Critical Success Factors to Optimise Power Plants Life Cycle Management[1]

Lalamani Budeli and Prof J H Wichers

Abstract

For power utilities to secure a competitive edge in the energy sector, improving efficiency of life cycle management programmes must be achieved through successful execution of projects. In today's competitive environment, producing products that are fit for purpose, meet or exceed quality requirements, as well as being cost competitive, are key factors to determine organisational failure or success.

Effective project management practices require a project management system that supports management to achieve its organisational project goals in order to position the organisation strategically for future performance. However, because of projects inaccurate monitoring resulting improper management, the project success rate is very low with great economic impact on organisations.

These papers demonstrate how utilities can achieve sustained project performance by identifying how the combination of project management best practices and life cycle management methodologies can recognise process improvement opportunities.

Keywords: Critical success factors, life cycle management, variation management, performance management.

Introduction

According to Gadonneix et al (2010-14), the development of power plants started in 1866 with a coal-fired power plant. The first central power station in New York was built in 1882. Gadonneix et al 16 (2013-33) indicates that the unit capability factor (UCF) monitors progress in attaining high unit and industry energy production availability. This indicator reflects the effectiveness of plant programmes and practices in maximising available electrical generation and provides an overall indication of how well plants are operated and maintained during their life cycles. The unplanned capability loss factor (UCLF), monitors industry progress in minimising project/outage time and power reductions that result from unplanned equipment failure or other conditions. This indicator reflects the effectiveness of plant programmes and practices in maintaining systems for safe electrical generation. The planned capacity loss factor (PCLF) is energy that was not produced during the period because of planned shutdowns or load reductions due to causes under plant management control. The relationship between UCF, PCLF and UCLF is represented by the equation below:

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$$UCF + PCLF + UCLF = 100\% \qquad (1)$$

The objective of the power plant life of plant plan (LOPP) is to ensure the sustainability of future energy supply. Every LOPP starts with a set of user's requirements which are translated into unique technical specifications for a specific environment for implementation purposes. As a result, the execution of a life cycle project is subject to numerous constraints that limit the commencement or progression of field operations, which invariably have a significant negative impact on overall project performance.

This study aims to provide basics for measurement and control of efficiency generating project where operating hours is proportional to system performance. System engineers design and prioritise the system requirements ensuring that the different system attributes are appropriately weighed when balancing the various technical efforts by deciding which risks are worth taking. They also determine whether a new approach to the problem is necessary, whether intense effort will accomplish the purpose, and whether the requirements can be surmounted to relieve the problem. The application of system thinking in project management will improve project delivery because all project stakeholders will focus beyond their direct responsibility.
Key concept definition

According to Gadonneix et al (2010-14), different project management scholars take different factors into account that affect the progress and the overall success of a project. Prabhakar (2008-7) believes that budget compliance and accurate schedules will matter less if the project results do not meet the project goals and expectations. Kerzner (2001-48) holds that factors that create an environment which ensures that projects are managed in a consistently successful way, are critical. Humphrey (2005-27) indicates that critical success factors are those factors that will significantly improve the chances of project success if addressed appropriately, which requires choosing processes and activities that will address critical factors.

Generally, a successful project will be completed on time, within cost, deliver quality as promised, meet or exceed stakeholder expectations and maintain a win-all situation. Kerzner (2001-24) states that companies increasingly make use of the project management methodology as a management tool to promote organisational change. Stewart (2001-47) holds that although numerous effects result from the stakeholders' expectations, aspects that lead to successful projects are part of the strategic perspective. Saynisch (2010-32) indicates that project management literature has identified some determining factors, which include complexity and uncertainty.

Adler and Ziglio (1996-44) point out that project management has a long-standing approach intended to assist organisations' project managers to manage project activities by applying techniques, skills and tools to meet stakeholders' needs, using effective project management practices. It is also generally acknowledged that good project management does not generally result in project success or bad project management to project failure. Dvir (1998-923) suggests that the success factors identified in other industries, cannot be used as valid factors for power plant life cycle projects, because factors are not universal to all projects.

Ernest (2002-40) states that due to projects delivering substandard products, most power utilities today are faced with a short product life cycle, technical products that are highly complex and increased project life cycle costs (PLCC). Steyn et al (2000-86) claims that there are many constraints in realising and executing LOPP-based project work. The key factors involve the organisational structure in which the project is set, forming high-performance teams and resolving any conflict that may arise, as well as the expertise required by effective project managers, the improbability and risks intrinsic to all projects, and a flawless definition of how project success should be measured (Hearkens , 2002-40).

