manage packag...
Plan packaging strategy
Identify and test packag...
Select and refine packag...
Manage product images
Manage product copy
Manage product market...
Analyse sales trends ...
Generate sales forecast
Establish overall sa...
Create budget
Calculate net profit
Determine fixed costs
Determine variable costs
Calculate product revenue
Calculate product mar...
Calculate product revenue
Calculate product mar...
Gather current and histo...
Develop partner and allia...
Establish partner and allia...
Design alliance progr...
Identify alliance opportunities
Select alliances
Establish partner and allia...
Communica te plann...
Develop sales partner...
Develop customer tr...
Define trade programs and fund...
Perform pre-sales activities
Develop opportunit y ...
Match opportunit ies...
Validate/qua lify leads/opp...
Identify/rec eive leads/opp...
Identify potential customers
Establish sales goals and
Manage opportunit y pipeline
Create strategic and
Develop promotiona l...
Conduct planning activit...
Process Properties
Activity Properties
Alerts
General
Input/Output
Details
Problems
Comments
Define Parameters
Input
Cost; escalation rate; change; human resource resolution time, critical factor; business state index ; efficiency, system resolution time; throughput, Energy; environmental technologies; monitor; value chain design; system maturity index;
Output
Turnaround time.
Define Documents
Input
The input parameters are described as business process variables with significant to the executions of collaborated business processes.
Output
Simulation response time.
Define Application Data
The application data considers each business process variables to be associated with performance enablers which are integrated with different numeric metrics.
