Enhancing Enterprise Resource Planning and Manufacturing Execution System Efficiency with Simulation-Based Decision Support

***C Medoh, A Telukdarie**
Post Graduate School of Engineering Management, University of Johannesburg, South Africa.
***medoh6001@gmail.com**

Abstract

Business units inclusive of large, medium and small-scale entities traditionally conducts activities based on business processes. Globalization has resulted in the gradual introduction of various automation systems at various levels of the business enterprise, specifically focussed on capturing essential business activities across the entity. These systems, inclusive of Enterprise Resource Planning (ERP), Manufacturing Execution Systems (MES) and Plant systems has been adopted by larger corporates in executing and optimizing business functions. These large multinationals are described as complex entities with complex business structures inclusive of business processes. The quantification of automation, escalations and critical variables of these business processes has not been effectively conducted. A "systems thinking" approach adds the complexity of integrating all enterprise functions but creates a framework for evaluating the limitations and synergies so as to optimize these processes. This research focuses on the development and configuration of a simulation model for modelling enterprise maturity via business processes.

This research approach includes hierarchical layout and segregation of these business processes, exploring these enterprise operations adopting business process tools, techniques, and methodologies aligned with a system thinking approach. A simulation framework is configured and tested. The results prove that a simulation model potentially benefits a complex organisation specific to evaluating time taken to conduct business processes. The results indicate that interdependent processes can be modelled together with determining impacts of multiple critical variables in reducing business process time.

Keywords

Manufacturing Execution System, Enterprise Resource Planning, Plant systems, Business process optimization, Systems thinking.

Introduction/Background Context

Business Processes (BP's) forms a critical component of multinationals and large businesses in general. Enterprise activities are described by Marianne & Gregory; Paradiso & Cruickshank; Harmon as a collection of unified enterprise functions, adding value to process inputs, concurrently transforming these inputs into outputs. The process age has resulted in large business entities adopting several enterprise automation systems, in optimizing business functions (Ryan; Stephen; KO & Wah, 2009). A system is defined as a collection of several types of machinery or elements that collaborate to yield an output (Kasser & Mackley, 2008). Enterprise systems are described as a group of machinery or elements adapted to support the business functions of any Business Unit (BU) typically comprising ERP, MES and Plant Systems (PS). These technologies can work independently comprising elements presenting enterprise managers with a myriad of benefits, and can also collaborate so as to enhance performance service level of business systems. Interdependencies or synergies of these systems offer more leverage opportunities to BU's, which includes improved Turnaround Time (TAT); improved analytic capabilities; present holistic BP views; enhance operational efficiency; expedited business decision making.

Review of literature provides limited research in effectively quantifying BP's of MES/ERP/PS technologies collectively. Gove & Uzdzinski established that no singular integrated concepts have been adopted in assessing system optimization from design deployment, development stage to the operational utilization of business systems. This research seeks to develop and configure a framework to quantifying and optimizing business activities of these technologies as a singular integrated entity relative to TAT. Rechtin established that synergies between elements making up a system produces a system-level output, and adds value as a unit rather than the yield it provides as an independent entity. Ko & Wah argued for BU's to remain competitive in this era of organizational competitiveness, such business entities must strive towards shorter BP TAT. In order to accomplish the above objectives of this research, the following sub-objectives are outlined:

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

This research commenced by searching through literature on systems thinking approach, automation systems, and BP modelling tools together with techniques. A conceptual model resulting from the critical examination of literature is developed. This is followed by an illustration and presentation of this research methodologies. This research wraps up by presenting, conversing and synthesizing gathered information/findings into conclusions. Owing to time constraints aligned with major objectives of this research, three (3) hierarchical levels (level 1, 2 & 3) adapted from (Rosenberg, 2010) for BP‘s, developed and configured to 80% process accuracy is examined. These investigations are found to be intent for the purpose of this research.

Literature Review/Conceptual Approach

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

Numerous BP modelling tools, techniques, and methodologies have been introduced, inclusive of Microsoft Visio, ARIS toolset, ADONIS tool-set, visual paradigm tool-set, Bonapart tool-set, and simulation packages. As refined tool-sets for system optimization activities. Lättilä established, that Simulation software's comes into perspective when developing sophisticated or refined tools in decision support systems, and attempting to improve the efficiency of BP's. Microsoft Visio tools and techniques inclusive of Process Mapping (PM) is also regarded as one of the essential resources in improving BP's, illustrating "what BP's are executed", "who executes the BP's", "how they are executed" and "where they are executed". The first step in developing a process model is the definition (Exhibit 1) of the "critical variables", "states" and assumed "normal values" potentially affecting TAT in business process optimization. For simplicity of Exhibits, this research adopts the following acronym as presented: CV = Critical variables; N = Normal Values; SLA = Service Level Agreement; A = Human resource resolution time; B = System resolution time; C = Escalation rate/Critical factor; D = Business state index and E = System maturity index; VVIF = Very Very Important Factor; VIF = Very Important Factor; STD = Standard; NC = Not Critical; MT = Manual Tier; AT = Auto Tier.