According to Gadonneix et al (2010-48), the major challenge of most power utilities is to improve the performance of the existing generating plant, specifically considering how to evaluate performance in the context of multiple objectives such as reliability, availability, efficiency, environmental performance, and flexibility. Ramage and Armstrong (2005-14) state that project failure or project delay is a global phenomenon. Baccarini (1999-63) argues that it is important to differentiate between project success criteria and project success factors. Criteria are used to measure success, while factors facilitate the achievement of success. Baccarini (1999-24) indicates that project success comprises two distinctive components, namely project management success and project product success. This is illustrated by the formula below.

$$\boldsymbol{Project\ success\ =\ Project\ management\ success\ +\ Project\ product\ success} \qquad (\mathbf{2})$$

Project management success concentrates on the project management process with specific reference to the successful achievement of the project goals regarding cost, time and quality. These three factors indicate the degree of the proficiency of project execution (Pinkerton, 2003-334). Project product success concentrates on the properties of the project's end-product. Though project product success differs from project management success, the successful outcomes of both are inseparably linked. If the endeavour is not a success, the product will most often also be unsuccessful (Pinkerton, 2003-345).

Sanvado et al (1992-102) points out that by using the project model, the success and performance of a project can be examined. The absolute value of the rating is indicative of the client's perception of the performance and success of the project. Chan and Kumaraswamy (2002-25) reviewed Sanvido's work on empirical studies from management journals to develop a conceptual framework on critical success factors. This resulted in five groups of independent variables which were identified as project related, procurement related, project management related and project participant related.

Julian (2008-44) indicates that project control and monitoring tools are based on expert judgement and parametric analysis. Pinto and Slevin (1988-71) found that some determining factors identified in project management literature are becoming increasingly evident. As projects become more complex, stakeholders play an increasingly important role in the success of project development, while projects are always surrounded by uncertainty with continuous changes. Shenhar et al (2001-707) points out that while expert judgement is an important tool in project management, it is limited, because resources are often limited. High complexity and accuracy make it difficult to apply the expected judgement required in projects.Rodriguez et al (2007-558) state that the application of artificial intelligence algorithms to the prediction of project success, reveal a wide selection of objectives that can be divided into predicting project success and identifying critical success factors. According to Holland (1975-12), statistical models were used as an initial approach, but these were unable to meet project management needs.

However, with artificial intelligence, researchers found tools and algorithms that more effectively address complex environments and project uncertainty during normal project development, while algorithms address specific goals. These include the identification of critical success factors and the prediction of project success. Atkinson (1999-341) believes that the project status model (PSM) is used to monitor and indicate changes in project status through constant updates during the project and at a certain point after it ends, thus assisting the project manager to monitor the progress of the project and its results. DeLone and McLean (1992-24) propose a compressive model for project success by merging the success dimensions from project management streams and information systems. They believe that these will assist project managers to assess the likely success early in the development stages.

Maylor (2003-53) specifies that factual evidence is used when a project is pronounced a success. However, different authors show a lack of consensus and objectivity as to what constitute a successful project. The mutual question to be asked is what constitutes a successful project? How do we measure project success? How can our efforts towards project management succeed? Ashley (1987-75) indicates that to identify factors that have a significant effect on the success of a construction project, several construction project personnel should be interviewed to identify factors which influenced average projects and outstanding projects, as well as the principal measure of project success and factors showing a strong correlation to project outcome.

Research methodology

In this article , a project control system based on the project success factors to holistically measure project performance from the initial phase to project closure (project life cycle), is developed to determine to what extent tasks, activities and projects were successful. The models introduce the effect of critical factor interdependency into the entire project management theory, by emphasizing that focusing on the whole in project management will increase the organisation's project performance. The model provides one standalone measure comparing projects performance in any stage of its life cycle providing performance benchmark for future projects. The model is based on project success factors (PSF) composed of five factors and the overall factor interdependency (effects towards each factor performance). This weighted critical success factors (CSF) system is used to measure and monitor project success by consolidating different success measure to one measure in order to generally compare plant life cycle management project success.

