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THEORY OF OPTIMISATION FOR PROJECTS

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ABSTRACT

Knowledge of the critical path and the degree of criticality and sensitivity of the task time is a specific problem requiring further research. Until now, there is no specific procedure to resolve resource contentions and general optimisation method due to its complexity (Herroelen, 2001) & (Penga & Huangb, 2013). The major result the author presents is a revision of the critical chain project scheduling process model by Tukel et al. (2006). The proposed TOP methodology presented, integrates different heterogeneous scenarios data sources to reduce the risk of the expected project time. The main contributions that the proposed TOP methodology can provide to the nuclear arena are the following: (1) delays are less likely when using the Criticality Index concept for selection of the critical chain using Monte-Carlo to manage highly uncertain tasks. The methodology will provide a unique, integrated and placid source of information, (2) complete view of heterogeneous critical task activities based on the array of information for validating the time sensitivity of tasks on the expected project time by correlation. The correlations display the degree of linear relationship between the task time and expected project time, (3) accurate information for project managers to make decisions. Using the TOP the nuclear area will be able to distinguish between the time sensitivity or insensitivity relationship between the task time and expected project time by Pearson product-moment, Spearman's rank and Kendall's tau rank that are not easily available with a simple system, and (4) ability to validate the time sensitivity of the task time on the expected project time by correlation using 50% sizing rule for time sensitivity dimension.

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INTRODUCTION

The management of projects has matured considerably due to its significant economic importance. Projects are constituted as one of the more effective ways of structuring work in most organisations (Svejvig & Andersen, 2015). Important efforts have been made by international project management (PM) practitioners and researchers to rethink project management, and disseminated findings among the PM community. Research papers published in the *International Journal of Project Management* over its first decade contributed to significant new tools and techniques of PM. The journal also indicates that there still is room for much needed improvements in the areas of theory formulation, theoretical concepts and for research collaboration between academia and industry (Kwak & Anbari, 2009). The 2015 pulse found that many industries have continued to waste US$109 million for every US$1 billion invested in projects, while only 64% have successfully met their original goals and organisation intent of projects, where 15 % were deemed as failures. The common cause of project failures is due to inaccurate task time estimates, resource dependency, inaccurate resource forecasting, limited resources, team member procrastination and task dependency (Project Management Institute, 2015).

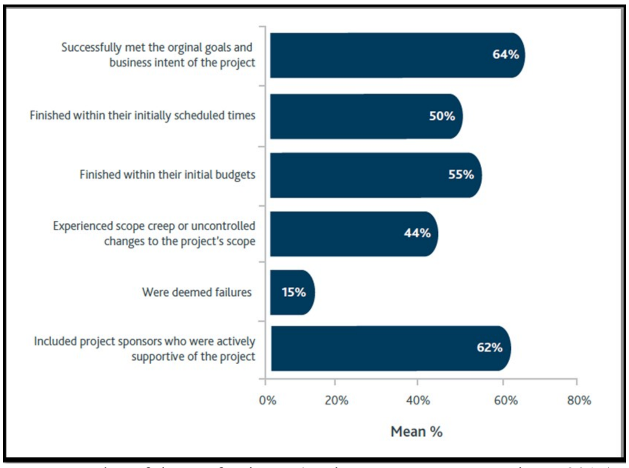
The first challenge addressed hypothesis H_1: Critical chain resource constraint scheduling (CCRCS) *task time* offers a longer *expected project time* than the methodology based on program evaluation review technique. The second challenge addressed hypothesis H_2: Implementing a methodology based on TOP will reduce the risk of the *expected project time*. H_2 appraises TOP by Monte-Carlo simulation and assays its effectiveness as a supporting tool for structuring nuclear projects. The simulated results is represented as a supporting tool for structuring work, and provides the nuclear industry in South Africa with a quantified assessment of its possible outcomes through simulation. The case study projects utilised for the research are extracts from Eskom's Koeberg spent fuel storage project and author's.

Masters Dissertation: The rest of the paper is arranged along the following sections: section 2 provides motivation for the research study, while section 3 describes the problems around project failures results. Section 4 provides background knowledge on project management theory. Section 5 explores the scoping review with the "aim to map rapidly the key concepts underpinning a research area and the main sources and types of evidence available, while section 6 of the paper provides an overview of the TOP methodology, potential benefits, implementation and extension followed by the conclusion.