Human Resource Resolution Time

(Hui & Qian, 2004) described this variable as the total time between when a human resource initiate and resolves a specific business task. Human resource resolution time is an essential variable as it has consequential impacts on overall business productivity, hence adopted as one of the proposed variables utilized in executing this research objectives. In this research, human resource resolution time is defined in six (6) associate levels so as to delineate different resolution time metrics. Proposed States include "Executive human resource resolution time", "Administrator human resource resolution time", "Manager human resource resolution time", "Supervisor human resource resolution time", "Operations human resource resolution time", and "Manual human resource resolution time".

Escalation Rate/ Critical Factor

Mori, defined "Escalation" as a methodology that refers to the fast lining of BP's, which has not been attended to or could not be resolved, and is transferred to another resource line. Escalation rate is thus, the delay time a process step encounters before been passed to a senior or another resource personnel. This variable delineates the potential to escalate a non-response, and a very essential variable having significant impacts on business functions (Mori, 2007). This variable is therefore adopted as one of the proposed variables utilized in executing this research objectives. Escalation rate necessitates a framework in eliminating unnecessary business delay time. "Manual tier 1 escalation", "Auto tier 1 escalation", "Manual tier 2 escalation" and "Auto tier 2 escalation" are the four (4) States proposed in this research for illustrating several escalation rates.

Critical factor describes a business terminology adopted in defining a process, at which one or more enterprise functions of a BU must undergo during execution phase, so as to achieve its set targets. This variable aligned with escalation potential illustrates critical core areas where process steps must be differentiated in order of hierarchy and importance, for efficient enterprise management (Koutsikouri, Dina, Dainty, Andrew and Austin, & Simon, 2006). This variable is therefore adopted in this research for achieving its set objectives. Process theory concepts adapted from Markus and Tanis is adopted in classifying this variable into five (5) critical factor States. This concept places attention on the succession of process steps directed towards process execution completion, these States includes: Very Very Important Factor (VVIF), Very Important Factor (VIF), Standard (STD), Not Critical (NC), and BASIC.

- Very Very Important Factor (VVIF): Task in process steps having major impact, requiring high escalation potential together with urgent attention by a top management team.
- Very Important Factor (VIF): Process steps requiring prompt attention with medium escalation potential.
- Standard (STD): Business functions requiring urgent attention with minimal escalation potential.
- Not Critical (NC): These are process steps which a BU should attend to but not a compelling task. Describing business activities for which there is no urgent time necessity in resolving them.
- BASIC: Described as a regular business function in a BU referring to BP's that happens normally.

These two variables are aligned simultaneously in investigating impacts of adopted variables on response time.

System Resolution Time

This variable refers to the total time taken by a system to initiate and resolve specific input to output (Subramanyam, 2012). System resolution time describes the total time taken by a system to complete a task, and a very critical variable with consequential impacts on business activities. The system resolution time is dependented on the status of maturity of the system in question(ERP/MES). System resolution time is adopted as one of the proposed variables utilized in executing this research objectives, and differentiated into eight (8) system States relative to either a manual or an automated process. These States include "Fully enabled ERP", "Module specific ERP", "Manual ERP", "Fully enabled MES", "Module specific MES", "Manual MES", "Connected Plant Control", and "Manual Plant Control". ERP, MES together with plant systems are the technologies under focus in evaluating this variable.

System Maturity Index

(Ryan, & Joe, 2013) defined system maturity index as an objective KPI adopted for facilitating system technology maturity optimization. This variable formally defines terms of any BU service contract, which includes TAT it takes an enterprise system to complete a business request, specifically a system incident. Evaluating system maturity index is very critical in assuring enterprise continuity which includes short and long term business goals (Paschke, and Schnappinger, 2006). This variable is therefore adopted as one of the proposed variables utilized in executing this research objectives. This research proposes four (4) system maturity index States in utilizing this critical variable, which include “Full Service Level Agreement (SLA) Less Than 2hrs”, Full SLA Less Than 4hrs”, “Partial SLA Less Than 6hrs”, and “Partial SLA Less Than 8hrs”. The logic behind adopted States is that this research proposes an entity must evaluate its system maturity index at a specific time cycle. SLA is thus an important KPI in investigating this variable, as it assist business entities set expectations and boundaries. Appraising an enterprise system maturity level, abreast such BU’s with information about distinct stand point in-terms of strength, weakness and status in the global maturity framework (Ibbs & Kwak, 2000).

Business State Index

Business state index is defined as a measure of the development stage of any BU. Determining if the business entity is achieving minimum set improvement targets. This variable helps to reflect an entity present and future business goals, by presenting a framework which can be adopted for performing regular business analytics through identifying a BU essential success factors and implement calculated metrics without difficulty (Paschke & Schnappinger, 2006). This variable is adopted as one of the proposed variables utilized in executing this research objectives. Three (3) States is proposed in this research when utilizing this critical variable, which includes “Greater Than 2yrs Last Changed”, “Less Than 2yrs Last Changed”, and “Less Than 1yr Last Changed”. Numerous benefits exists in appraising an enterprise business state index, these benefits is established in previous researches as adapted from (Shafiei, 2014; Subramanyam, 2012; Garimella & Williams, 2008; and Paschke & Schnappinger, 2006).