A questionnaire survey was sent out to individuals working for power utilities that are members of the association of power utilities of Africa (APUA) which include north, south, east, west and central power pool. The individuals targeted were project managers, system engineers, consultants, contractors and supplies to determine the critical project success factors, project deliverable (products) critical success factors, organisational/corporate critical success factors and critical power utility constraints. A two-stage Delphi technique utilizing a panel of experts was performed to verify and validate the factors identified. Stage-three Delphi was performed to identify the impact of each factor in relation to PMBoK guidelines.

Respondents were asked to respond using a five-point Likert scale where 1: strongly disagree, 2: disagree, 3: Neither agree nor disagree, 4: Agree and 5: Strongly agree, in order to indicate their level of agreement. Statistical methods, including analysis of variance (ANOVA), Pearson correlation coefficient and the T-test were performed to understand the critical factors relationships.
Research findings

The survey data collection was done utilizing the online web system monkey survey. The respondents were sent survey links via emails and statistical data was collected using the online software, which produce statistical results as participants responds. The figure below summarizes the survey and Delphi results.

Questionare	Survey	Delphi 1	Delphi 2	Delphi 3
Sent	489	48	35	35
Returned	423	35	35	32
Not returned	61	13	0	3
Percentage response	87%	73%	100%	91%

Critical success factors and critical constraints were sorted by the average score and only the ones with an average score of four and above where identified to be critical. The mean rank was used to identify the top five critical factors or constraint to be used for modelling. The analysis was aided by the use of statistic package where scores assigned to each factor by the respondents were entered and consequently the responses from the questionnaires were subjected to statistical analysis for further insight. Contribution of each factors was examined and the ranking of the attributes in terms of their criticality as perceived by the respondents was done by use of relative importance index (RII) which was computed using equation and the results of the analysis are presented using the formula:

$$\text{RII} = \frac{\sum W}{A * N}(0 < RII < 1)$$

Where: W - is the weight given to each factor by the respondents and ranges from 1 to 5, (where “1” is “strongly disagree” and “5” is “strongly agree”); A - is the highest weight (i.e. 5 in this case) and; N – is the total number of respondents. The final results for critical factors and contraints are summarized in the table below.

Table 1 Critical factor results summary

Project critical success factors	Average	RII	Rank
S1: Project management techniques are applied	4.166667	0.774803	1
S2: Standards are actively used to drive quality of outputs	4.3	0.770079	2
S3: Regular and careful progress monitoring	4.088889	0.765354	3
S4: Pre-project planning is thorough and considered	4.066667	0.754331	4
S5: Direct and indirect suppliers are aware of project	4.077778	0.741732	5
Product (Deliverable) critical success factors	Average	RII	Rank
P1: Value for money	4.011111	0.748031	2

P2: Improve efficiency of the system	4.066667	0.762205	1
P3: Satisfactory overall equipment effectiveness	3.733333	0.746457	4
P4: Minor and major upgrades required to improve reliability	3.6	0.705512	5
P5: Unexpected disruptions beyond the control of project management	3.777778	0.730709	3
Organisational/corporate critical success factors	Average	RII	Rank
Q1: Business benefits realised	3.905512	0.781102	1
Q2: Strategic benefits realised	3.850394	0.770029	3
Q3: New core competency realized	3.92126	0.784252	2
Q4: New organizational capability realized	3.606299	0.72126	4
Critical delay/failure/constraints	Average	RII	Rank
F1: Construction methods by contractors	3.811111	0.765354	1
F2: Waiting time for approval Consultants	3.433333	0.744882	2
F3: Decision making by owners	3.488889	0.743307	3
F4: Inappropriate communication	3.355556	0.730709	4
F5:Material quality	3.655556	0.703937	5

Statistical analysis

Analysis of variance (ANOVA)

The one-way ANOVA was performed to compare the means between the groups you are interested in and determines whether any of those means are statistically significantly different from each other. Specifically, it tests the null hypothesis:

$$H_O: \mu_1 = \mu_2 = \mu_3 = \cdots = \mu_k$$

where μ = group mean and k = number of groups. If, however, the one-way ANOVA returns a statistically significant result, we accept the alternative hypothesis (HA), which is that there are at least two group means that are statistically significantly different from each other. The hypothesis test was developed in order to understand the relationship between different factors groups.

> Null hypothesis: H_0 : There is no important relationship between project success factor, product success factor and organisational success factors
>
> Alternative hypothesis: H_1 : There is an important relationship between project success factor, product success factor and organisational success factors

The figure below shows the one way ANOVA results for the critical success factors.

