Critical success factors of project management in African power utilities: Enhancing project management performance [1]

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Abstract

In recent years, the project management and systems engineering body of knowledge has significantly grown but about a third of projects are still failing. Due to these failures, researchers and project consultant needs to understand the local and international factors of success and failures. In most studies, it is accepted that the project differs immensely concerning novelty, complexity, and technological uncertainty. In Africa, project failure rates are unacceptably high across different industries and for projects of varying size. In most cases, a project's failure has a major impact on the organization. The goal for all project stakeholders is to complete the project on time, within cost, and achieving the desired quality. Effective project management practices require a project management system that supports management to achieve its organizational project goals.

Power plant projects are frequently influenced by delay/failure factors that constraint the project to meet its goals or success factors that help project parties reach their goals as planned. The purpose of this article is to identify success and delay factors that can help project stakeholders reach their intended goals with greater efficiency. This was done by identifying these factors and determining the correlation within them to determine influential factors to ensure success or failure.

Keywords: Critical success factor, Project management success, African power utilities

Introduction

Power generating plants require a large initial investment and significant further expenditure to continue operations over its intended life cycle. This means that the cost requirements for the continuing operations should be determined to sustain the plant output over its intended life cycle. Besides, regular detailed life cycle plans that reflect essential refurbishment and replacement activities of all relevant plant systems, are needed. These plans must reflect modifications, projects, and technological improvements that may be required to address any changes in plant conditions, operations, capacity, and legislative requirements, as well as primary energy supply or operational life span.

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The power industry landscape in Africa continuously experiences disruptions mostly due to existing business models, systems, and methods of operation, as well as the blend of players and the electricity subsector. Due to the constraint in which power plants are constructed and operated, it can be expected that there will be differences in efficiency and performance. Real plant design constraints also limit power plant efficiency beyond utilities' control, which is not necessarily a result of ineffective design or operation. Several factors are perceived to affect the efficiency of power plant projects, but this study focuses on efficiency problems due to design and maintenance which is subdivided into plant design, deterioration, plant maintenance and component availability. It is believed that improving access to power will go a long way towards eliminating poverty and unemployment while providing an opportunity for entrepreneurial spirit. Due to challenges that African countries have in terms of capital borrowing, ensuring that they install generating capacity to meet or exceed its designed capacity, becomes a necessity.

Background of the study

Ramage and Armstrong (2005-14) understood that project failure or project delays are a global phenomenon and Africa is not an exception. Baccarin (1999-63) argues that it is significant to differentiate between project success criteria and project success factors because criteria are used to measure success although factors facilitate the achievement of success. Project management success concentrates on the project management process and in specific on the achievement of the project goals concerning cost, time, scope, and quality. These dimensions designate the degree of the proficiency of project execution, said Pinkerton (2003-334). Developing project management methodologies that consider sustainable project life cycle management effectively addressing social and environmental aspects of sustainable development will position power utilities to better place themselves as an energy source of the future.

Wu et al. (2017:852) assume that construction project success factors can be grouped into one of four components, namely:

- Comfort – warranting that leadership determinations are well aligned for the implementation of the project
- Competence – having appropriate technology, experience, and expertise available for the project
- Commitment – ensuring that all parties concerned and all levels of the management hierarchy of each participating organization are willing to manage, plan, design, construct and operate the facility harmoniously.
- Communication – clarifying and disseminating all necessary project information and status to all internal and external project stakeholders.

Barbalho et al. (2016:87) indicate that project control and monitoring tools are based on expert judgment and parametric tools. Projects are how companies implement their strategies. Nicholas and Steyn (2017:177) hold that some determining factors identified in project management literature, are increasingly becoming evident as projects become more complex, stakeholders play an increasingly important role in project development success, and projects are always surrounded by uncertainty with continuous changes. Nicholas and Steyn (2017:234) suppose that expert judgment as an important tool in project management is limited because resources are mostly limited. Nicholas and Steyn (2017:198) further hold that high complexity and accuracy make it difficult to apply the expected judgment required in projects.

Cunha et al. (2014:233) believe that applying artificial intelligence algorithms to the prediction of project success, brings to light a wide selection of objectives, which can be divided into predicting project success and identifying critical success factors. Nicholas and Steyn (2017:67) point out that statistical models were used as an initial approach, but were unable to meet project management needs. With artificial intelligence, however, researchers have found tools and algorithms that address complex environments and project uncertainty during normal project development with algorithms addressing specific goals, namely:

- Critical success factors identification - Bayesian model, genetic algorithms, fuzzy cognitive maps, and neural networks.
- Project success prediction - adaptive boosting neural networks, bootstrap aggregating neural networks, k-means clustering, fast messy genetic algorithm, support vector machine, and evolutionary fuzzy neural inference model.

Norang et al. (2016:762) assume that the main finding deduced from the reviewed theory is that artificial intelligence tools are more accurate than traditional tools, but are still complementary to traditional tools. Nicholas and Steyn (2017:201) suppose that artificial intelligence tools are really helpful for the project manager to control and monitor the project. According to Nicholas and Steyn (2017:308), models also have weaknesses and limitations, thus requiring project managers to use expert judgment and compare artificial intelligence results with traditional tools before decisions are made; so, they adjust if necessary.

