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RESEARCH ARTICLE OPEN ACCESS

A METHODOLOGY FOR THE PRESENT ACUMEN OF KNOWLEDGE ON 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 research study offers an innovative optimisation methodological approach to resolve resource contention. The latest method of developing theory (through simulation) was adapted by the author (Figure 1 – Developing Theory Through Simulation Methods). As a result of the TOP, delays are less likely when managing highly uncertain tasks. The methodology will provide a unique, integrated, and placid source of information. It may provide a complete view of heterogeneous critical task activities. It provides accurate information for project managers to make decisions. Ability to validate the time sensitivity of the task time on the expected project time using 50% sizing rule for time sensitivity dimension. The motivation for carrying out the research study originated through observations in the light of the phenomena[1] by Herroelen (On the Merits and Pitfalls of Critical Chain Scheduling, 2001). The author performed observations for more than twenty five years across the engineering, quality, construction and nuclear industry in the field of project management. During this time, delivering projects as expected was often found to be one of the biggest challenges being observed. The common cause of project failures observed were mostly due to inaccurate *task time* estimates, resource dependency, inaccurate resource forecasting, limited resources, team member procrastination and task dependency. The apparent observations led to question being asked by the author: a) Why were no specific procedures presented for resolving resource contention? This question proceeded to more relevant research questions; b) Why there were no general optimisation methods for critical chain resource constraint scheduling (CCRCS)(Penga & Huangb, 2013)?; c) What research should be considered to improve the expected project time? These questions were further refined to;d) What the difference between CCRCS task time and the expected project time methodology based

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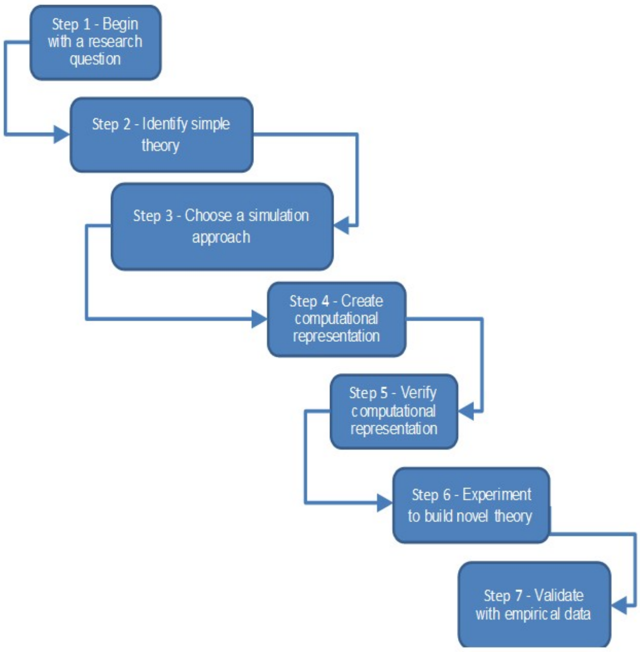
[1] Phenomena –project failures observed were mostly due to inaccurate task time estimates, resource dependency, inaccurate resource forecasting, limited resources, team member procrastination and task dependency



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

Figure 1. Developing Theory Through Simulation Methods

on PERT; and e) How may the theory of optimisation contribute to improvement the accuracy of the expected project time of nuclear projects? The current benefits of introducing the Criticality Index concept for selection of the critical chain is not sufficiently addressed(Ghaffari & Emsley, 2015).The major result the author presents is a revision of the critical chain project scheduling process model by Tukel *et al*.(2006).Until now, there is no specific procedure to resolve resource contentions and general optimisation method due to its complexity(Herroelen, 2001)&(Penga & Huangb, 2013). This study contributes to the literature in the field of nuclear project management in South Africa. A search in EBSCO host 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 with in 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 researcher across source type underlying the field in nuclear project management.

METHODOLOGICAL

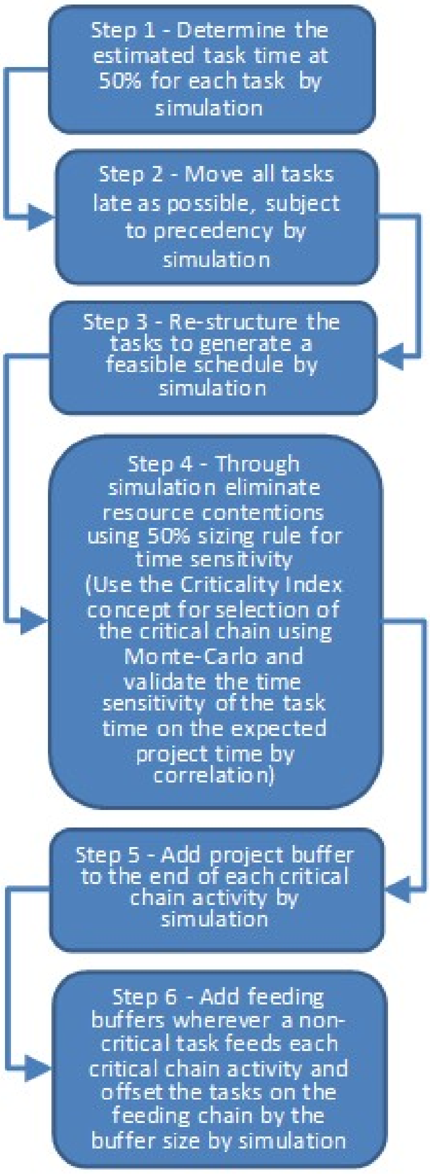
The originality of the thesis consists also in its methodology. The author has demonstrated how a testable research question, simple theory, together with the discrete event approach and computational representation is used, for building theory in the nuclear arena. It is shown that implementing a methodology based on TOP will reduce the risk of the *expected project time* and is a supporting tool for structuring nuclear projects. Implementing 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). The TOP data model provides an innovative 6–step methodological approach (Figure 2 – Theory of Optimisation for Projects), initiating with the selection and definition of the data sources. Having the source of data, develop a baseline schedule, followed by the subsequent steps:

Steps 1 to 2–Determine the estimated task time at 50% for each task. Move all tasks late as possible, subject to precedency by simulation.

Step 3 – Re-structure the tasks to generate a feasible schedule.

Step 4 to 5 – Through simulations eliminate resource contentions using 50% sizing rule for time sensitivity(Use 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). Add buffer to the end of each critical chain activity by simulation.

Final step 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.



6–step critical chain project scheduling (Lavelot R. , 2017)

Figure 2. Theory of Optimisation for Projects

Validity of study

In the thesis, three measurements validated the time sensitivity of tasks on the expected project time by correlation. These measurements were calculated by using Pearson’s Product-Moment, Spearman’s Rank and Kendall’s Tau Rank Correlation.These correlations were used to display the degree of linear relationship between the *task time* and *expected project time*.Spearman's differs from Pearson's Correlation only in that the computations are performed after the values are converted to ranks(Lane, 1997b).

Table 1. Pearson's Chi-square Test for Independence of Nuclear Project A

Data Set	Without CCS by Software Package MS Project 2010	With CCS by Software Package MS Project 2010	Without CCS by Software Package Pro Track V3	With CCS by Software Package Pro Track V3	Without CCS with RCS by Software Package MS Project 2010	With CCRCS by Software Package MS Project 2010	Without CCS with RCS by Software Package Pro Track V3	With CCRCS by Software Package Pro Track V3
Pearson's Correlation coefficient (rho)	0.993		0.961		0.961		0.993	
Chi-square Test with 2df^1 (*p*-value)	0.584		0.095		0.590		0.678	

Table 2. Results of Correlations for Monte-Carlo Simulation Scenario 1 – 9 for Nuclear Project B

Scenario 1 **Non-critical & critical tasks are ahead**	**Scenario 2** **Non-critical tasks are on plan & critical tasks are ahead**	**Scenario 3** **Non-critical are delayed & critical activities are ahead**
• Pearson reports a weak positive correlation	• Pearson reports no correlation	• Pearson reports a moderate to perfect positive correlation
• Spearman reports a weak to moderate positive correlation	• Spearman reports a near perfect positive correlation	• Spearman reports a moderate to perfect positive correlation
• Kendell reports a weak to moderate positive correlation	• Kendell reports a perfect positive correlation	• Kendell reports a moderate to perfect positive correlation
Scenario 4 **Non-critical tasks are ahead & critical tasks are on plan**	**Scenario 5** **100% on time performance**	**Scenario 6** **Non-critical tasks are delayed & critical tasks are on plan**
• Pearson reports a weak to moderate positive correlation	• Pearson reports no correlation	• Pearson reports a moderate to perfect positive correlation
• Spearman reports a weak to moderate positive correlation	• Spearman reports perfect positive correlation	• Spearman reports a moderate to perfect positive correlation
• Kendell reports a weak to moderate positive correlation	• Kendell reports a perfect positive correlation	• Kendell reports a moderate to perfect positive correlation
Scenario 7 **Non-critical activities are ahead & critical activities are delayed**	**Scenario 8** **Non-critical & critical tasks are on plan**	**Scenario 9** **Non-critical and critical tasks are delayed**
• Pearson reports a weak to moderate positive correlation	• Pearson reports no correlation	• Pearson reports a weak to moderate positive correlation
• Spearman reports a weak to moderate positive correlation	• Spearman reports a near perfect positive correlation	• Spearman reports a weak to moderate positive correlation
• Kendell reports a moderate to perfect positive correlation	• Kendell reports a perfect positive correlation	• Kendell reports a weak to moderate positive correlation

Thereafter, the degree of similarity is further displayed between two sets of ranks for the same set of objects by Kendall's Rank Correlation (Kendall, 1955). 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. It 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(Construction of a transient interim storage facility for the storage of casks, to whom the researcher is assigned to as the nuclear project manager (extract of baseline project schedule)) was identified and is selected by the researcher as it has vast referencing empirical testing data.

The research design has addressed hypothesisH_1:

H_1: CCRCS *task time* offers a longer *expected project time* than the methodology based on PERT.