Table 2 One-way ANOVA results

	Treatments				
	1-Project success	2-Product success	3-Organisational success	4-Failure factors	Total
N	5	5	5	5	20
∑X	20.7	19.1889	19.5222	17.7444	77.1556
Mean	4.14	3.8378	3.9044	3.5489	3.8578
∑X2	85.7362	73.7962	76.3819	63.1075	299.0217
Std. Dev.	0.0977	0.1959	0.199	0.1834	0.2688

The ANOVA results are summarised in the table below:

Table 3: ANOVA results summery

Source	SS	df	MS	
Between-treatments	0.8882	3	0.2961	F = 9.77633
Within-treatments	0.4845	16	0.0303	
Total	1.3727	19		

The f-ratio value is 9.77633. The p-value is .000666. The results between the four groups are significant at $p < .05$].

Pearson correlation coefficient

Correlation between sets of data was conducted to measure how well they were related. The types of correlation can be categorised by considering as one variable increases what happens to the other variable (positive correlation, negative correlation or no correlation).

The starting point of any such analysis should thus be the construction and subsequent examination of a scatterplot. In this study, r was used to measure the strength and direction of the relationship between ratings of critical factors.

Table 4: Pearson coefficient

Pearson coefficient	∑	Mean	SSx	∑	Mean	SSx	N	∑	r
1. Project success vs project failure	3.806	0.76	0	3.72	0.743	0	5	0	0.856
2. Project success vs product success	3.806	0.76	0	3.69	0.739	0	5	0	0.989
3. Project success vs organisation success	3.806	0.76	0	3.78	0.756	0	5	0	0.935
4. Failure factor vs product success	3.715	0.74	0	3.69	0.739	0	5	0	0.858
5. Failure factor vs organisational success	3.715	0.74	0	3.78	0.756	0	5	0	0.852
6. Product vs organisational success	3.693	0.74	0	3.78	0.004	0	5	0	0.888

T-test

The third phase of the Delphi technique evaluated the effect of each factors towards nine project management body of knowledge area (PMBoK). The independent t-test which is an inferential statistical test that determines whether there are statistically significant differences between the means in two unrelated groups was performed in order to determine the overall average score and final T-test score. The null hypothesis for the independent t-test is that the population means from the two unrelated groups are equal:

$H0: u1 = u2$

Proof is required in most cases that the null hypothesis is rejected and accepts the alternative hypothesis, which is that the population means are not equal:

$H1: u1 \neq u2$

In this research, significance is evaluated based on the p-value where a low p-value indicates that the test is significant and conclusions can be drawn. The table below indicates the factors that were within the t-test value < 0.05, which signifies that the test is significant.

Table 5: T-test results summary

Success factor	Unit	Integration	Scope	Time	Cost	Quality	Human	Communication	Risk	Procurement	Average
Project factors	Average	4.56	4.14	4.34	4.42	4.22	3.82	4.08	4.34	3.34	4.14
	T-test	0.02	0.03	0.04	0.04	0.04	0.07	0.06	0.04	0.06	0.05
Product success	Average	4.16	4.14	3.96	4.04	4.08	3.68	3.16	3.76	3.56	3.84
	T-test	0.02	0.07	0.06	0.05	0.03	0.06	0.06	0.05	0.07	0.05
Organisational success	Average	4.18	4.08	3.98	3.98	4.15	3.70	3.73	3.65	3.05	3.83
	T-total	0.00	0.06	0.06	0.06	0.05	0.07	0.05	0.05	0.08	0.05
Failure factor (constraint)	Total	4.56	4.14	4.34	4.42	4.22	3.82	4.08	4.34	3.34	4.14
	T-test	0.02	0.03	0.04	0.04	0.04	0.07	0.06	0.04	0.06	0.05
Total	Score	4.36	4.12	4.15	4.21	4.17	3.76	3.76	4.02	3.32	3.99
	T-test	0.02	0.05	0.05	0.05	0.04	0.07	0.06	0.05	0.07	0.05

Factors’ impact on the body of knowledge were sorted by their total scores. The knowledge areas score equal to four or less were considered insignificant and ignored. The knowledge area priorities were numbered according to the t-test values with numbers closer to zero as high priority and further from zero as low priority.