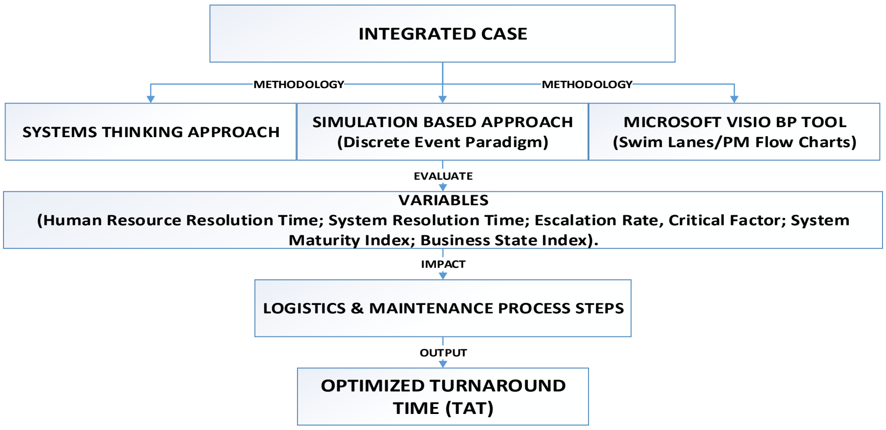
This research adopts systems thinking approach together with simulation and Visio BP modelling tools and techniques in presenting and optimizing proposed integrated case. These tools, techniques and methodologies is brought together to develop, configure, analyse and illustrate these proposed critical variables “human resource resolution time”, “escalation rate”, “critical factor”, “system resolution time”, “system maturity index”, and “business state index” with distinct associated constraints has an impact on process TAT relative to logistics and maintenance systems. Synopsis of these variables is presented below.

This research adopts a systems thinking approach together with simulation and Microsoft Visio modelling tools and techniques in presenting and optimizing proposed integrated case. These tools, techniques, and methodologies are brought together to develop, configure, analyse and illustrate these proposed critical variables “A”, “B”, “C”, “D”, and “E” with distinctly associated business states has an impact on process TAT relative to logistics and maintenance systems.

Methodology

The critical variables and the logistics/maintenance process (Exhibit 1) below, is adopted as a mixed methodology for this research. The details are expanded below.

Exhibit 1: Conceptual Model Presenting an Overview of the Proposed Case for Integration.



The proposed integrated case develops an experimental and optimized framework to test scenarios, impacts, and potential benefits of determined critical variables, relative to optimizing TAT of process steps making up these integrated systems (ERP, MES & PS). Though numerous enterprise functions exist, logistics together with maintenance systems is described by previously established research as core enterprise functions of these technologies. These business operations are reasoned to be among the essential differentiators for optimum process optimization operations in large corporates, relative to international best practices (Al-Turki, Ayar, Yilbas, & Sahin, 2014; Wang & Wang, 2013; Malamura and Murata, 2012; Lättilä, 2012). These core enterprise functions are therefore deemed appropriate in accomplishing this research set objectives, aligned with Microsoft Visio tools and techniques which is also found very effective for the intent of this research (Bradford, 2015; Gregory, 2015; Grigoryev, 2015; Sargeant, 2013; Lättilä, 2012; Marianne, & Ahmadi, 2012; Malamura, and Murata, 2012). For simplicity of this research objectives, proposed critical variables detailed above is also found effective and efficient (Ryan & Joe, 2013; Subramanyam, 2012; Mori, 2007; Koutsikouri, Dina, Dainty, Andrew and Austin, & Simon, 2006; Paschke & Schnappinger, 2006; Hui & Shelly, 2004; Markus and Tanis, 2000) in investigating process steps of these automation systems. Simulation-based decision support approach is adopted in testing the effects of these critical variables, at different proposed business states. Synopsis of adopted business states is detailed in later sections of this research. Testing or quantifying the impacts of determined critical variables on BP's, necessitates a framework for enterprise scholars and managers, to holistically view the entirety of processes (auto & manual) making up these integrated technologies (top floor to shop floor).

Systems Thinking Approach

Souvairan defined "system thinking" as an approach which utilizes tools in identifying and understanding leverage points of interdependent structures. Bringing about desired outcomes of dynamic systems. This approach involves studying and illustrating BP's holistically, observing how changes in one or more critical variables affect other critical variables or the entire system. System thinking presents a framework for illustrating interdependencies or interrelationships of processes, rather than static activities of these processes (Senge, 2006). Adopting system thinking concepts in any BU develops a practical approach platform, in managing international best practice development projects or activities in the era of complexity. Balancing BP's in terms of delays, limits and behavior over time (Richmond & Peterson, 2001). This research seeks to investigate "leverage points of logistics and maintenance BP's" and "time behavior of these BP steps" relative to process TAT, hence justification of a "systems thinking" methodology for this research.