Research Hypotheses

The following are research hypotheses:

1. There are critical success factor which is influential to avoid failure factors in African power plant project and programs
2. There are failure factors that currently exist in the African power industry which can assist to expose the fundamental problem affecting project delivery performance
3. Applying the project success life cycle model (PSLCM) can assist power utilities to focus and invest in the right resources needed for the success of the project

Research method

A survey (primary data source) was conducted on a randomly sampled group in the population to investigate the objectives of this study of which findings will be used to draw conclusions and make recommendations. An online system monkey survey was used to collect data for the survey, which also assisted with basing statistical analysis. The survey plan was as below:

Table 1 Survey questionnaire plan

Category	**Number of questions**
Project success factors	35
Product success factors	13
Organizational success factors	4
Project delay/failure factors (constraints)	27
Total	**79**

Survey results

The results of the survey recognize significant success, failure, product, and product success factors identified by Africa's power plant professionals. These factors were the most significant factors identified to determine project success and their impact will be further investigated.

Project success

The project data was analyzed from the perspectives of owners, contractors, consultants, subcontractors, and engineers. Each success factor's relative important index (RII) indicated by respondents was calculated for inclusive exploration. By assigning ranks to each success factor, the project success factors for power plant life cycle projects were identified. The number of respondents who selected a level of importance was grouped in terms of their respective scores. The RII and average score for project success factors were calculated and summarized in the table below.

Table 2 Average score for project success factors

Success factors		1	2	3	4	5	R 11	Mean	SD
Effective governance	clearly identified leadership			9	139	66	0.580	4.266	0.162
	clarity how authority is distributed	5	7	12	131	59	0.548	4.084	
	clear reporting lines			2	128	84	0.712	4.383	
	clear regular communications	10	15	5	112	72	0.657	4.033	
Goals and objectives	Goal clearly specified and recognised by all stakeholders	3	1	17	133	60	0.557	4.150	0.374
	Subsidiary objectives are clearly specified	14	24	23	118	35	0.417	3.636	
	Project leadership has a clear vision	2			128	84	0.708	4.364	
Commitment	lack of commitment clearly recognised and dealt with	12	16	3	101	82	0.739	4.051	0.154
	Project leadership maintains	2		1	128	83	0.703	4.355	

	commitment								
Capable sponsors	Project has active sponsors			28	141	45	0.457	4.079	0.214
	Project sponsors have ultimate responsibility and accountability	2	3	14	161	34	0.333	4.037	
	Project sponsors stay in a role for the life-cycle of the project	10	24	13	141	26	0.309	3.696	
Secure funding	The project has a secure funding base			1	124	89	0.751	4.411	0.431
	Needs for contingency funding are recognised from the start	21	17	18	121	37	0.413	3.636	
	Tight control of budgets	7	15	38	130	24	0.343	3.696	
Project planning	First, start-off, phase of the project is effective	2	4	15	157	36	0.354	4.033	0.191
	Pre-project planning is thorough and considered			1	119	94	0.793	4.435	
	Regular and careful progress (time, scope, cost) monitoring				144	70	0.589	4.327	
	Realistic time schedules	3	5	7	154	45	0.410	4.089	
	Active risk management	8	0	4	141	61	0.532	4.154	
	Flexible to respond to unforeseen			1	136	77	0.650	4.355	
	Post-project review is undertaken (lessons for the future)	2	1	2	127	82	0.699	4.336	
Supportive organizations	Environment in which the project operates friendly and hostile	11	2	19	122	60	0.572	4.019	0.204
	Organisation provides embedded support for project activity	1	1	10	131	71	0.628	4.262	
	The project team has the influencing skills to engage				123	91	0.765	4.425	
Competent project teams	Project professionals are fully competent	8	7	19	131	49	0.486	3.963	0.113
	Team members fully competent in their roles	3	2	8	141	60	0.534	4.182	
	The project team engages in positive behaviors which encourage success		0	29	151	34	0.367	4.023	
Aligned supply chain	Direct and indirect suppliers are aware of project needs and schedules				121	93	0.782	4.435	0.28
	Tiers of supply chains are co-ordinated	4	8	16	144	44	0.434	4.037	
Proven methods and tools	Project management techniques are applied	3	2	2	103	104	0.887	4.416	0.264
	Management tools, methods, and techniques applied		8	3	137	66	0.579	4.220	
	Maintains an effective balance between flexibility and robustness	14	17	13	104	66	0.636	3.893	

Appropriate standards	Standards are actively used to drive quality of outputs	1	1	3	110	99	0.844	4.430	
	Adherence to all standards is regularly monitored			5	114	95	0.813	4.421	0.006

Spearman's rank correlation coefficient was used to measure the degree of agreement between groups. A positive correlation was shown, which indicate that there is a significant relationship at 0.05 level (2 tailored)

Table 3 Spearman's correlation (project success factors)