Table 6: Critical factors' impact on PMBoK area

Factor	Integration	Scope	Time	Cost	Quality	Risk	Total
Project success	1	2	3	4	5	6	3.5
Project failure	4		1	2	3	5	3
Product success	1				2	3	2
Organisation success	1					2	1.5
T-total	1.8	2	2	3	3.3	4	

Sanvido et al (1992-102) points out that by using the project model, the success and performance of a project can be examined. The absolute value of the rating is indicative of the client's perception of the performance and success of the project. Chan and Kumaraswamy (2002-25) reviewed Sanvido's work on empirical studies from management journals to develop a conceptual framework on critical success factors. This resulted in five groups of independent variables which were identified as project related, procurement related, project management related and project participant related.

However, with artificial intelligence, researchers found tools and algorithms that more effectively address complex environments and project uncertainty during normal project development, while algorithms address specific goals. These include the identification of critical success factors and the prediction of project success. Atkinson (1999:441) believes that the project status model (PSM) is used to monitor and indicate changes in project status through constant updates during the project and at a certain point after it ends, thus assisting the project manager to monitor the progress of the project and its results. DeLone and McLean (1992-24) propose a compressive model for project success by merging the success dimensions from project management streams and information systems. They believe that these will assist project managers to assess the likely success early in the development stages.

Proposed project management equation based critical success factor

Measuring and comparing the performance of life cycle projects is an important task. Controlling and monitoring projects for maximum impact must therefore be achieved through early design and planning, as well as monitoring and using the correct matrix for interpretation. This will result in a project plan that is aligned with a better response to the risks identified during project design, planning and execution. To determine critical factor priorities, a scale was used as shown in the table below:

Table 7: Weight factors for the final project success factors

Project management success factor	Relative Important Index (RII)	Weighted value	Corresponding weighting
Integration ($X_{1,2,3,4,5}$)	0.789	3.2	0.230
Scope (X_1)	0.765	3	0.216

Time (X_2)	0.758	3	0.216
Cost (X_3)	0.732	2	0.144
Quality (X_4)	0.726	1.7	0.122
Risk (X_5)	0.682	1	0.072
Sum		13.9	1

The project management success (PMS) equation is therefore:

$$\boldsymbol{PMS = \frac{3.2}{13.9}(I) + \frac{3}{13.9}(S) + \frac{3}{13.9}(T) + \frac{2}{13.9}(C) + \frac{1.7}{13.9}(Q) + \frac{1}{13.9}(R)} \ldots\ldots\ldots\ldots..(3)$$

$$\boldsymbol{PMS = 0.23(I) + 0.216(S) + 0.216(T) + 0.144(C) + 0.122(Q) + 0.0719}(\mathrm{R})\ldots\ldots\ldots\ldots(4)$$

$$\mathbf{PMS(X_1) = 0.23\left(X_{1.1,2,3,4,5}\right) + 0.216(X_1) + 0.216(X_2) + 0.144(X_3) + 0.122(X_4) + 0.0719(X_5)}$$

$X_{1,2,3,4,5}$ = interdependency
X_1 = Scope
X_2 = Time
X_3 = Cost
X_4 = quality
X_5 = Risk

The figure below shows critical factors and outputs of a project management process