Visio (Modelling & Process Mapping Approach)

The Visio toolset is described by Sargeant as a tool adopted for BP modelling projects globally, and utilized for a variety of business functions within the context of respective set targets. Microsoft Visio tool is a software that can be adopted when attempting to develop a framework of BP's before actual modelling and simulation actions occur. Macal & Sterman established the necessity to develop comprehensive objectives and design an extensive framework before commencing any modelling and simulation design. This approach integrates PM flowcharts and swim lane techniques in illustrating a detailed BP step information of logistics together with maintenance functional processes. PM is one of the integral functions of Microsoft Visio software (Hussain, 2015). PM is defined by Walter as a tool which aids in understanding and defining a process, providing visualization of how these BP's produces an output. PM necessitates a framework in studying the intricacies of BP's, together with the necessity to capture and envisage knowledge that resides with business managers, who executes various functions in a BU (Hussain, 2015).

Simulation (Decision Support tool-set) Approach

Malamura and Murata established that simulation tools are the most globally adopted operations research techniques adopted for process optimization activities. This tool-set allows for any arbitrary model complexity and circumvents analytically intractable models. The simulation approach has the ability to recognize or envisage logics behind a BP, challenges, and upgrade of a business entity, also exploring process traits for different BP steps or parameter values (Podnar & Mikac, 2001). Lättilä affirmed that simulation tool comes into perspective when developing sophisticated or refined tools in decision support systems, and trying to optimize the efficiency of BP's. Ilya validated this knowledge, by establishing that simulation and modelling presents a base in developing a framework that makes use of mathematical languages or rules in representing real-world systems for process optimization. Gopakumar established that configuring a discrete event simulation model within processes, presents a platform towards decreasing TAT. Karnon also described discrete events models as performing well in almost any process where there is variability, constrained, or limited resources or complex systems interactions, providing a sensitive and non-rigid approach to representing intricate systems. The variables are configured in Anylogic specific to each BP(Grigoryev, 2015).

Variables Constraints, KPI's and Parameters

The key question relates to the impact of business critical variables with associated business states on BP's. There are a large number of critical variables which can be investigated in measuring the success of any BU process steps. This research has simplified the complexities by limiting the critical variables to "Human resource resolution time", "Escalation rate", "Critical factor", "System resolution time", "System maturity index" and "Business state index". These six (6) critical variables is adopted in presenting an integrated case. Escalation rate and critical factor work concurrently in effecting TAT of process steps. Adopted numeric values are utilized for the purpose of measuring and testing the validity of this research critical variables. During simulation runs, this research data refers to (Cstd), the addition of a (+0.1) factor to (Cstd) refers to (Cmax), while subtraction of a (-0.1) factor to (Cstd) refers to (Cmin). Numerous intermediate options exist when trying to evaluate for an infinitesimal time distribution difference between these critical variables. This research has simplified the complexities by limiting these intermediate options to (+0.1) and (-0.1) range of constraints. This range is found the best fit and limit complexities in meeting this research objective. Achieved after investigating several intermediate options adopting simulation-based decision support approach. A 30 days duration is proposed as BP steps.

Research Findings/Analysis

This research adopts sequential investigations in exploring insights into proposed integrated case. Executed by investigating interactions together with significant impacts, between determined critical variables aligned with associated business states. Adopting this sequential methodology is one major limitation of this research, but is found fit for the major objectives of this research at masters' level. Attention is directed into developing an established experimental design/model for future studies. The Business process and critical variables were configured for simulation in Anylogic software.

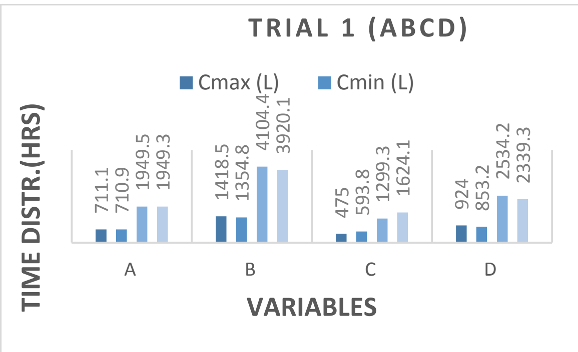
This research adopts a three-tier simulation process in determining the impact of these critical variables, so as to logically understand the effect(s) of the distinct (individually and in combination) critical variable on response time. Tier 1 adjusted these critical variables individually one at a time, trail 2 examines these critical variables in multiples of two, while tier 3 investigates these critical variables grouped in three(s), four(s), and five(s). Each tier investigates impacts of these critical variables at distinct business states set (Cstd, Cmax, and Cmin). This research assumes activation of the escalation rate potential is dependent on certain critical factor states (VVIF, VIF, STD, NC, and Basic) aligned with distinctly associated multipliers. Thus, these two (2) critical variables (escalation rate and critical factor) is executed in any large corporate aligned together. This research, therefore, integrates these two (2) critical variables as one (1) unit, in testing for impacts together with interactions of these critical variables on response time. Patterns, results, statistical graphs, analysis and deductions of distinct iterations is presented in the themes below.