Critical project success factors			Owner	Engineer	Contractor	Consultant
Spearman's rho	Owner	Correlation coefficient	1	0.7468.	0.9456	0.704
		Sig (2 tailored)		0.00482.	0.03739.	0.01739
		N	214	214	214	214
	Engineer	Correlation coefficient	0.5867.	1	0.6134	0.7134
		Sig (2 tailored)	0.0192.	0.00321.	0.00482.	0.00282.
		N	214	214	214	214
	Contractor	Correlation coefficient	0.4531	0.5123	1	0.6312
		Sig (2 tailored)	0	0	0	0
		N	214	214	214	214
	Consultant	Correlation coefficient	0.461	0.782	0.631	1
		Sig (2 tailored)	0.0292	0.00891	0.0569	0.00432
		N	214	214	214	214

Project delay/failure

Data analysis was done in respect of all stakeholders. Each delay or failure factor RII specified by respondents was calculated for inclusive exploration. By assigning ranks to each success/delay factor, the project failure factors for power plant life cycle projects were identified. The RII and average scores for project failure factors were calculated and are summarized in the table below.

Table 4 Average score for project failure factors

Causes of project failure/delay		1	2	3	4	5	R 11	Mean	SD
Owners	Payment of completed work (Finance)	2	2	3	130	77	0.662	4.299	0.061
	Decision making	4	3	5	102	100	0.864	4.360	

	Unrealistic contract duration	4	4	2	117	85	0.732	4.257	
	Unclear requirements	8	6	4	115	81	0.711	4.192	
	Owner coordination	4	3	5	124	78	0.679	4.257	
Contractors	Construction methods			1	105	108	0.911	4.500	0.155
	Site management	2	5	17	104	86	0.782	4.248	
	Subcontracting		10	18	106	80	0.742	4.196	
	Lack of experience	5	11	23	98	77	0.737	4.079	
	Proper planning	2	5	25	101	81	0.763	4.187	
	Construction errors	4	3	28	116	63	0.618	4.079	
Consultants	Waiting time for approval		5	4	103	102	0.879	4.411	0.109
	Quality control and assurance				143	71	0.597	4.332	
	Drawing and specification approval			16	121	77	0.693	4.285	
	Contract management		3	18	137	56	0.527	4.150	
Labour and equipment	Material shortage		3	3	142	66	0.569	4.266	0.083
	Material quality	1	1	13	108	91	0.805	4.341	
	Equipment availability	5	3	5	103	98	0.849	4.336	
	Labour productivity	5	2	13	102	92	0.819	4.280	
	Labour supply			43	99	72	0.726	4.136	
Contract	Errors in contract documents	7	4	25	97	81	0.765	4.336	0.016
	Change order			17	108	89	0.796	4.360	
Contract relationship	Inappropriate communication	4	2	5	105	98	0.846	4.360	0.213
	Organisational structure	11	17	18	124	44	0.463	3.808	
	Disputes	1	2	16	129	66	0.605	4.201	
	Regulatory changes			5	144	65	0.561	4.280	
	Unfavourable site condition	2	4	5	139	64	0.562	4.210	

Spearman’s rank correlation coefficient was used to measure the degree of agreement between groups. A positive correlation was shown, which indicates that there is a significant relationship at the 0.05 level (2 tailed)

Table 5 Spearman’s correlation (constraint/failure/delay factors)

Constraint/failure/delay factors			Owner	Engineer	Contractor	Consultant
Spearman’s Rho	Owner	Correlation coefficient	1	0.451	0.557	0.615
		Sig (2 tailored)		0.00478	0.0479	0.0474
		N	214	214	214	214
	Engineer	Correlation coefficient	0.601	0.713	0.652	0.781
		Sig (2 tailored)	0.0595	0.00518	0.00402.	0.0049
		N	214	214	214	214

	Contractor	Correlation coefficient	0.698	0.673	1	0.662
		Sig (2 tailored)	0.0445	0.00568	0.00452.	0.0594
		N	214	214	214	214
	Consultant	Correlation coefficient	0.661	0.608	0.5901	1
		Sig (2 tailored)	0.0292	0.00891	0.0569	0.00432
		N	214	214	214	214

Project product success factor (project deliverable)

Data analysis was done in respect of all stakeholders. Each project product success factor RII specified by respondents was calculated for inclusive exploration. By assigning ranks to each project product success factor, the project product success factors for power plant life cycle projects were identified. The RII and average scores for project product success factors were calculated and are summarised in the table below.

Table 6 Average score for product success factors

Product success factors		1	2	3	4	5	R 11	Mean	SD
Added value success	Improves efficiency in other areas (additional)	1	2		10 7	10 4	0.879 4	4.453	0.03
	Real benefits outperform focused benefits		4	1	10 4	10 5	0.893 5	4.449	
User satisfaction	Continuous good interaction with the environment		4	8	13 5	67	0.593 5	4.238	0.034
	Do not limit other systems' performance		7	1 1	12 8	68	0.615 9	4.201	
	Adhere to the Occupational Health Safety Act	1	4	8	12 4	77	0.678 5	4.271	
	Minor and major upgrades required to improve reliability	5	7	7	97	98	0.861 7	4.29	
	All functional requirements realised	2	7	8	11 9	78	0.693 5	4.234	
System created	unexpected disruptions beyond the control of project management	1	3	1 0	10 2	98	0.858 9	4.369	0.074
	No secondary effects to other systems	8	4	4	11 4	84	0.732 7	4.224	
	Deficiencies of the predecessor system eliminated	3	4	1	11 8	88	0.753 3	4.327	
System experienced	Within economic life cycle cost	6	5	1	10 1	10 1	0.867 3	4.336	0.144