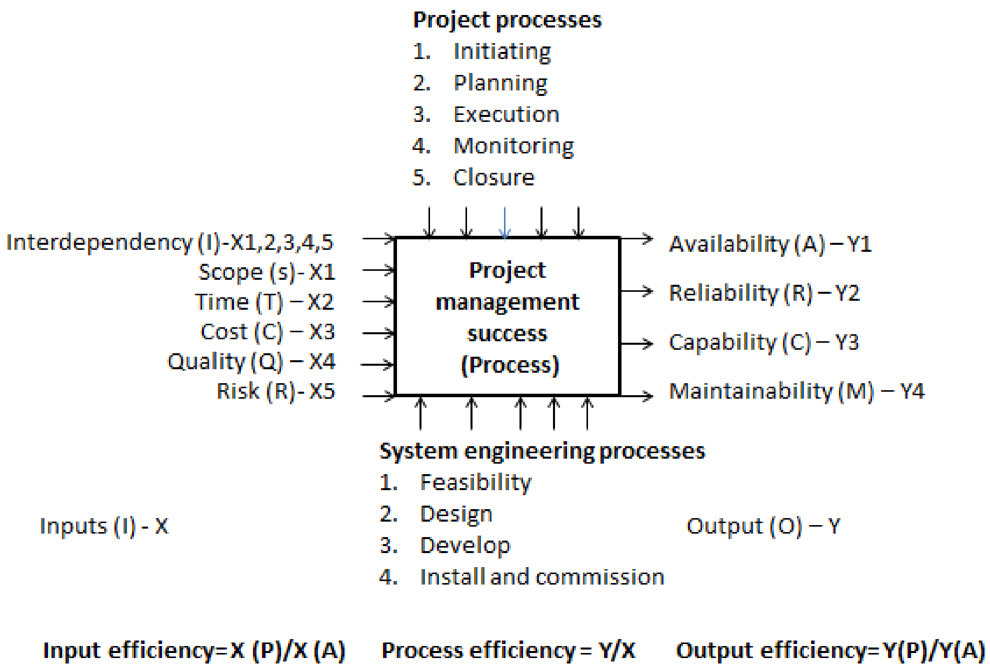

Figure 1 Project management success process

Maylor (2003-53) specifies that factual evidence is used when a project is pronounced a success. However, different authors show a lack of consensus and objectivity as to what constitutes a successful project. The mutual questions are what constitute a successful project? How do we measure project success? How can our efforts towards project management succeed? Ashley (1987-75) indicates that to identify factors that have a significant effect on the success of a construction project, several construction project personnel should be interviewed to identify factors which influenced average projects and outstanding projects, as well as the principal measure of project success and factors showing a strong correlation to project outcome.
Task, process, project variability

Projects, like any industrial process, are affected by variations caused by the relationship between individual tasks and the project's end date. Current project management practices do not take into consideration the realities faced in day-to-day events. Understanding and measuring process variations in project tasks will assist project managers to continuously improve project performance or success because sources of variability will be identified. Understanding that the input and process variability of tasks will affect the output quality, requires project managers to first understand the impact of the whole, before tasks are carried out (managing interdependencies). The figure below illustrates the project's critical life cycle operational measures as identified by research results.

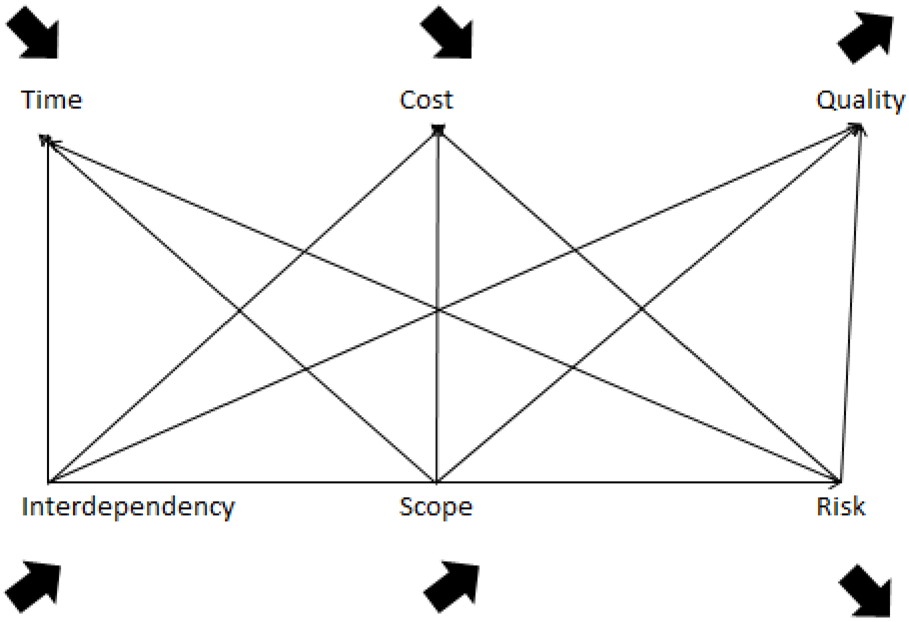

Figure 2 Operational measurements' relation to project performence

The figure above indicates that each factor generally falls under two types , (1) those that the project manager must maximize (integration, scope and quality) and (2) those that must be minimized (time, cost and risk). The factors are:

Interdependency (integration): The effects of interdependencies towards success or failure in engineering projects have become evident as systems grow more complex and manufacturers compete in new product innovation. A life cycle project continuously demands both internal interdependency management (integrating different components from different manufacturers to form a system) and external interdependency management (old subsystem that should form a system with the new subsystem). The research results indicated that system interdependencies (integration) must be given number one priority when designing and implementing life cycle projects. This will be achieved by measuring all interfaces' success during design and project execution (integration efficiency). The results indicate that interdependency accounts for 23% of the influence towards life cycle project success or failure.