2:04 PM
6/26/2019

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Activity Properties
Alerts
General
Input/Output
Details
Problems
Comments
Define Parameters
Input
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Output
Turnaround time.
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Input
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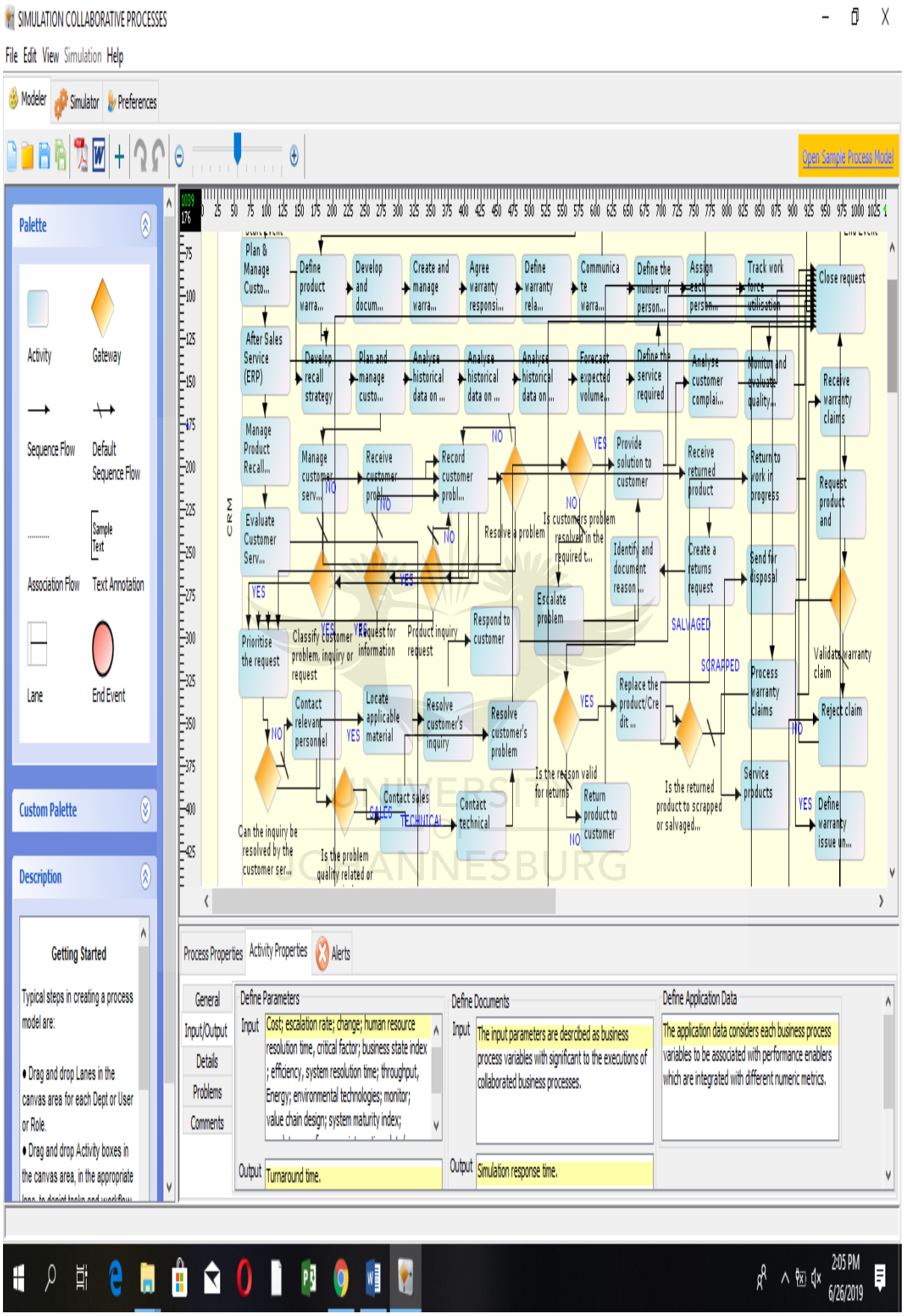
Output
Simulation response time.
Define Application Data
The application data considers each business process variables to be associated with performance enablers which are integrated with different numeric metrics.
2:05 PM
6/26/2019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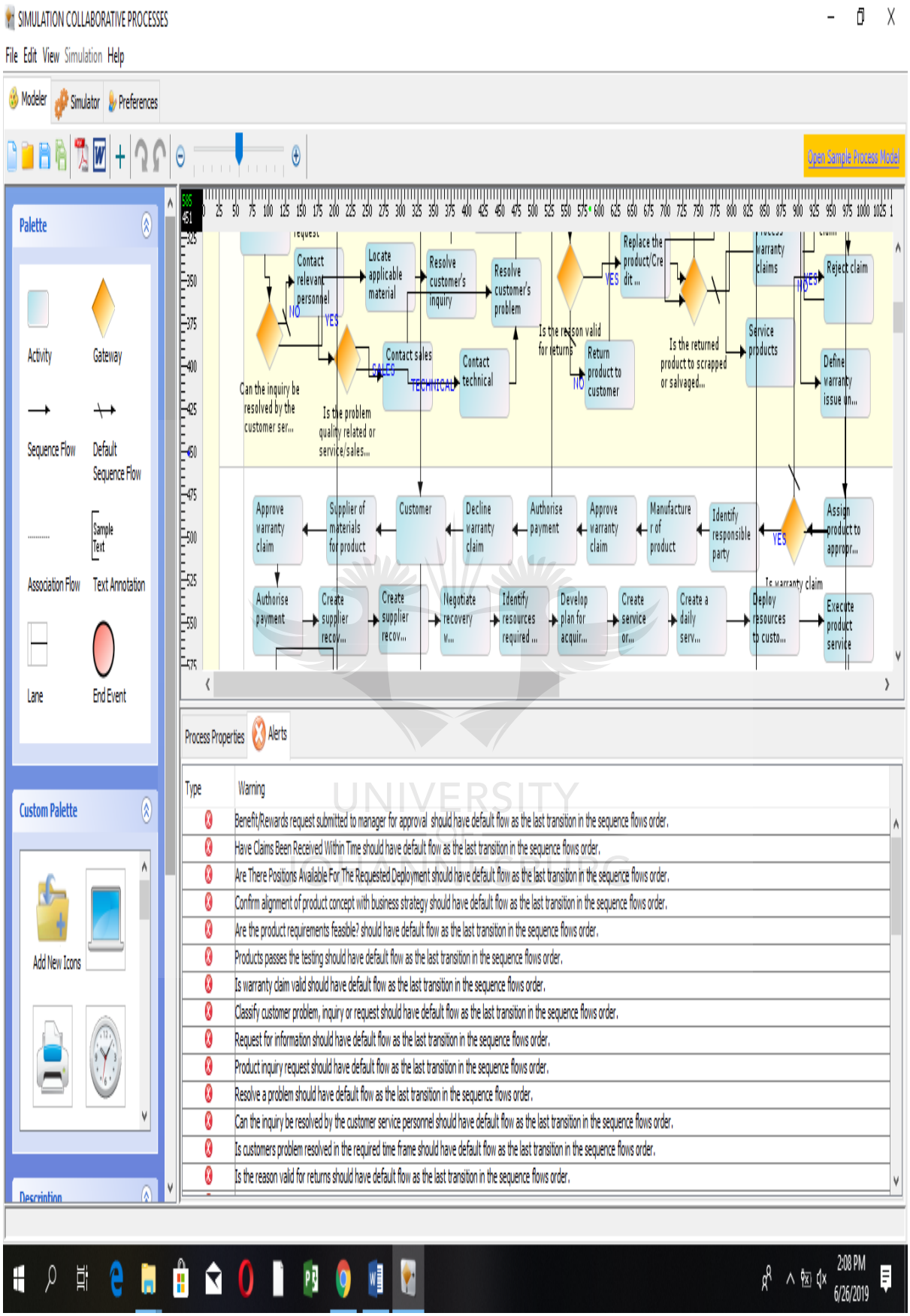
Preferences
Open Sample Process Model
Palette
Activity
Gateway
Sequence Flow
Default Sequence Flow
Sample Text
Association Flow
Text Annotation
Lane
End Event
Custom Palette
Description
Getting Started
Typical steps in creating a process model are:
• Drag and drop Lanes in the canvas area for each Dept or User or Role.
• Drag and drop Activity boxes in the canvas area, in the appropriate
Plan & Manage Custo...
Define product warra...
Develop and docum...
Create and manage warra...
Agree warranty responsi...
Define warranty rela...
Communica te warra...
Define the number of person...
Assign each person...
Track work force utilisation
Close request
After Sales Service (ERP)
Develop recall strategy
Plan and manage custo...
Analyse historical data on ...
Analyse historical data on ...
Analyse historical data on ...
Forecast expected volume...
Define the service required
Analyse customer complai...
Monitor and evaluate quality...
Receive warranty claims
Manage Product Recall...