Motivation for the study: Worldwide, all spent nuclear fuel (SNF) discharged from nuclear fission reactors are commonly stored on–site. Forego of reprocessing facilities and delays with establishing a permanent repository have destined spent fuel to spent fuel dry storage facilities. The storage of the uranium spent fuel will endure until a repository facility is made available in countries such as South Africa. While several studies suggest it would be more coercing to establish an on–site (above ground) interim storage program other than the immediate bulk storage of SNF, following the Fukushima accident (Davied, 2011). During 2018, Koeberg's spent fuel wet storage will be expended with spent nuclear fuel assemblies, based on its latest 10 year production plan. An interim solution will be to reduce the existing spent fuel pools (SFPs) seismic mass and/or radioactive material for the nuclear power station to continue operating; otherwise SNF may not be loaded or off–loaded from its nuclear fission reactors. This interim solution paved the way to the formulation of the Eskom's Koeberg spent fuel storage project strategy, which is being carried out over three distinct project phases, one being Nuclear Project A of the case study. With no reprocessing, repository or interim spent fuel dry storage facilities for additional cask emplacement, Koeberg may be shut down pre–maturely (Eskom, 2014b) & (Eskom, 2015).

A rethink of PM methods is needed to successfully carry out the Koeberg spent fuel storage project strategy. One of these new methods is Critical Chain Project Management (CCPM), which was first presented by Goldratt at the Jonah International Conference in 1990. The principle of the Theory of Constraints PM was extended through publishing of the 'Critical Chain' in 1997. With regard to CCPM, the unique constraint is the longest activities chain in the project network in the project environments, taking into account critical chain (both resource dependencies and activity precedence). Critical Path (CP) Method and Program Evaluation and Review Technique (PERT) project scheduling methods have remained relatively unchanged, while CCPM was considered as an innovative breakthrough (Ghaffari & Emsley, 2015). The implementation of CCPM the traditional way is complex and challenging for larger projects. Considerable effort has been made to solve the problems on the research of resource-constrained scheduling (RCS). On the other hand, literature also reveals that minimal efforts were made on the research of optimisation methods for projects. Therefore, research is required to be able to schedule projects in an automated approach by using the theory of optimisation for projects (Penga & Huangb, 2013). This research paper aims at identifying the benefits of introducing the criticality index (CI) concept for selection of the critical chain project management (CCPM) using Monte-Carlo simulation by modelling the theory for optimisation of projects (TOP) using nuclear case study projects of South Africa.

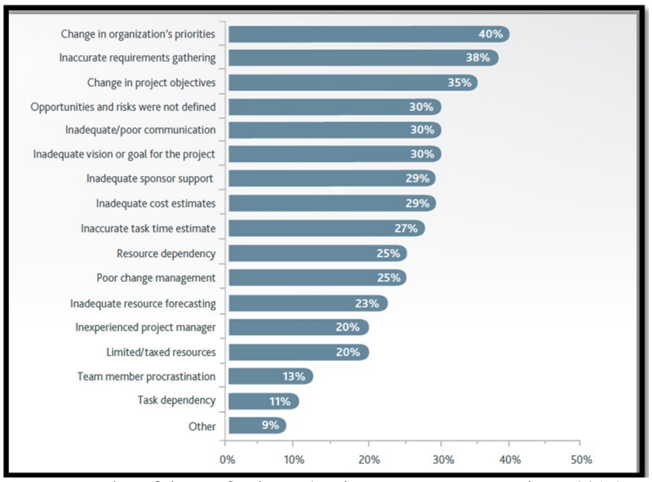
Project Failures: 'The iron triangle' approach represents the basis of the criteria for project success (Cserháti & Szabó, 2014). This approach easily assesses the critical criteria for the success of a project such as, the completion time, cost and performance specifications. Researchers have become more depended on the aspect of measurement for success. While certain organisational studies have shown that environmental impact, technical success and effects on business operations as the most important criteria for project success. Moreover, critical factors for project success could contribute to the failure of a project and would also require special attention. Earlier studies have revealed three critical factors for the success of projects or not fail is namely; schedule adherence, maintain high-levels of performance, and to keep costs within budget (Cserháti & Szabó, 2014). The 2015 pulse found that many industries have continued to waste US$109 million for every US$1 billion invested in projects, while only 64% have successfully met their original goals and organisation intent of projects, where 15 % were deemed as failures (refer to Figure 1). The organisation with the high-level performance will meet their project goals 2½ times more frequently, and will waste thirteen times less on money than the low-level performing organisation. A number of critical project factor contribute to this success, including the focus on the basics such as, aligning projects to strategy (Project Management Institute, 2015).