$H_{1.0}$ is stated as: *Task time* for CCRCS does not offer a longer *expected project time* than the methodology based on PERT. The results deduct support for

H_1. Testing the H_1 theory on an existing historical Nuclear Project A and observing it across two contexts, correlate with the outcomes as predicted. For context, Pearson Product-Moment Correlation is used as it is the most common measurement as it displays the degree of the linear relationship between two variables. It is designated by the Greek letter rho (ρ) when measuring a population. Pearson's Correlation analyses were computed from the two sets of SR test data results, to evaluate whether a strong link exist With CCS and Without CCS.

If the results of the correlation had a value of +1, then the data set is a perfect positive correlation. If zero, then there is no correlation (values not linked), while -1 is a perfect negative correlation(Lane, 1997a).In the Table 1, the values show how good the correlations are with CCRCS and without CCRCS. The two sets of data are strongly linked ($0.96 \leq \rho \leq 0.99$). A uniform relationship exists between the two variables on the Nuclear Project A. It is shown that the CCRCS task time offers a longer expected project time than the methodology based on PERT (without CCRCS). The high correlation coefficient favours a significant correlation, however further analysis is required.

The chi-square testis further applied to the two variables using with CCS and without CCS for the single population. The chi-square test is used to determine whether a significant association exists between two variables by using the p-values in Table 1. The variables are independent across all data sets. Microsoft Excel 2010 software is used to find the p-values. As the p-values are greater than the 0.05 significance level, we do not reject the null hypothesis

$\mathbf{H_{1.0}}$that the CCRCS task time offers a longer expected project time than the methodology based on PERT (without CCRCS). The research hypothesis (H_1) is strongly supported and neither a type I error[2] nor a type II error are applicable for the historical Nuclear Project A. Monte-Carlo simulation analyses for estimating the relationships among variables of H_2 were evaluated for the research. Nuclear Project B(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)) was identified and selected as it also had vast reference data for empirical testing. The selection of the PM case study together with the measurement of the criticality and sensitivity to improve the accuracy of expected project time is not a trivial decision made by the author. Assenting to H_2 confirms that the two–folded measuring process (i.e. criticality and sensitivity)will reduce the risk of the *expected project time* and its consequent success of a project.

The research design has also addressed hypothesis H_2:

$\mathbf{H_2}$: Implementing a methodology based on TOP will reduce the risk of the *expected project time*; with corresponding$\mathbf{H_{2.0}}$that implementing a methodology based on TOP will not 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. For H_2, the measurement was calculated by using the Pearson's product-moment, Spearman's rank correlation and Kendall's tau rank correlation tests and was used to validate the probability of the experimental simulations. The validation process was examined to determine whether the H_2theory–buildingresultscould 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 (□ = *100*) due to lengthy computations. Modern methods of computing were utilised to appraise the TOP by Monte-Carlo simulation to test hypothesis H_2. The *expected project time* were simulated for the case study. The simulations performed were kept by this sequence, in particular:

- Generate nine heterogeneous simulations by Pro Track 3.0 version running on Windows;
- The input parameters were: number of activities in a project 42[3] and number of resource types 3;
- Enter the generated information to Pro Track 3.0 software;
- Record the finish date of the expected project schedule;
- Generate 42 task times using Pro Track 3.0 software;
- Calculate new expected project time;
- Limit the sensitivity threshold sizing rule to50% for the crucially index;
- Record the completion date of the case study project and compare it to the expected project deadline;
- Repeat the steps for different percentages and different probabilities;
- Summarize and analyse results; and
- Validate experimental results using correlation coefficient value range between 0.00 and +1.00.

The author confirm 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 thresholdsizing rule*. The results deduct support for $\mathbf{H_2}$. Testing $\mathbf{H_2}$ theory on an existing Nuclear Project B and observing it across nine heterogeneous contexts, correlate with the outcomes as predicted (**Table 2**).

Extending the proposed TOP?

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

- 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.

Conclusion and Recommendation

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 resultscould 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. 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 (Figure 2 – Theory of Optimisation for Projects) to reduce the risk of the *expected project time.* The recommendations are related to the empirical findings and to the proposed TOP. Nuclear project management will gain benefits in their decision-making process if the methodology is implemented. To minimize several potential limitations, finalize the process of defining the cost of human capital. Based on the proposed TOP, the author suggests that access be created for users and for several users to be educated for adopting the model. The proposed model will, facilitate the decision-making process, by providing coherent data to the decision makers. Other recommendations include the definition of the supporting tool for structuring nuclear projects to be implemented and designing the data model integration process to include the *50%*

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[2] Type I errors occurs when the $H_{1.0}$is incorrectly rejected, whereas type II errors occur $H_{1.0}$ is incorrectly accepted.

[3] Parameter based on bottom-up approach(Lavelot R. , 2014) and area of significance for ^{K}oeberg Nuclear Power Station

sizing rule. As a result of the research study, the author had learned that more work can be done with the proposed TOP model, both organisational and in the academic arena. Given the novelty of the topics addressed in this study, future research is required to updating the theory-building process through simulation. In general, research efforts are needed in the field of nuclear project management, since human resources are scarcely considered in the literature.

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