Manage customer serv...
Receive customer probl...
Record customer probl...
Provide solution to customer
Receive returned product
Return to work in progress
Request product and
Evaluate Customer Serv...
Resolve a problem
Is customers problem resolved in the required t...
Identify and document reason ...
Create a returns request
Send for disposal
Prioritise the request
Classify customer problem, inquiry or request
Request for information
Product inquiry request
Respond to customer
Escalate problem
SALVAGED
SCRAPPED
Validate warranty claim
Contact relevant personnel
Locate applicable material
Resolve customer's inquiry
Resolve customer's problem
Replace the product/Cre dit ...
Process warranty claims
Reject claim
Is the reason valid for returns
Return product to customer
Is the returned product to scrapped or salvaged...
Service products
Define warranty issue on...
Contact sales
Contact technical
Can the inquiry be resolved by the customer ser...
Is the problem quality related or
CRM
Process Properties
Activity Properties
Alerts
General
Input/Output
Details
Problems
Comments
Define Parameters
Input
Cost; escalation rate; change; human resource resolution time, critical factor; business state index ; efficiency, system resolution time; throughput, Energy; environmental technologies; monitor; value chain design; system maturity index;
Output
Turnaround time.
Define Documents
Input
The input parameters are described as business process variables with significant to the executions of collaborated business processes.
Output
Simulation response time.
Define Application Data
The application data considers each business process variables to be associated with performance enablers which are integrated with different numeric metrics.