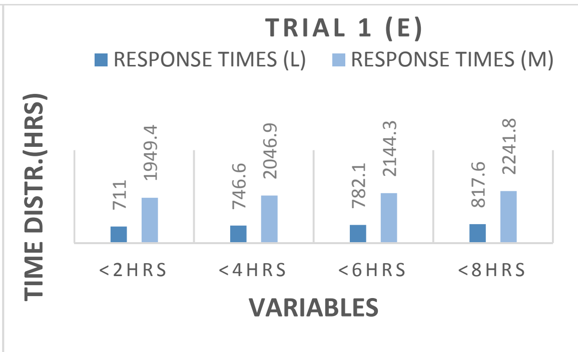
Tier 1: Individual Critical Variable

At Cstd: All critical variables are set at the midpoint to obtain response time. This response time is adopted when testing for best optimization scenarios of these critical variables, comparing with Cmax and Cmin business states. This research assumes at the midpoint (Cstd), critical factor aligned with escalation rate has not been integrated, therefore has a zero (0) numeric metric. Business state index change policy of greater than (2) years aligned with associated numeric metric (1) is also adopted at Cstd. For simplicity of iteration exhibits, this research assigns letters L = Logistics and M = Maintenance. Normal values (N) in hours as obtained from simulated case is (N (L) = 711 and N (M) = 1949.4). **At Cmax:** All critical variables set at the midpoint. Individual critical variable is adjusted one at a time to Cmax so as to investigate distinct change on response time. Business state index change policy of less than (1) year aligned with associated numeric metric (1.3) is adopted at Cmax. **At Cmin:** All critical variables set at the midpoint. Individual critical variable is adjusted one at a time to Cmin so as to investigate distinct change on response time. Business state index change policy of less than (2) years aligned with associated numeric metric (1.2) is adopted at Cmin.

Further examinations are required when investigating system maturity index (critical variable E), thus examined separately. This critical variable is categorised into four states as detailed in previous sections of this research. Individual state aligned with distinct resolution time is investigated one at a time, to ascertain the impacts of system downtime or breakage on process response time. This research assumes ten system downtime for each resolution scenario investigated. Outputs and graphical illustrations obtained from tier 1 are presented in Exhibits 2 and 3 below.

Exhibit 2: Critical variables ABCD outputs and graphical illustrations Exhibit 3: Variable E Outputs and Graphical Illustration.



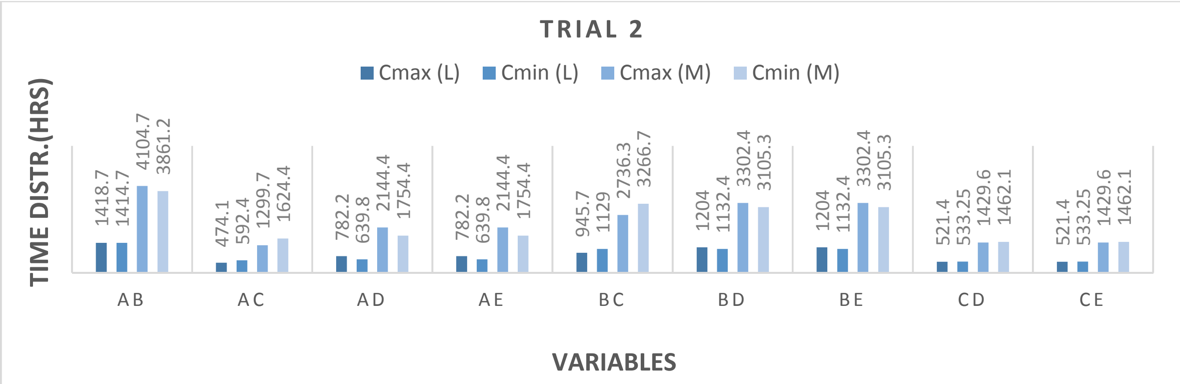


Deductions: Findings from outputs and combined statistical graphs presented above illustrates after comparison with Cstd, that critical variables ABD all increases when setting at Cmax and decreases when setting at Cmin. Outputs illustrate a significant time reduction in response time when integrated with critical variable C. Results also shows critical variable C decreases when setting at Cmax and increases when setting at Cmin. Analysed outputs show best optimization state, for any large corporate with a business state index change policy of greater than (2) years. As there is significant time increase when testing for this critical variable at Cmax and Cmin business states. Analysis of system maturity index investigations also illustrates lowest response time for BU's with a full SLA system maturity index policy aligned with a resolution time of less than two (2) hours. This research, therefore, adopts a full SLA system maturity index policy aligned with a resolution time of less than two (2) hours and a business state index change policy of greater than (2) years, in investigating optimization scenarios for tiers 2 & 3.

Tier 2: Critical Variables (Multiple of two)

At Cmax: All critical variables set at the midpoint. Two critical variables are adjusted at a time to Cmax, obtaining a change in response time; **At Cmin:** All critical variables set at the midpoint. Two critical variables are adjusted at a time to Cmin, obtaining a change in response time. Outputs and graphical illustrations obtained from tier 2 are presented in Exhibit 4 below.