	Satisfactory overall equipment effectiveness	1	2	22	145	44	0.4364	4.07	
	Recent technology and great cost savings			13	124	77	0.6841	4.299	

Spearman's rank correlation coefficient was used to measure the degree of agreement between groups. A positive correlation was shown, which indicate that there is a significant relationship at 0.05 level (2 tailored)

Table 7 Spearman's correlation (product success factors)

Critical product success factors			Owner	Engineer	Contractor	Consultant
Spearman's Rho	Owner	Correlation coefficient	1	0.669	0.865	0.724
		Sig (2 tailored)		0.00592	0.0389	0.0449
		N	214	214	214	214
	Engineer	Correlation coefficient	0.5934	1	0.6134	0.694
		Sig (2 tailored)	0.0692	0.00552	0.00634.	0.02342
		N	214	214	214	214
	Contractor	Correlation coefficient	0.673	0.634	1	0.573
		Sig (2 tailored)	0	0	0	0
		N	214	214	214	214
	Consultant	Correlation coefficient	0.511	0.802	0.714	1
		Sig (2 tailored)	0.0398	0.0567	0.0381	0.00432
		N	214	214	214	214

Organizational success

Data analysis was done in respect of all stakeholders. Each organizational success factor RII specified by respondents was calculated for inclusive exploration. By assigning ranks to each organizational success factor, the project organizational success factors for power plant life cycle projects were identified. The RII and average score organizational success factors were calculated and are summarised in the table below.

Table 8 Business success factors

Business success factors		1	2	3	4	5	R 11	Mean	SD
Organizational success	Business benefits realised	1	1	8	102	102	0.8832	4.41589	0.068
	Strategic benefits realised	1	7	10	98	98	0.8664	4.33178	

	New core competency	2	5	10	101	94	0.8299	4.28037	
	New organisational capability	4	2	17	102	89	0.8037	4.26168	

Spearman's rank correlation coefficient was used to measure the degree of agreement between groups. A positive correlation was shown, which indicate that there is a significant relationship at 0.05 level (2 tailored)

Table 9 Spearman's correlation (product success factors)

Critical organizational success factors			Owner	Engineer	Contractor	Consultant
Spearman's Rho	Owner	Correlation coefficient	1	0.716	0.914	0.594
		Sig (2 tailored)		0.00445	0.04456	0.0298
		N	214	214	214	214
	Engineer	Correlation coefficient	0.8102	1	0.6935	0.7945
		Sig (2 tailored)	0.0692.	0.00341.	0.00479	0.00337
		N	214	214	214	214
	Contractor	Correlation coefficient	0.6531	0.534	1	0.773
		Sig (2 tailored)	0.0442.	0.00357.	0.00597	0.00436
		N	214	214	214	214
	Consultant	Correlation coefficient	0.711	0.812	0.721	1
		Sig (2 tailored)	0.0345	0.00951	0.00669	0.00488
		N	214	214	214	214

Discussion of the results

An RII of 0.70 and a mean of 4.2 were used to identify critical project success factors as shown in the table below. The results of the critical success factors obtained from the survey are summarised in the table below:

Table 10 Critical project success factors

Project success factors	RII	Mean
Clear reporting lines	0.712	4.383
Project leadership has a clear vision	0.708	4.364
Project has active sponsors	0.739	4.355
The project has a secure funding base	0.751	4.411
Pre-project planning is thorough and considered	0.793	4.435
The project team has the influencing skills to	0.765	4.425

engage		
Direct and indirect suppliers are aware of the project	0.782	4.435
Project management techniques are applied	0.887	4.416
Standards are actively used to drive the quality of outputs	0.844	4.430
Right quality (meet all specifications requirements)	0.813	4.421

The five critical success factors identified for further analysis are:

- S1: Project management techniques are applied – project management tools and techniques make it easy for project managers to plan, organize, coordinate, direct, and control the combined efforts to achieve project success. Project management tools and techniques include work breakdown structures, work accounts, work authorization processes, schedule planning, and financial planning.
- S2: Standards are actively used to drive quality of outputs – project management requires a process to ensure that the project will fulfill the purpose for which it was undertaken. This includes activities of the overall management function that determine the quality policy, objectives, and responsibilities, and implements them through means such as quality planning, quality control, quality assurance, and quality improvement, within the quality system.
- S3: Regular and careful progress monitoring – progress monitoring requires that time should be taken to plan all aspects of the project because it saves time and resources later and improves expected project results.
- S4: Pre-project planning is thorough and considered – project management industry practitioners have long recognized the importance of pre-project planning and its potential impact on project success. Previous researchers have discovered that there is a positive relationship between thorough pre-project planning and enhanced project performance.
- S5: Direct and indirect suppliers are aware of project – material procurement is an important part of projects due to increased project complexity, changing roles, and interactions. The material and construction contracts are normally signed very early during project development, when the chances of unforeseen contingencies are considerable.