2:05 PM
6/26/2019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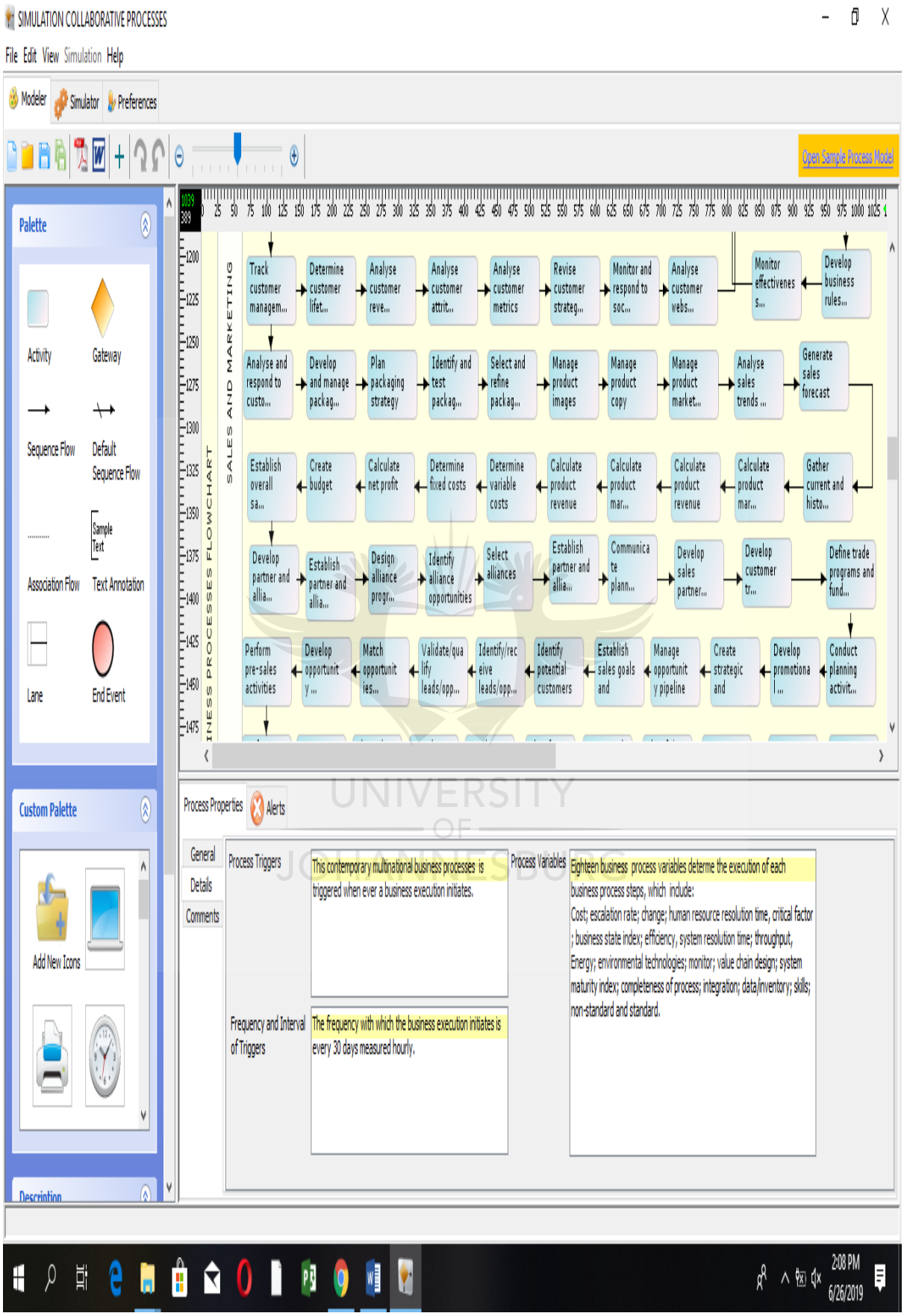
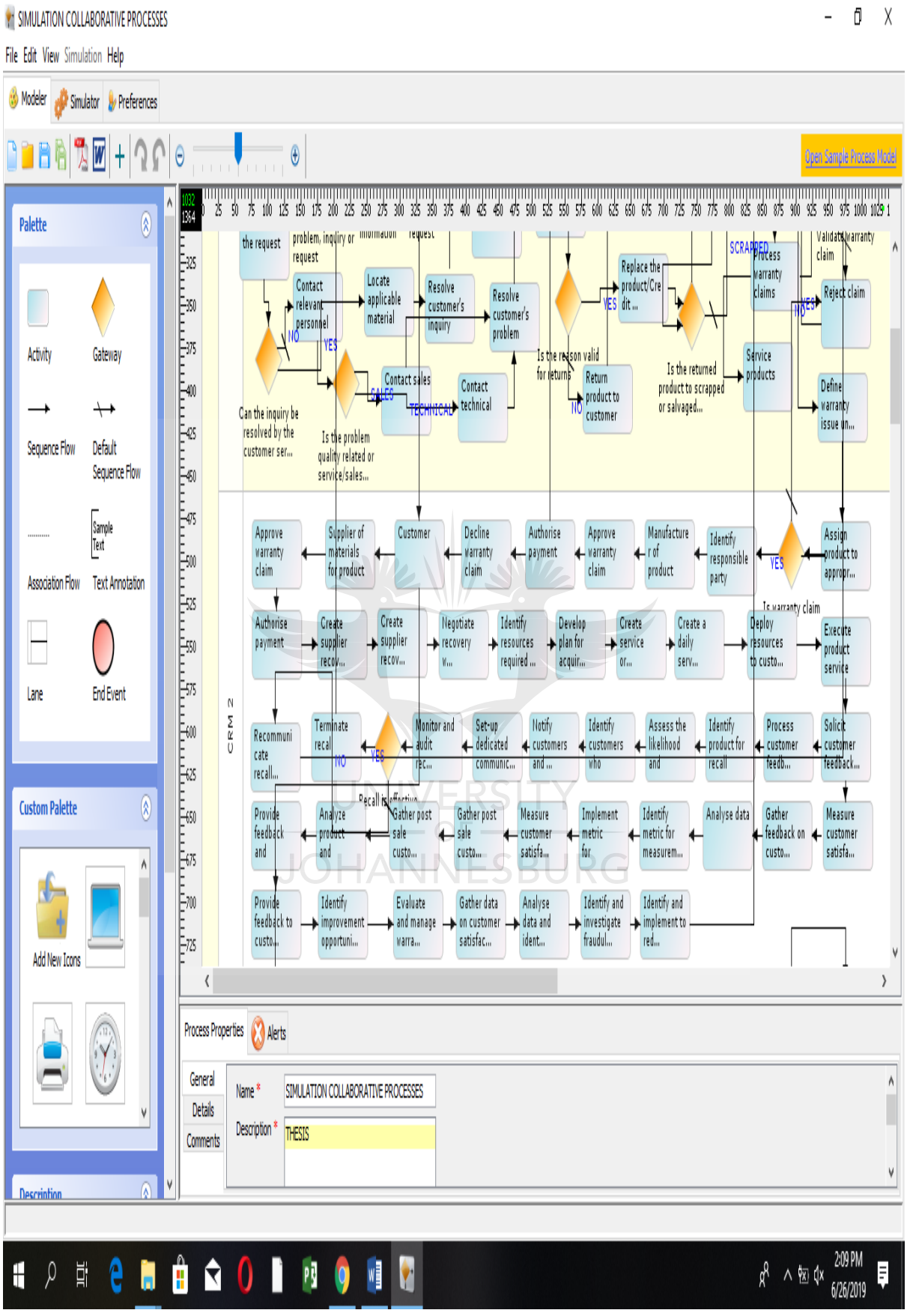
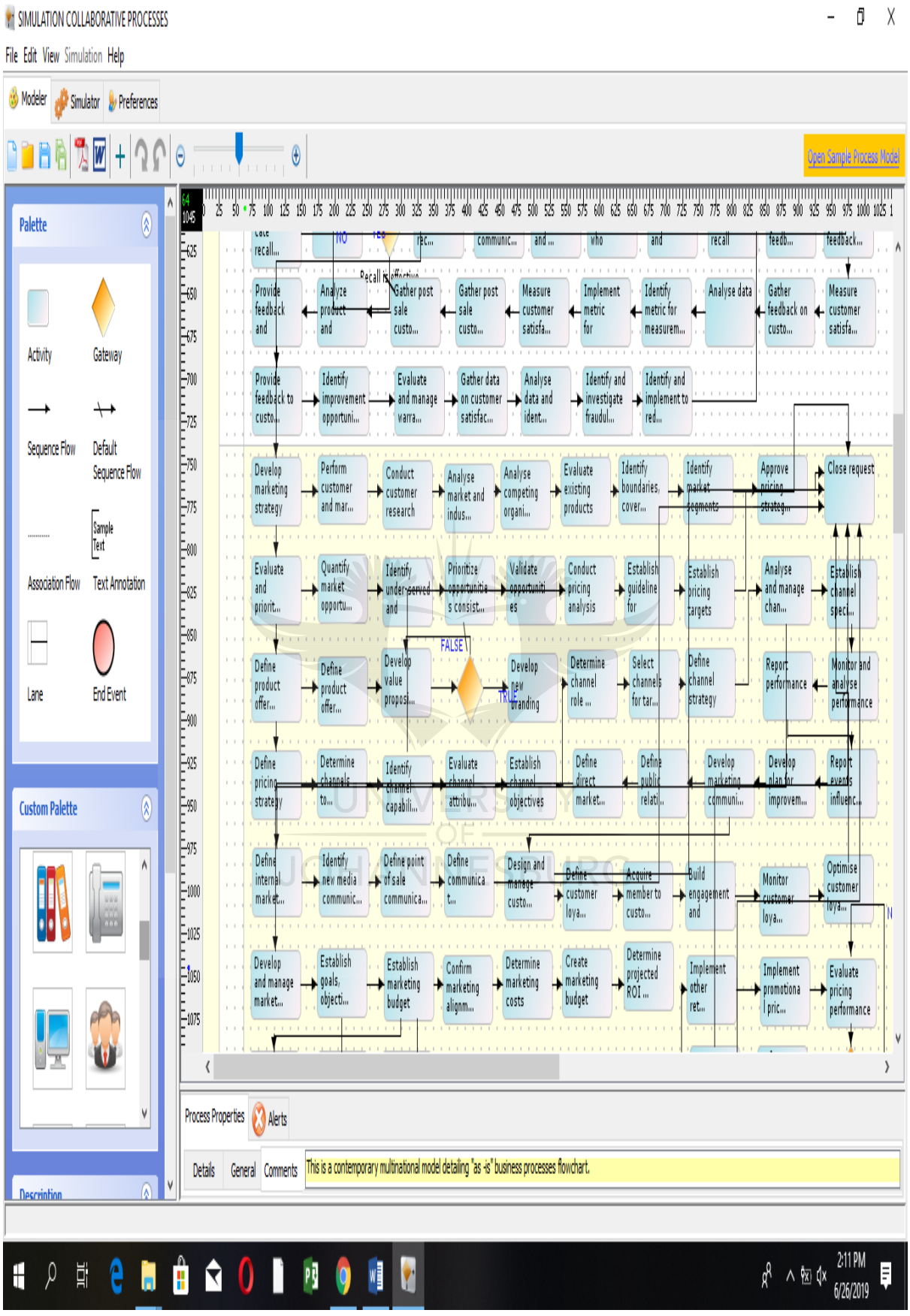
Preferences
Open Sample Process Model
Palette
Activity
Gateway
Sequence Flow
Default Sequence Flow
Association Flow
Sample Text
Text Annotation
Lane
End Event
Custom Palette
Add New Icons
Description
Contact relevant personnel
Locate applicable material
Resolve customer's inquiry
Resolve customer's problem
Can the inquiry be resolved by the customer ser...
Is the problem quality related or service/sales...
Contact sales
Contact technical
Is the reason valid for returns
Return product to customer
Replace the product/Credit ...
Is the returned product to scrapped or salvaged...
Service products
Reject claim
Define warranty issue un...
Approve warranty claim
Supplier of materials for product
Customer
Decline warranty claim
Authorise payment
Approve warranty claim
Manufacturer of product
Identify responsible party
Assign product to appropr...