Exhibit 4: Trial 2, Variables ABCDE Outputs and Graphical Illustration.

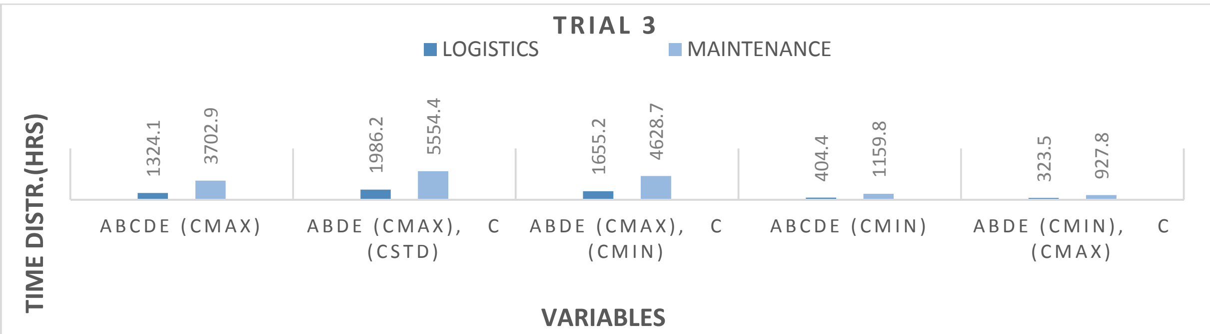


Deductions: Findings from outputs above and combined statistical graph presented below illustrates, that optimization scenarios for these critical variables occur at conditions integrated with critical variable C at Cmax. This research also observed that critical variables ABDE has higher response times when setting at Cmax and lowest response times when setting at Cmin business states, while critical variable C has lowest response times when setting at Cmax and higher response times when setting at Cmin. This research, therefore, infers from observation of tiers 1 & 2, that critical variables ABDE is best optimized at Cmin and critical variable C are best optimized at Cmax. This assertion is adopted in investigating tier 3, which serves as a confirmatory framework of investigations.

Tier 3: Critical Variables (Multiple of three, four, five & six)

Tier 3 investigates how a collection of critical variables grouped in three(s), four(s), and five changes response time. Simplified configurations are iterated aligned with observations from earlier tiers (1 & 2) detailed above to make generalizations. This research assumes at the midpoint (Cstd), critical variable C has not been integrated, therefore has a zero (0) numeric metric. Outputs and graphical illustrations obtained from tier 3 are presented in Exhibit 5 below.

Exhibit 5: Trial 3, Variables ABCDE Outputs and Graphical Illustration.



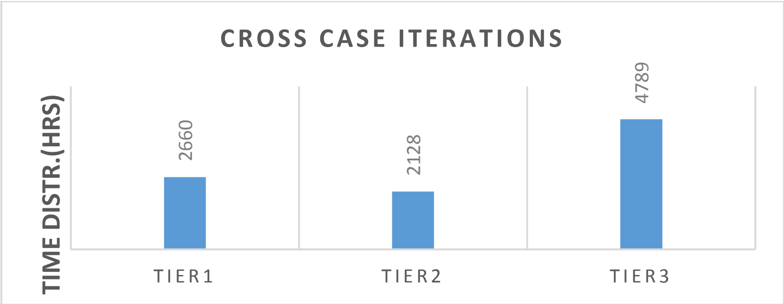
Deductions: Comparing response times as illustrated in Exhibit 6, best optimization level occurs at condition “ABDE (Cmin) and C (Cmax) for both maintenance and logistics process steps. Minimal numeric values for critical variables ABDE and maximum numeric value for critical variable C leads to a proportionate decrease in TAT of BP’s in any BU. Outputs also illustrate that conditions aligned with critical variable C have a significant decrease in response time.

Overall Deductions

Outputs of each iteration tier together with depicted combined graphical illustration is examined and deductions are outlined, so as to ascertain best optimization framework for these critical variables. Analysis of outputs (tier 1, 2 & 3) illustrates that TAT is best optimized at any BU with **lowest** "Human resource resolution time (A)", "System resolution time (B)", "Business state index (D)", "System maturity index (E)" and **maximum** "critical factor aligned with escalation potential (C)". A full SLA system maturity index policy, with a resolution time of less than two (2) hours together with a business state index change policy of greater than (2) years is also recommended. This research further investigated three (3) scenarios as detailed below

Scenario 1: Cross-Case Iterations
Tier #1 (Auto/Manual Entity), **Tier #2** (Fully Automated Entity), and **Tier #3** (Fully Manual Entity) are explored to test for respective conditions set and make generalizations together with drawing conclusions. Cross case iterations assume logistics and maintenance BP steps is integrated so as to function as a unit, obtaining total response time.

Exhibit 6: Cross-Case Iteration Outputs and Graphical Illustrations.



Deductions

Analysing outputs and graphical illustration presented in Exhibit 6 above. Comparison with tier 1 iteration outputs, shows a significant response time decrease for tier 2 condition, and a significant response time increase for tier 3 condition. Although it is technically impossible to automate the whole functional activities present in any BU, as certain process step has to be executed by a manual resource. Enterprise managers should, however, strive to automate a large number of business functions as possible. Cross-case analysis and graphical depiction illustrate that the more process steps automated necessitate a significant decrease in TAT. Thus leading to an optimized or standardized system.