Scope: The scope efficiency of a life cycle project can be measured using work packages. Work packages identify all resources, capacity, requirements and facilities required to perform and complete the project task. The research results indicate that scope efficiency accounts for 21,6% of life cycle project success or failure.

Time: The research results indicate that time efficiency accounts for 21,6% of the life cycle project's success or failure. Time is always an important factor in life cycle projects because units are normally on outage to perform this project work, directly linking to the power plan's planned capacity load factor (PCLF).

Cost: The research results indicate that cost efficiency accounts for 14,4% of the life cycle project's success or failure. Most research in project management has shown that although most projects exceed their budgets, the outcomes are not necessarily better than desired. The concept of value for price paid, measured by the cost efficiencies in project must be embraced to improve cost management in projects.

Quality: Project complexity determines how quality control must be performed by determining the follow-up levels required for performing the project. A scale of 0 to 10 is used where a higher value is an indication of a highly complex task in a project and a low value represents a less complex task in project. The actual number of requirements that need to be tested and monitored is required and is used to measure quality efficiency as the project progresses. The research results showed that 12,2% of project success and failure depends on quality efficiency.
Risk: A scale of 0-10 is used to measure the level of certainty existing in the life cycle project projects task. A high value indicates a risky project with high uncertainty levels which require advanced technology to be used. Research results indicated that 7% of life cycle project success and failure is influenced by risk efficiency.

According to Muller (2001-2), the variation ratio of a task or project can be calculated by determining the difference between planned and actual values, divided by the planned values.

$$Tv = \left(\frac{A-P}{P}\right) \ldots\ldots\ldots\ldots\ldots (5)$$

The variations ratio of time, cost and risk can be calculated as follows:

$$VRt \text{ or } VRc \text{ or } VRr = \left(\frac{A-P}{P}\right) \ldots\ldots\ldots\ldots (6)$$

Scope, integration and quality should be maximised. The equation to measure the variation ratio as indicated below.

$$VRi\ or\ VRs\ or\ VRq = \left(\frac{P-a}{P}\right) \ldots \ldots \ldots \ldots \ldots \ldots (7)$$

V = Variation ratio
P = Planned value (target)
A = Actual value

Calculating the project management variation (PMV), the PSM equation is substituted by the equation above.

$$\boldsymbol{PMS\ (V) = 0.23(VRi) + 0.216(VRs) + 0.216(VRt) + 0.144(VRc) + 0.122(VRq) + 0.0719}(\text{VRr})$$

To calculate at completion values, the current performance variance is considered, which will bring much better prediction accuracy if the status quo remains. This also provides early warnings to project teams giving them more than enough time to address the problem. The example below indicates (applicable to all other critical measures) how cost at completion (CAC) is calculated:

$$\boldsymbol{CAC = CP\ (PUD) + \left(\frac{A-P}{P}\right) PFP + PFP)}$$
$$\boldsymbol{CAC = CP\ (PUD) + (VRc) PFP + PFP)}$$

Where:

CAC = Cost at completion
CP = Current performance (Performance to date)
VRc = Variation ration cost
A = Actual value
P = Planned value
PUD = Performance up to date
PFP = Future planned performance (At specific point)
Project monitoring and control

The study results have brought a new measure that uses the duration as its milestone (like most project planning and monitoring systems), but differs from all planning and monitoring tools that mostly use percentage completion to measure overall progress. This proposed method calculates the project management success (PMS) indicated as a percentage, as well as the project management variability (PMV), indicated as a percentage. The table below indicates a generator rotor upgrade project case study for planning and monitoring.

Table 8: Generator rotor upgrade project data

Task	Start date	Period (days)	PMS (%)	PMV (%)
Feasibility	3/3/18	25	95	0.0012
Design	3/28/18	20	74	0.0687

Procurement	4/18/18	8	87	0.0823
Fabrication	4/26/18	10	88	0.065
Manufacturing	5/8/18	30	84	0.072
Installation	6/8/18	28	82	0.081
Commissioning	7/6/18	10	86	0.072
Total		131	85.85714	0.063171

The new model salvages standard project processes in project management recording results and adjusting (managing process variability) where necessary so that performance improvement could be achieved. The Gantt chart below shows how progress is monitored and updated, indicating both the success and variation of the project tasks.