Is warranty claim
Authorise payment
Create supplier recov...
Create supplier recov...
Negotiate recovery w...
Identify resources required ...
Develop plan for acquir...
Create service or...
Create a daily serv...
Deploy resources to custo...
Execute product service
Process Properties
Alerts
Type
Warning
Benefit/Rewards request submitted to manager for approval should have default flow as the last transition in the sequence flows order.
Have Claims Been Received Within Time should have default flow as the last transition in the sequence flows order.
Are There Positions Available For The Requested Deployment should have default flow as the last transition in the sequence flows order.
Confirm alignment of product concept with business strategy should have default flow as the last transition in the sequence flows order.
Are the product requirements feasible? should have default flow as the last transition in the sequence flows order.
Products passes the testing should have default flow as the last transition in the sequence flows order.
Is warranty claim valid should have default flow as the last transition in the sequence flows order.
Classify customer problem, inquiry or request should have default flow as the last transition in the sequence flows order.
Request for information should have default flow as the last transition in the sequence flows order.
Product inquiry request should have default flow as the last transition in the sequence flows order.
Resolve a problem should have default flow as the last transition in the sequence flows order.
Can the inquiry be resolved by the customer service personnel should have default flow as the last transition in the sequence flows order.
Is customers problem resolved in the required time frame should have default flow as the last transition in the sequence flows order.
Is the reason valid for returns should have default flow as the last transition in the sequence flows order.
2:08 PM
6/26/2019



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Description
Process Properties
Alerts
Details
General
Comments
This is a contemporary multinational model detailing "as -is" business processes flowchart.
Provide feedback and
Analyse product and
Gather post sale custo...
Measure customer satisfa...
Implement metric for
Identify metric for measurem...
Analyse data
Gather feedback on custo...
Provide feedback to custo...
Identify improvement opportuni...
Evaluate and manage warra...
Gather data on customer satisfac...
Analyse data and ident...
Identify and investigate fraudul...
Develop marketing strategy
Perform customer and mar...
Conduct customer research
Analyse market and indus...
Analyse competing organi...
Evaluate existing products
Identify boundaries, cover...
Identify market segments
Approve pricing strateg...
Close request
Evaluate and priorit...
Quantify market opportu...
Identify under-served and
Prioritize opportunitis consist...
Validate opportuniti es
Conduct pricing analysis
Establish guideline for
Establish pricing targets
Analyse and manage chan...
Define product offer...
Develop value proposi...
FALSE
TRUE
Develop new branding
Determine channel role ...
Select channels for tar...
Define channel strategy
Report performance
Monitor and analyse performance
Define pricing strategy
Determine channels to...
Identify channel capabili...
Evaluate channel attribu...
Establish channel objectives
Define direct market...
Develop marketing communi...
Develop plan for improvem...
Define internal market...
Identify new media communic...
Define point of sale communica...
Define communica t...
Design and manage custo...
Define customer loya...
Acquire member to custo...
Build engagement and
Monitor customer loya...
Optimise customer loya...
Develop and manage market...
Establish goals, objecti...
Establish marketing budget
Confirm marketing alignm...
Determine marketing costs
Create marketing budget
Determine projected ROI ...
Implement other ret...
Implement promotiona l pric...