Source: Pulse of the Profession® (Project Management Institute, 2015)

Figure 1. Projects Completed across Countries over 12 months

The percentile of project failures and its causes over a 12 months period across North America, EMEA[3], Asia Pacific and Latin Pacific are depicted in Figure 2. It is shown that the common cause of project failures is due to inaccuracy of task time estimates, resource dependency, inaccurate resource resources, team member procrastination and task dependency.



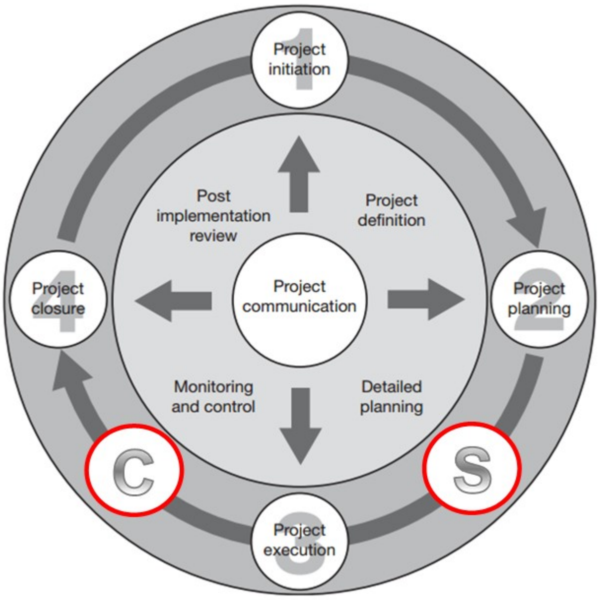
Source: Pulse of the Profession® (Project Management Institute, 2015)

Figure 2. Projects deemed as failures over 12 months

It is revealed that there is a lack of PM support to complete projects successfully. The shortcoming of project failures is problematic to the delivery of projects, hence the need for further research.

Knowledge of PM Theory: PM life cycles are constituted over the initiation, planning, execution and closure phases. They are valuable for project definition, detailed planning, monitoring and controlling control and post implementation review for those involved and producing PM knowledge. Archibald (1976) argues that there are a number of common characteristics shared by several PM life cycle models. These commonalities are due to the major milestones between the phases and the overlapping of the phases.

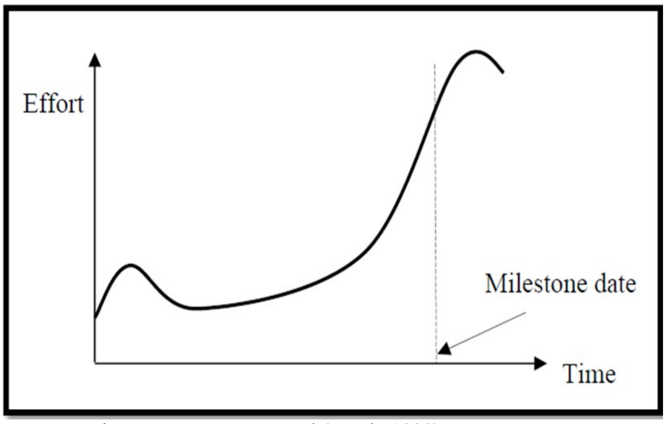
In addition, the 1st edition of the project management body of knowledge (PMBOK), the PM life cycle was not alluded to. Only in future editions Project Management Institute (PMI) included the PM life cycle into the PMBOK. The PM life cycle concept of this research study is adapted to Klein (2000).