Critical delay factors

The delay factors shown in the table below were identified for further analysis

Table 11 Project constraint/delay/failure Factors

Constrain/delay/failure factors	RII	Mean
Decision making by owners	0.864	4.360
Construction methods by contractors	0.911	4.500

Waiting time for approval consultants	0.879	4.411
Material quality	0.805	4.341
Type of contract used	0.796	4.360
Inappropriate communication	0.846	4.360

The five critical delay/failure factors identified for further analysis are:

- F1: Construction methods by contractors - project success or failure can be determined by choosing an appropriate project delivery method. Certain methods are not available for certain projects due to variations in state and local regulations. Most forms of construction include design-build, job-order contracting, contractor prequalification, multi-prime, and best value selection.
- F2: Waiting time for approval consultants – a literature review of various experts in the field of project management and system engineering confirmed that incomplete drawings and contract document discrepancies are major causes of project delays, with most being associated with incomplete drawings that require extensive changes and approvals during construction. In the 21st century, most organizations transferred the design responsibility to consultants who are responsible for the design management of the project.
- F3: Decision-making by owners – in project management, critical or non-critical decisions are taken daily improving the probability of success or failure, but owners have more responsibility and accountability. To ensure unbiased critical decision making requires that complete and accurate data is obtained and logically examined.
- F4: Inappropriate communication – most project management authors have noted that ineffective communication harmed successful project execution. The reality is that most projects lack effective communication management, resulting in major economic impact. Well,-thought-out communication strategies and tools designed to manage information are needed for execution.
- F5: Material quality – Many projects throughout the world are exposed to material quality problems, which require organizations to understand their supplier performance to be successful. Due to globalization, companies are supplying materials internationally where error correction becomes difficult or impossible, which requires a fist-time approach towards supply chain and quality management.

Product success factors

The product success factors in the table below were identified for further analysis

Table 12 Project product (deliverable) success factors

Product success factors	RII	Mean
Value for money	0.867	4.336

Unexpected disruptions beyond the control of project management	0.859	4.369
Improve the efficiency of the system	0.879	4.453
Minor and major upgrades required to improve reliability	0.862	4.290
Satisfactory overall equipment effectiveness	0.893	4.449

The five critical project product success factors identified for further analysis are:

- P1: Value for money – organizations invest money in projects to generate money for an intended period. Value for money invested commonly referred to as return on investment is important for all project owners. Various researchers have discovered that most projects are executed consuming organizational resources with no benefits to show.
- P2: Improve the efficiency of the system – improving project, product, or business efficiencies is important due to improved competition. Highly efficient organizations compete easily while inefficient organizations mostly face liquidation. Improving efficiency by developing smooth running systems, include improving quality, improving process and system bottlenecks, reducing downtime and lead times, simplifying, measuring, and monitoring system performance.
- P3: Satisfactory overall equipment effectiveness –ensuring that the system satisfies the overall performance requirements. This means that the overall design function focused on achieving a balanced system devised to provide a practical, holistic solution to the challenge of meeting the project, product, or organization's needs.
- P4: Minor and major upgrades required to improve reliability – advanced technology provides a wealth of information that allows users to better maintain plant equipment. New products featuring integrated electrical controls are introduced almost daily, but these innovations make legacy equipment seem antique. Adding new system functionalities to existing plant systems can enhance the equipment's function and extend its service life.
- P5: Unexpected disruptions beyond the control of project management –project manager's performance must include deliverable performance because the success of a product is inseparably linked. This will ensure that critical requirements during project execution are attended.

Organizational success factors

The organizational success factors in the table below were identified for further analysis

Table 13 Critical organizational/corporate success factors

Organizational/corporate success factors	RII	Mean
Business benefits realized	0.883	4.416

Strategic benefits realized	0.866	4.332
New core competency	0.830	4.280
New organizational capability	0.804	4.262

The four critical organization/corporate success factors identified for further analysis are:

- Q1: Business benefits realized – companies undertake projects and change programs to deliver benefits, but they are often criticized for failing to achieve them. Studies show that over 70% of business improvement projects fail to deliver their expected benefits and even when they are achieved in part, they are often far from fully realized.
- Q2: Strategic benefits realized – in a highly competitive internal organizational landscape, sponsors and project managers need to present the business case for their projects to position the benefits of their proposal against the other potential projects in the portfolio. They must also provide evidence of a clear linkage to the strategic direction of the business.
- O3: New core competency realized – organizations developed measures that delivered project competency to reduce waste and maximize efficiency. These competencies must be objectively measured to ensure that organizational capabilities are realized.
- O4: New organizational capability realized – Most researchers indicate that delivering projects that are aimed at implementing strategy, remains a challenge for most organizations. The purpose of strategy is to change an organization's trajectory and the project linked to the strategy must contribute a fair share in doing just that.