Scenario 2: Automatic/Manual Escalation Iterations

This sub-theme investigates how manual and automatic escalation potential effects on process steps relative to TAT. This research assumes all process steps are integrated with an escalation potential in the following escalation states detailed in earlier sections. Each state aligned with associated adopted numeric metric is multiplied by total response time and then divided by distinct critical factor states (detailed in earlier sections) aligned with associated multiplier.

Analysis from Exhibit 8 illustrated below indicates lowest response time for process steps escalated at autotier2 escalation potential. Though it might be technically impossible to automatically escalate BP's up to a tier2 escalation potential as certain BP's has to be manually executed. This research, however, recommends that enterprise human resources strive to escalate most process steps automatically, aiming at autotier2 escalation potential. For BP's executed manually, it is recommended that business entities endeavour to escalate up to manualtier2 escalation potential. These recommendations necessitate an overwhelming decrease in TAT of process steps.

Scenario 3: Escalation Potential on Human Resource critical variables
This sub-section assumes all process steps are integrated with an escalation potential, adopting autotier2 escalation resolution numeric metric in investigating this sub-theme. Effects of escalation rate on each adopted human resource resolution time state (detailed in earlier sections), aligned with associated numeric multiplier is examined.

Exhibit 7: Auto/Manual Escalation Graphical Illustration

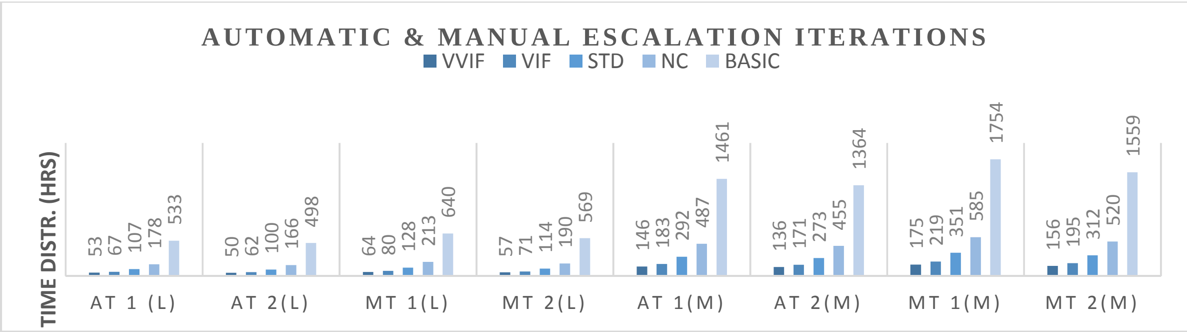
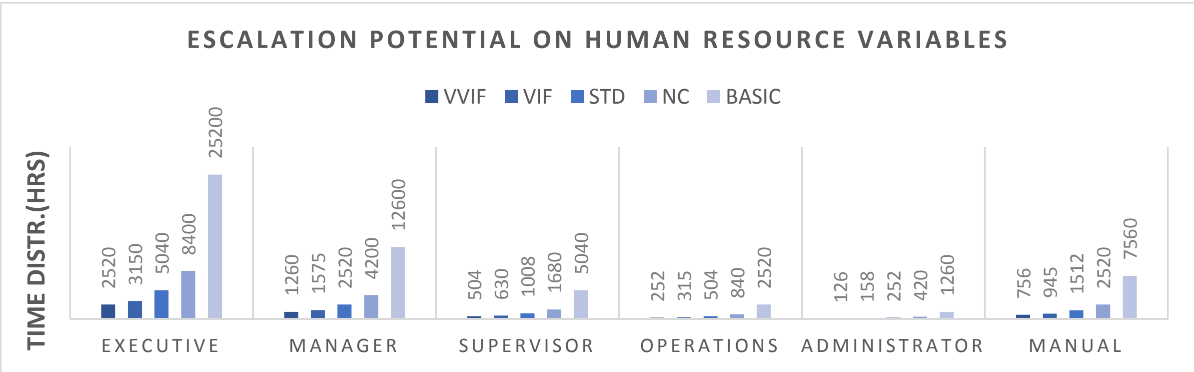


Exhibit 8: Escalation Potential on Human Resource Graphical Illustration



Analysis from Exhibit 8 illustrated above shows lowest resolution time for human resource critical variable "Administrator" escalated aligned with autotier2 escalation potential numeric metric. This research suggests escalation response is activated in any business entity aligned to a higher human resource with minimal resolution time in order of lowest hierarchical TAT as illustrated above.

Conclusions

Despite limitations of this research in proposing six critical variables out of a large number of critical factors influencing business processes execution, and adopting sequential investigations in analysing outputs. Results, as simulated in Anylogic, corroborate that a simulation model potentially benefits any large corporate, specific to evaluating time taken to conduct business processes(TAT). The results indicate that collaborated processes can be modelled, together with investigating impacts of multiple critical variables in reducing interdependent business process time. Future studies can be carried out in evaluating the whole critical factors affecting enterprise processes, and adopting a statistically established methodology in analysing outputs.