Source: The PM Life Cycle Model (Jason Westland, 2006) – Adapted to Klein (2000)

Figure 3. Phases of the PM Life Cycle

Klein's concept includes two additional phases (i.e. in which the project has to be scheduled is denoted by "S" and the project controlled is denoted by "C"). Traditional PM has developed several techniques based on scientific methods to be able to plan the process of PM to achieve the expected of time, costs and quality performance of resources. Hajdu (2013) indicated that there are hypotheses underlying every technique. Two (2) models are briefly examined for structuring work, one is the CPM model by Kelley and Walker (1959); and the second is PERT project scheduling by Malcolm et al. in 1957 (Malcolm, 1959). CPM and PERT project scheduling methods have remained relatively unchanged since its introduction in the 1950s, while CCPM was considered as an innovative breakthrough (Ghaffari & Emsley, 2015). Goldratt (1997) acknowledged that project costs were a function of project schedule performance. He emphasised that contingency (task) times were being wasted due to its stochastic allocation within project schedules; leading to an issue known as the student syndrome. Another problem causing adverse human behaviour is Parkinson's Law.



Source: Project Management Journal (Leach, 1999)

Figure 4. Student's Syndrome

The safe estimates for task time were initially decided by the project team. This provided a cushioning effect, approximately the same as the expected task time. For critical chain projects, it will start with the removal of these cushions from its task times, leaving only the average time to be used. The critical chain project scheduling process was developed by Tukel et al. (2006) and is generated over the following 6-steps, in particular:

1. Determine the estimated task time at 50% for each task;
2. Move all tasks late as possible, subject to precedency;
3. Re-structure the tasks to generate a feasible schedule (as the initial schedule), to eliminate resource contentions;
4. Identify the critical chain of the initial schedule that was identified in the preceding step;
5. Add project buffer to the end of each critical chain activity; and
6. Add feeding buffers wherever a non-critical task feeds each critical chain activity and offset the tasks on the feeding chain by the buffer size.

No specific procedure is presented to resolve resource contentions, referred to in step three. In a project instance, several critical chain schedules may be produced, as there may be several initial schedules (Herroelen, 2001).

Scoping Review

Part 1 of the scoping review (or preliminary study) fundamentally assess the relationship between the CCRCS and PERT on the PM case study project and its project time. Part 1 is referenced to the Christensen theory–building concept. The scoping review consolidates the observation, categorisation and measurement in numbers and words, followed by the classification underlying categories, and the investigation between the categories and observations of their outcomes. An initial regression analysis for estimating the relationships among variables of H_1 is evaluated for the research. Nuclear Project A was identified and is selected by the author as it has vast referencing empirical testing data.

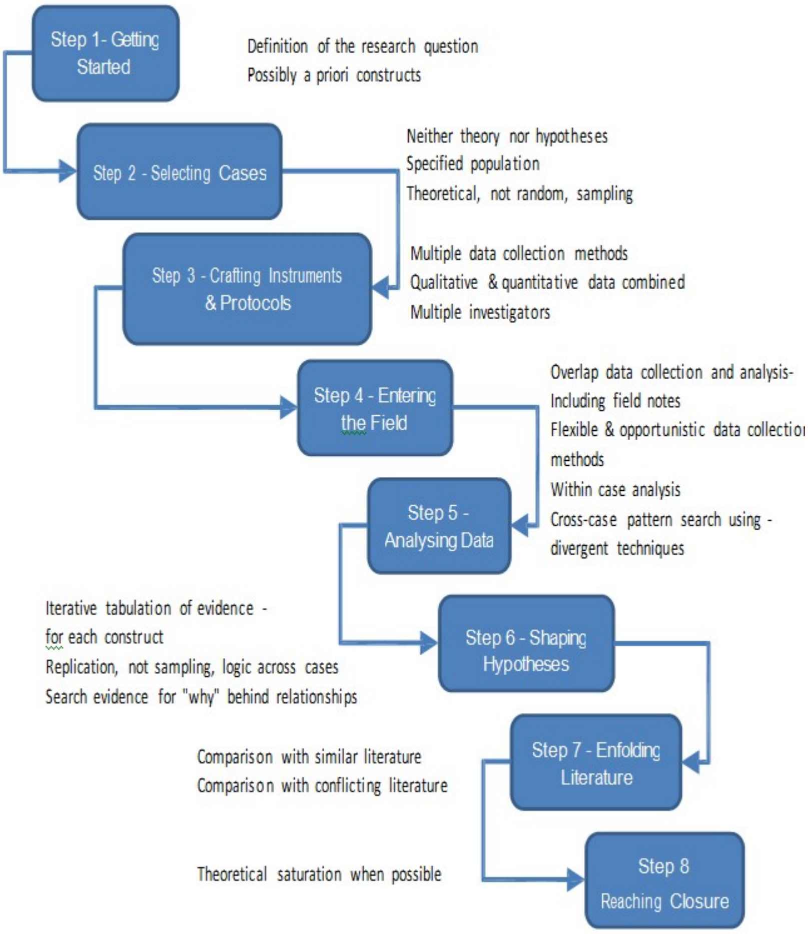
Part 2 appraises the TOP and assays its effectiveness for critical chain scheduling on the PM case study project and its project time. Part 2 is referenced to Eisenhardt, et al. theory–building concepts. By combining the contributions of Eisenhardt (Figure 5 – Eisenhardt Theory–Building Process) and Eisenhardt, et al. (Figure 6 – Developing Theory Through Simulation Methods), it is revealed that *measurability* lies at the core of the theory–building concept for the PM case study under investigation. *"The grandest discoveries of science have been but the rewards of accurate measurement and patient long-continued labour in the minute sifting of numerical results" (Lord Kelvin also known as William Thompson, 26 June 1824 – 17 December 1907, Physicist and Engineer).* The author impulsively raised questions on *measurability*, which were used to formulate the research questions. Once research questions were refined, the PM case study was selected, and the measurement instruments formulated for the data collection process.