The five most significant critical factors determining project, product, and organizational success were selected for further investigation, and are indicated in the table below. The table below shows factors that will be included to develop a measurement and monitoring model

Table 14 critical factors summary

Project success factors	**Delay/failure factors**
S1: Project management techniques are applied	F1: Construction methods by contractors
S2: Standards are actively used to drive the quality of outputs	F2: Waiting time for approval consultants
S3: Regular and careful progress monitoring	F3: Decision making by owners
S4: Pre-project planning is thorough and considered	F4: Inappropriate communication
S5: Direct and indirect suppliers are aware of the project	F5: Material quality
Product success factors	**Organizational success**
P1: Value for money	O1: Business benefits realized
P2: Improve the efficiency of the system	O2: Strategic benefits realized
P3: Satisfactory overall equipment effectiveness	O3: New core competency realized
P4: Minor and major upgrades required to improve reliability	O4: New organizational capability realized

P5: Unexpected disruptions beyond the control of project management	

Application of critical success factor to measuring performance

DEA is used to measure efficiency with multiple inputs and multiple outputs, assuming that there is no random noise, measurement errors, or outlier cases in the data. The weighted input efficiency can be calculated as follows:

$$E_k = \frac{\sum_{j=1}^{M} u_j\, O_{jk}}{\sum_{i=1}^{n} V_i\, I_{ik}} \qquad (1)$$

Where:

$V_i = weight\ for\ input\ i$
$U_j = weight\ for\ input\ j$
$O_{jk} = Output\ data$
$I_{ik} = Input\ data$
$E_k = Efficiency\ of\ a\ DMU\ (0\%\ to\ 100\%)$

Using this method, the number of variables does not matter because the correct data that is used to represent input and output is known.

Data envelope analysis makes it possible to use different variables with different measuring units by calculating individual efficiencies and that the factors linked to these processes were evaluated before and the table below links the above processes to these factors.

Table 15 PSLCM alignment

Process	**Technical Performance measure**	**Description**	**DEA measurements**
Project management success	Interdependency	Efficiency	Efficiency
	Scope	Work packages	Efficiency
	Time	Days	Efficiency
	cost	Rand	Efficiency
	Quality	Compliance	Efficiency
	Risk	Mitigation	Efficiency
Project product success	Availability	Percentage	Efficiency
	Reliability	Percentage	Efficiency
	Capability	Percentage	Efficiency
	Maintainability	Percentage	Efficiency

Organizational success	Life cycle cost	Rand	Efficiency
	Benefits realization	Rand	Efficiency

The model represented by the formula below has a holistic view of life cycle performance measurement and applies both system and process thinking, which provides more benefits than the two models used separately. This proposed model also provides a tool to calculate process efficiency, which will make it easy to identify system problems compared to process problems. The proposed model easily guides designers, project managers, and operators by providing information that is normally only available to them through other methods, thus improving decision making because the information gap is eliminated. The formula:

$$\boldsymbol{PS} = \left[0.23\left(\left(\frac{\Delta\mu O_i}{\Delta\mu i_i}\right)i\right) + 0.216\left(\left(\frac{\Delta\mu O_i}{\Delta\mu i_i}\right)S\right) + 0.216\left(\left(\frac{\Delta\mu O_i}{\Delta\mu i_i}\right)T\right) + 0.144\left(\left(\frac{\Delta\mu O_i}{\Delta\mu i_i}\right)C\right) + 0.122\left(\left(\frac{\Delta\mu O_i}{\Delta\mu i_i}\right)Q\right) + 0.0719\left(\left(\frac{\Delta\mu O_i}{\Delta\mu i_i}\right)r\right]$$
$$* \left[\left(\left(\frac{\Delta_{\mu o_i}}{\Delta\mu i_i}A\right) * \left(\frac{\Delta_{\mu o_i}}{\Delta\mu i_i}R\right) * \left(\frac{\Delta_{\mu o_i}}{\Delta\mu i_i}M\right) * \left(\frac{\Delta_{\mu o_i}}{\Delta\mu i_i}C\right)\right]$$
$$* \left[\frac{\left(\frac{\Delta_{\mu o_i}}{\Delta\mu i_i}\right)R}{\left(\frac{\Delta_{\mu o_i}}{\Delta\mu i_i}\right)C}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

African utility performance measurement and monitoring using PSLCM

This means that the contribution of the life cycle project impact to the organization by delivering technological advancement or eliminating current deficiencies, can be easily monitored and determinations can be made if the projects were worth undertaking. The figure below summarizes the power utility performance using PSLCM

Table 16 Power utility PSLCM performance survey (Foster and Briceño-Garmendia, 2009)

Power utility	Counties	PMS	PPS	OS	PS (PSLCM)
ESKOM	South Africa	0.971	0.924	0.883	0.79223113
ENEO	Cameroon	0.932	0.913	0.884	0.75220974
NAWEC	Gambia	0.897	0.845	0.824	0.62456316
LEC	Lesotho	0.814	0.864	0.845	0.59428512
EDM	Mozambique	0.778	0.865	0.887	0.59692439
EWSA	Rwanda	0.792	0.895	0.854	0.60534936
STEG	Tunisia	0.956	0.875	0.796	0.665854
SONELGAZ	Algeria	1.041	0.945	0.963	0.94734644
SNE	Congo Brazzaville	0.835	0.841	0.987	0.69310595