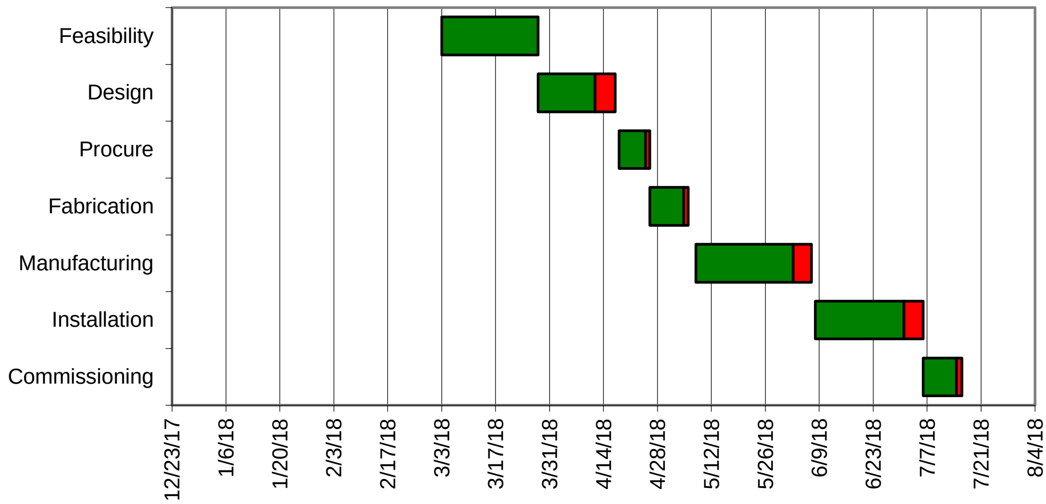

Figure 3: Generator rotor Gantt chart

The new measure holistically considers all critical success factors in designing, planning and executing life cycle projects. This method appreciates that tasks have inherent variations regarding their controlled variables based on the capability of a project management process that should improve capabilities while controlling variations.

6. Conclusions

The prioritisation of success and failure factors at any stage of a project, product or organisation life cycle, allows a unified approach to decision making. These factors force everyone involved in decision making to look beyond their responsibilities, imposing decision making to support the good of the organisation, which is achieved by using real data to continuously evaluate project, product, asset, process efficiency and effectiveness. Organisations that seek to improve their life cycle management will have to refocus the way life cycle projects are executed, operated and maintained. This will require the organisation's internal business processes to be fine-tuned and to realistically measure performance in order to align the practices and values of the organisation. The life cycle measure of success is the best tool to compare the performance of different tasks, projects, products (deliverables) and organisations performance during different stages of life cycle management.

7. Recommendations

It is recommended that a methodology is developed to better manage critical factors for success in power plant life cycle management, identify constraints and providing health checks throughout the product's life cycle. This will enable the organisation to respond to increased pressure for excellence in system engineering and project management. It will assist organisations to understand life cycle project success and its real impact, as well as identifying dependencies of success between life cycle projects, its product (deliverable) and the organisation (corporate success).

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About the Authors

Lalamani Budeli

South Africa

Lalamani Budeli obtained his degree as an Engineer in Electrical Engineering at the Vaal University, BSc honour in Engineering Technology Management at University of Pretoria, Master in engineering development and Management at North West University, Master of business administration at Regent Business School and currently busy with Doctor of Philosophy in Engineering Development and Management at North West university, Potchefstroom, South Africa. Currently, he is a technical support manager at Eskom. His research interests include plant life cycle management, advanced systems analytics, project early warning system and the use of artificial intelligence in project management. Lalamani Budeli can be contacted at BudeliL@eskom.co.za

Prof J H (Harry) Wichers

South Africa

Prof. Harry Wichers has been a part-time lecturer at the North West University (NWU), former Potchefstroom University for CHE, on pre- and postgraduate levels in Systems Engineering and Reliability Engineering from 1986 - 2000. He continued to lecture on pre and postgraduate level at the same university in various Engineering Management subjects from 2003 to 2010. These subjects included Creative Entrepreneurship, Maintenance Management and Entrepreneurial Career Skills. He has also lectured at the Vaal University of Technology (VUT), Vanderbijlpark, in the subjects Maintenance Engineering. He was instrumental in 2004 in the establishment of the Centre for Research and Continued Engineering Development in the Vaal Triangle, (CRCED Vaal), focusing on delivering Master and Doctoral degrees in Engineering Management to Industry. Prof. Wichers is a registered Professional Engineer with ECSA, member of the Institutes of Business Management and Mechanical Engineers (SAIME) and founder member and ex-president of the Southern African Maintenance Association (SAMA).