Monte-Carlo simulation analyses for estimating the relationships among variables of H_2 were evaluated for the research. Nuclear Project B was identified and selected by the author as it also had vast reference data for empirical testing.

Part 3 of the research validation study is referenced to the Eisenhardt, et al. theory–building concept (Figure 6 – Developing Theory Through Simulation Methods). This latest method of developing theory (through simulation) was adapted by the author after considering Eisenhardt former theory–building process (refer to Figure 5 – Eisenhardt Theory–Building Process). Through the validity study the research problem is solved.

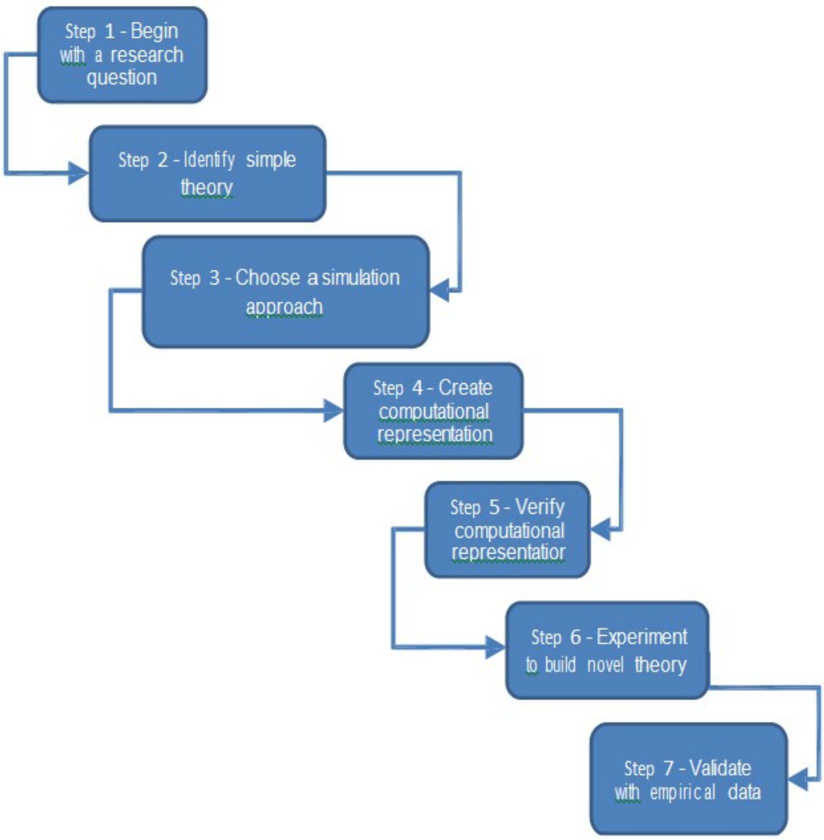
OVERVIEW OF THE TOP METHODOLOGY

Today, it is revealed that there is a lack of PM support to complete projects successfully in organizations. The shortcoming of project failures is problematic to the delivery of projects. The proposed TOP methodology presented in chapter 6 (Figure 7 – Theory of Optimisation for Projects), integrates different heterogeneous scenarios data sources to reduce the risk of the *expected project time*.