ECG	Ghana	0.978	0.945	0.956	0.88354476
LEC	Liberia	0.746	0.783	0.794	0.46378969
NAMPOWER	Namibia	0.879	0.845	0.824	0.61203012
SINELAC	Rw-DRC-Bur	0.789	0.814	0.845	0.54269787
UEGCL	Uganda	0.756	0.978	0.878	0.6491651
PRODEL-EP	Angola	0.852	0.934	0.897	0.7138039
CIE	Côte d'Ivoire	0.813	0.925	0.918	0.69035895
VRA	Ghana	0.934	0.891	0.901	0.74980679
GECOL	Libya	0.714	0.789	0.714	0.40222904
NIGELEC	Niger	0.784	0.878	0.821	0.56513699
SENELEC	Senegal	0.812	0.934	0.942	0.71442034
ZESCO	Zambia	0.878	0.845	0.934	0.69294394
ENDE-EP	Angola	0.834	0.895	0.876	0.65387268
CI ENERGIES	Côte d'Ivoire	0.923	0.914	0.897	0.75672893
GRIDCo	Ghana	0.945	0.945	0.985	0.87962963
ZESA	Zimbabwe	0.795	0.845	0.804	0.5401071
SBEE	Benin	0.824	0.876	0.878	0.63376147
EDD	Djibouti	0.885	0.956	0.895	0.7572237
EDG	Guinea Conakry	0.834	0.887	0.878	0.64950752
ESCOM	Malawi	0.835	0.945	0.901	0.71095658
BPC	Botswana	0.946	0.928	0.961	0.84365037
EEHC	Egypt	0.923	0.894	0.947	0.78142841
EDM-SA	Mali	0.834	0.887	0.857	0.63397261
TCN	Nigeria	0.825	0.913	0.894	0.67338315
MWRE	Sudan	0.981	0.932	0.842	0.76983386
EAGB	Guinea Bissau	0.832	0.887	0.912	0.67304141
SNE	Chad	0.878	0.867	0.847	0.64475842
SONABEL	Burkina Faso	0.795	0.815	0.876	0.5675823
EEP	Ethiopia	0.854	0.889	0.914	0.69391428
KenGen	Kenya	0.887	0.862	0.884	0.6759011
ONEE	Morocco	0.913	0.902	0.883	0.72717346
ENERCA	CAR	0.7485	0.845	0.813	0.51420827
REGIDESO	Burundi	0.798	0.846	0.851	0.57451691
CEB	Benin/Togo	0.814	0.864	0.897	0.63085651
SEEG	Gabon	0.794	0.877	0.845	0.58840561
	Average	**0.855648**	**0.886341**	**0.879182**	**0.67105025**

Verification and validation using Data envelope analyses (DEA)

The diagram below indicates the simple form of a process:

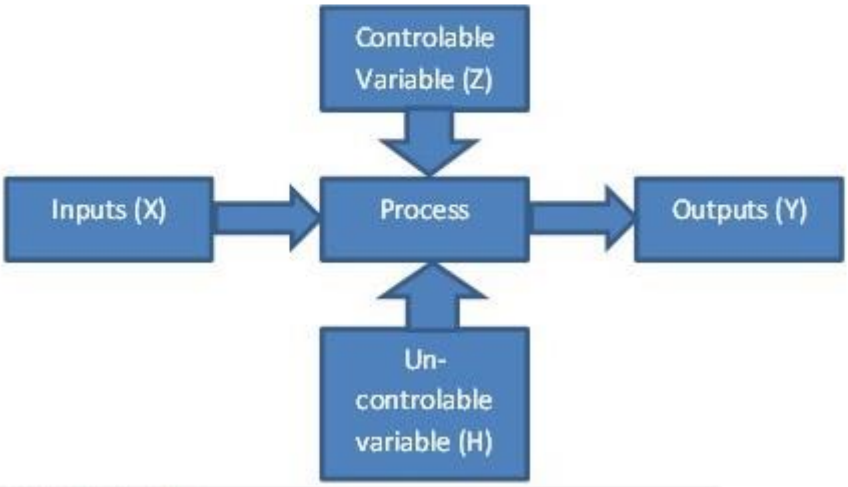

Figure 1: Simple form of a process

The objective of this experiment is to determine which variables are most influential on the response y, determine the maximum and minimum points to determine the nominal point, identify how to control inputs to reduce output variability, and to determine where influential X must be controlled so that the effects of the uncontrollable variables are minimized. The results of running all combinations of chosen factors at two levels (high and low) are shown in the table below. The order was randomized to offset any lurking variable to the process.