Evaluate pricing performance
2:11 PM
6/26/2019

Appendix H: Mean, and standard deviation, of simulation random trials (decision nodes)

FACTOR	VALUE (Hours)
Mean	388.3
Standard Deviation	3.34
Minimum	383.6
Maximum	393.3
Count (Simulation runs)	10
Confidence Level (95.0%)	2.39

Appendix I: Experimental values (Source: Authors own compilation)

S/N	BUSINESS VARIABLES	PERFORMANCE ENABLERS	METRICS
1	**Automation**	Fully Enabled Automation	0.8
		Partially Enabled Automation	1.0
		No Automation	1.2
2	**System Resolution Time**	Full (Service Level Agreement) SLA Less Than 2HRS	1.0
		Full SLA Less Than 4HRS	1.05
		Partial SLA Less Than 6HRS	1.1
3	**Business State Index**	Less Than 1Yr Last Changed	1.0
		Less Than 2Yrs Last Changed	1.2
		Greater Than 2Yrs Last Changed	1.4
4	**Escalation Rate**	Manual-tier 2 ER	0.85
		Auto-tier 2 ER	0.75
		Manual-tier 1 ER	0.80
		Auto-tier 1 ER	0.70
5	**Critical Factor**	BASIC	1
		Not Critical (NC)	3
		Standard (STD)	5
		Very High Priority (VHP)	10
		Very Important Factor (VIF)	8
6	**Standard and Non-Standard**	Standard	0.8
		Neutral	1.0
		Non-standard	1.2
7	**Change**	Poor	0.50
		Good	0.75
		Excellent	1.00
8	**Human Resource Resolution Time**	Executive	36000secs
		Manager	18000secs
		Supervisor	7200secs
		Operations	3600secs
		Administrator	1800secs

		Manual	10800secs
9	**System Maturity Index**	Fully Enabled ERP	0.8
		Fully Enabled MES	0.8
		Connected PCN	0.8
		Module Specific MES	1.0
		Module Specific ERP	1.0
		Manual ERP	1.2
		Manual MES	1.2
		Manual PCN	1.2
10	**Monitor**	Poor	0.50
		Good	0.75
		Excellent	1.00
11	**Cost**	Low	1.0
		Medium	1.2
		High	1.4
12	**Value chain design**	Very High	0.35
		Fairly High	0.68
		Fairly Low	1.00
13	**Completeness of process**	Poor	0.50
		Good	0.75
		Excellent	1.00
14	**Integration**	Not Integrated	1.2
		Fully Integrated	0.8
		Partially Integrated	1.0
15	**Data/Inventory**	Fairly low	0.35
		Fairly High	0.68
		Very High	1.00
16	**Environmental Technologies**	Medium	0.2
		High	0.5
		Extremely High	0.8
17	**Efficiency/Energy**	Low	1.4

		Medium	1.2
		High	1.0
18	**Skills**	Fully-Skilled	1.2
		Partially-Skilled	1.0
		No-Skill	0.8

Appendix J: Matrix of (λ_2) FI combinations

EFFECTS	λ_2(ASCENDING ORDER)	ABSOLUTE EFFECTS (ASCENDING ORDER)	CUMULATIVE (%)
10.15	CK	41.875	11%
4.075	EJ	41.875	22%
-2.575	FG	41.875	34%
20.65	EG	21.05	39%
41.875	FJ	21.05	45%
20.45	KO	21.05	51%
20.45	CJ	20.65	56%
-21.05	EK	20.65	62%
41.875	FO	20.65	67%
20.65	GO	20.65	73%
4.225	CO	20.45	78%
41.875	EF	20.45	84%
-21.05	GJ	20.45	89%
-2.575	CE	10.15	92%
20.65	JK	10.15	95%
20.45	EO	4.225	96%
4.225	GK	4.225	97%
20.65	CF	4.075	98%
10.15	CG	2.575	99%
-2.575	FK	2.575	99%
-21.05	JO	2.575	100%

Appendix K: Matrix of (λ_3) FI combinations

EFFECTS	λ_2(ASCENDING ORDER)	ABSOLUTE EFFECTS (ASCENDING ORDER)	CUMULATIVE (%)
-22.025	CEF	22.025	14%
-0.325	CEO	19.75	24.46%
19.2	JKO	19.75	38.98%
5.975	CEJ	19.2	51.14%
19.75	EFJ	16.35	61.50%
5.975	EFO	13.4	69.99%
16.35	FGK	13.4	78.48%
-0.325	GJO	13.4	86.97%
-13.4	FGJ	7.325	91.61%
-7.325	CEK	5.975	95.39%
-13.4	EFG	5.975	99.18%
-0.325	CEG	0.325	99.38%
-0.325	EFK	0.325	99.59%
-13.4	FGO	0.325	99.79%
19.75	GJK	0.325	100.00%