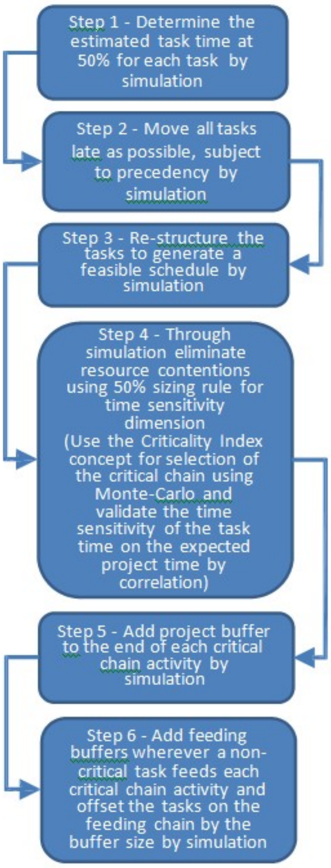
Source: Adapted Building Theories from Case Study Research (Eisenhardt, 1989).

Figure 5. Eisenhardt Theory–Building Process



Source: Developing Theory Through Simulation Methods (Eisenhardt K.M, 2007)

Figure 6. Developing Theory Through Simulation Methods



Selected data sources include the following: Construction of a transient interim storage facility for the storage of casks, to whom the author is assigned to as the nuclear project manager (extract of baseline project schedule) and A licensing plan for coupling a nuclear energy source to a chemical process plant. SASOL Secunda as a case study (extract of baseline project schedule) (Lavelot.R, 2014). For each Nuclear Project the suggested software tools are presented for groundwork and implementation. During the research, to design the TOP the author followed part of the area of knowledge of PM theory underlying PERT/CPM and CCPM including the CCRCS life cycle as the methodological approach). The author performed a search in EBSCOhost and established that the hypothetical connotation proposed by the author in terms of the TOP methodology: If you can measure it, you can improve it was reported across only 10 source types between 2000 and 2016, primarily within the already stated 2 periodicals within health services and environment technology, and in 1 periodical within total quality management. Correspondingly, it is reported in 3 academic journals within hospital management, clinical and experimental rheumatology and health services, equally in 3 newspaper articles within the Washington Times, UK Times and USA Today. Finally, 1 is sourced in the Editorial & Opinion within clinical leadership & management. Nothing was obtained by the author across source type underlying the field in nuclear project management.

Potential benefits from the top: One of the most documented articles on theory is by Lewin (1945) who states that "nothing is quite so practical as a good theory" therefore: "good theory is practical precisely because it advances knowledge in a scientific discipline, guides research toward crucial questions, and enlightens the profession of management" (Van de Ven, 1989). From the proposed TOP methodology, project managers can view and perform different tasks. The methodology covers only a part of the selected system for resolving resource contentions as suggested by Tukel et al. (2006) critical chain project scheduling process. The proposed TOP can integrate different subject areas as presented and is useful for project management and the decision–making process.

In brief, the main benefits that the proposed TOP methodology can provide to the nuclear arena are the following:

- Delays are less likely when using the Criticality Index concept for selection of the critical chain using Monte-Carlo to manage highly uncertain tasks. The methodology will provide a unique, integrated and placid source of information.
- Complete view of heterogeneous critical task activities based on the array of information for validating the time sensitivity of tasks on the expected project time by correlation. The correlations display the degree of linear relationship between the task time and expected project time.
- Accurate information for project managers to make decisions. Using the TOP the nuclear area will be able to distinguish between the time sensitivity or insensitivity relationship between the task time and expected project time by Pearson product-moment, Spearman's rank and Kendall's tau rank that are not easily available with a simple system.
- Ability to validate the time sensitivity of the task time on the expected project time by correlation using 50% sizing rule for time sensitivity dimension. The validity of simulation results increases with a higher number of simulationruns.