References

Ahmadi, M., 2012. The application of system dynamics and discrete event simulation in supply chain management of Swedish manufacturing industries.

Al-Turki, U.M., Ayar, T., Yilbas, B.S. and Sahin, A.Z., 2014. *Integrated Maintenance Planning in Manufacturing Systems*. Cham: Springer.

Bradford, M. 2015. Modern ERP: Select, implement & use today's advanced business systems. 3rd edition; Raleigh, NC: Lulu press.

Bradford, Marianne, Gerard, Gregory J. 2015. Using Process Mapping to Reveal Process Redesign Opportunities During ERP Planning.

Gove, R. and Uzdzinski, J., 2013. A Performance-Based System Maturity Assessment Framework. *Procedia Computer Science*, *16*, pp.688-697.

Grigoryev, I., 2015. *Anylogic 7 in three days: a quick course in simulation modelling.* Anylogic North America.
Hussain, Abubakker. 2015. A practical guide to creating better-looking process maps.
Huxley, C., 2003. An improved method to identify critical processes.
Kasser, J., and Mackley, T., 2008, June. Applying systems thinking and aligning it to systems engineering. In *INCOSE International Symposium* (Vol. 18, No. 1, pp. 1389-1405).
Karnon, J., Stahl, J., Brennan, A., Caro, J.J., Mar, J., and Möller, J., 2012. Modelling using discrete event simulation a report of the ISPOR-SMDM modelling good research practices task force–4. *Medical decision making*, *32*(5), pp.701-711.
Koutsikouri, D., Dainty, A.R. and Austin, S.A., 2006. Critical success factors for multidisciplinary engineering projects.
KO, R.K., Lee, S.S. and Wah Lee, E., 2009. Business process management (BPM) standards: a survey. *Business Process Management Journal*, *15*(5), pp.744-791.
Lättilä, L., 2012. Improving transportation and warehousing efficiency with simulation-based decision support systems. *Acta Universitatis Lappeenrantaensis*.
Li, H., and Qian, S.X., Vitria Technology, Inc., 2004. *Real-time business process analysis method and apparatus*. U.S. Patent 6,763,353.
Macal, C.M. and North, M.J., 2010. Tutorial on agent-based modelling and simulation. *Journal of simulation*, *4*(3), pp.151-162.
Malamura, E., and Murata, T., 2012. Simulation-based plant maintenance planning with multiple maintenance policy and evaluation of production process dependability. In *2012 International MultiConference of Engineers and Computer Scientists, IMECS 2012*.
Markus, M.L., Axline, S., Petrie, D. and Tanis, S.C., 2000. Learning from adopters' experiences with ERP: problems encountered and success achieved. *Journal of information technology*, *15*(4), pp.245-265.
Mcintyre, W. 2009. Lean and Mean process improvement. https://books.google.co.za/books?
Mori, K., 2007, July. A Correlation Analysis Concerning Customer Satisfaction and Business System. In *Proceedings of the 51st Annual Meeting of the ISSS-2007, Tokyo, Japan* (Vol. 51, No. 2).
Paradiso, J., and Cruickshank, J.R., 2007. Process mapping for SOX and beyond. *Strategic Finance*, *88*(9), p.30.
Paschke, A. and Schnappinger-Gerull, E., 2006. A Categorization Scheme for SLA Metrics. *Service Oriented Electronic Commerce*, *80*, pp.25-40.
Podnar, I. and Mikac, B., 2001. Software maintenance process analysis using discrete-event simulation. In *Software Maintenance and Reengineering. Fifth European Conference on* (pp. 192-195). IEEE.
Richmond, B. and Peterson, S., 2001. *An introduction to systems thinking*. High Performance Systems, Incorporated.
Rosenberg Ann. 2010. SAP Modelling Handbook – Modelling Standards: Process Hierarchy.
Sargeant, M. 2013. Business process modeling with Visio at the Gartner BPM summit.
Senge, P. 2006. The fifth disciple: The art and practice of the learning organization New York, double day.
Shafiei, A., 2014. Developing a Business Process Management Maturity Model. Retrieved from *https://www.erpublication.org/admin/vol_issue1/.../IJETR022695.pdf.*
Siha, S.M. and Saad, G.H., 2008. Business process improvement: empirical assessment and extensions. *Business Process Management Journal*, *14*(6), pp.778-802.
Souvairan, E. 2014. Practical approaches to managing international development project in the face of complexity.
Subramanyam, Shati. 2012. A response time metric for service level agreements. https://dzone.com/articles/response-time-metric-service.
Wang, H. and Wang, Z., 2013, June. Study on the method and procedure of logistics system modelling and simulation. In *2nd International Conference on Science and Social Research (ICSSR 2013)* (pp. 776-780). Atlantis Press.
ZHU, J., and SONG, N., 2011. Evaluating Business Process Management Maturity: A case study on a Chinese electronic company.