Implementing the top: The implementation of CCPM the traditional way is complex and challenging for larger projects. Minimal efforts were made on the research of optimisation methods for projects (Penga & Huangb, 2013). Implementing a methodology based on TOP will reduce the risk of the *expected project time* and is a supporting tool forstructuring nuclear projects. The initiating point for implementing the TOP is with the selection and definition of the data sources. Having the source of data, we will start with the development of a baseline schedule. The baseline schedule represents a central role in this process and the lack thereof would lead to incomparable computational representation of its data. Determine the estimated task time at 50% for each task. Move all tasks late as possible, subject to precedency. Re-structure the tasks to generate a feasible schedule, use the Monte-Carlo approach and 50% sizing rule time sensitivity dimension to eliminate resource contentions. Identify the critical chain of the schedule will be the subsequent step. At this stage, we need to add buffer to the end of each critical chain activity. The final step will be to add feeding buffers wherever a non-critical task feeds each critical chain activity and offset the tasks on the feeding chain by the buffer size.

In terms of tools, the nuclear project management can use different software tools such as Monte-Carlo simulation contained in the ProTrack V3 version running on Windows. Currently, the nuclear project management at Koeberg does not have the proposed software tools.

Extending the proposed top?

In the authors view, the subsequent steps need to be considered in order to extend the proposal:

- Definition of the data model to be implemented;
- Design of the data model integration process to include the 50% sizing rule for time sensitivity dimension;
- Creation of access to the data model; and
- Users to be educated to perform their analysis on the data model.

How to integrate the data model?

In order to integrate 50% sizing rule, we have to follow the critical chain life cycle of Tukel et al. (2006). The initiating point for implementing the TOP is with the selection and definition of the data sources. Having the source of data, we will start with the development of a baseline schedule. Steps 1 to 2, determine the estimated task time at 50% for each task. Move all tasks late as possible, subject to precedency. Step 3, re-structure the tasks to generate a feasible schedule, *develop an interface that will allow users to load data using the Monte-Carlo approach for the 50% sizing rule time sensitivity dimension to eliminate resource* *contentions.* Step 4 to 5, identify the critical chain of the schedule and add buffer to the end of each critical chain activity. Final step 6 will be to add feeding buffers wherever a non- critical task feeds each critical chain activity and offset the tasks on the feeding chain by the buffer size. A description of the proposed model is presented in Figure 7 – Theory of Optimisation for Projects. The idea of using the TOP data model for decision making in an organization may be widely accepted. Theory building using software simulation began with simple theory using Eisenhardt theory–building process to test H_2. The proposed model previews *the Monte-Carlo approach for the 50% sizing rule time sensitivity dimension to eliminate resource contentions*. Data integration process consists in the creation of the author's integrator in step 3 (*50% sizing rule time sensitivity dimension* to eliminate resource contentions*).* Other findings are related to the scoping review using the Christensen theory–building process to test H_1.

CONCLUSION

From the research study, the major result the author presented in this research is a revision of the critical chain project scheduling process model by Tukel et al. (2006) that allows the integration of *the 50% sizing rule time sensitivity dimension to eliminate of resource contentions*. The proposed TOP model integrates the creation of the author's integrator in step 3 (*50% sizing rule time sensitivity dimension)*. The validation process was examined to determine whether the H_2 theory–building results could be correctly represented in the real life practice. The results of the experiments were compared with the task time and expected project time by correlation. The validity of simulation results increases with a higher number of simulation runs. For Nuclear Project B, 100 simulation runs were performed by the author making the total of 900 simulations. The simulated results ended with a predefined number of runs (k = 100) due to lengthy computations. It is confirmed that nine heterogeneous key tasks activities denote the likelihood of being critical on the case study. The author confirms the TOP methodology by *using the Criticality Index concept for selection of the critical chain using Monte Carlo and validate the time sensitivity of the task time on the expected project time by correlation using 50% time sensitivity threshold sizing rule.* The results deduct support for H_2. Testing H_2 theory on an existing Nuclear Project B and observing it across nine heterogeneous contexts, correlate with the outcomes as predicted. Project managers may now be aided to resolve resource contentions by following the author's six–folded critical chain project scheduling process to reduce the risk of the *expected project time.*

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