Table 17 Experiment for performance and variation

Project	PMS (X)	PPS(Y)	OS(Z)	Performance(PS)	Variation(V)
1	-1	-1	-1	28.26	3.99
2	1	-1	-1	36.49	2
3	-1	1	-1	38.09	1.58
4	1	1	-1	50.09	0.58
5	-1	-1	1	41.01	0.94
6	1	-1	1	58.46	0.18
7	-1	1	1	65.15	0.02
8	1	1	1	87.09	0.01

Coded factor levels indicated by mathematical symbols positive and negative are used to depict actuals levels respectively. The following formula is used to calculate the effects per input variables.

$$Effects\ (Y1\ or\ Y2) = \frac{\sum X(+)}{n} - \frac{\sum X(-)}{n}$$

In this experiment, the effects of the one three-factor (X, Y, Z), three two factor interaction (XY, XZ, YZ), and one three-factor interaction (XYZ), which gives a total of seven effects. To estimate the overall mean, one degree of freedom was used to estimate the overall mean. The table below indicates the calculated effect on the output (y) by each input combination (X). The main effects and interaction impacts on the output can be observed.

Table 18 PSLCM input interdependency

Project	X	Y	Z	XY	XZ	YZ	XYZ	Performance(PS)	Variability(V)
1	-1	-1	-1	1	1	1	-1	28.26	3.99
2	1	-1	-1	-1	-1	1	1	36.49	2.00
3	-1	1	-1	-1	1	-1	1	38.09	1.58
4	1	1	-1	1	-1	-1	-1	50.09	0.58
5	-1	-1	1	1	-1	-1	1	41.01	0.94
6	1	-1	1	-1	1	-1	-1	58.46	0.18
7	-1	1	1	-1	-1	1	-1	65.15	0.02
8	1	1	1	1	1	1	1	87.09	0.01
Effects (PS)	**23.53**	**19.05**	**98.78**	**2.07**	**4.79**	**7.34**	**0.18**	**50.58**	
Effects (V)	**-0.94**	**-1.23**	**-7.00**	**0.44**	**0.56**	**0.69**	**-0.06**		**1.16**

Calculate the absolute value of effects

Effects must be converted to absolute values before plotting them using a very sensitive scale to detect significant outcomes. The half-normal, which is a graph-based on a positive half of a curve is used to accommodate the absolute value scale (This is like folding a bell-shaped curve, folding it in half at the mean). The half-normal plot Y-axis displays the cumulative probability of getting results below given levels by adjusting the scale to account for using the effect of absolute value. Before data is plotted in the probability paper, data points were sorted in ascending order, the cumulative probability (0-100%) scale was divided into equal segments, and data plotted at the midpoint of each probability segment. The probability segment of a full segment is 100% divided by 7 variables which results in 14.28. Dividing the answer by two for the half graph, we get 7.14% as the lowest point in the midpoint of the first segment. The table below shows how values will be plotted on a half normal probability graph for performance.

Table 19 Absolute value for effect in performance

Point	Effects	Absolute value of effects	Cumulative probability
1	Z	24.70	7.14%
2	X	23.53	21.43%
3	Y	19.05	35.71%
4	YZ	7.34	50%
5	XZ	4.79	64.29%
6	XY	2.07	78.57%
7	XYZ	0.18	92.86%

The table below shows how values will be plotted on a half normal probability graph for variations.

Table 20 Absolute value for effects on variation

Point	Effects	Absolute value of effects	Cumulative probability
1	Z	-1.75	7.14%
2	Y	-1.23	21.43%
3	X	-0.94	35.71%
4	YZ	0.69	50%
5	XZ	0.56	64.29%
6	XY	0.44	78.57%
7	XYZ	-0.06	92.86%

The Pareto analyses summarise a graphic representation of the principle offering a simpler view of effects via a bar graph depicting the 80/20 principle. The figure below shows the Pareto chart for effects on performance. The few factors on the left are identified as the vital few, while all those on the right are considered the trivial many.

The two main interaction factors for this project are systems effectiveness and return the project will have in the business. Both of the measured responses are greatly impacted by factor interaction which requires much attention. The table below shows data for interaction between those factors.

Table 21 Half normal for performance and variation

Standard	Y	Z	PS	V
1,2	-1	-1	32.375	2.995
3,4	1	-1	44.09	1.08
5,6	-1	1	49.735	0.56
7,8	1	1	76.12	0.015

The results achieved by the half-normal plot and Pareto analyses can be verified by performing an analysis of variance (ANOVA) and the diagnostic of residual error to confirm the integrity of statistical data. To calculate the sum of the square, the following formula was used;

$$Sum\ of\ squares\ (SS) = \frac{N}{4}(Effects)^2$$

The actual ANOVA is depicted by adding the resulting sum of squares as per the formula below

$$SS_{Model} = SS_X + SS_Y + SS_z$$

The residual, which is the estimation of error, will use small effects closer to zero calculated using this formula:

$$SS_{residual} = SS_{XY} + SS_{xz} + SS_{yz} + SS_{zyz}$$

Table 22 ANOVA for performance

Source	Sum of squares	DF	Mean squares	Prob > F
SS model	3053	3	1018	< 0.005
X	1107	1	1107	< 0.005
Y	726	1	726	< 0.005
Z	1220	1	1220	< 0.005
Residual	163	4	40.75	
Core total	3216	7		

Table 23 ANOVA for variation

Source	Sum of squares	DF	Mean squares	Prob > F
SS model	16	3	5.3	< 0.005
x	7	1	7	< 0.005
y	3	1	3	< 0.005
z	6	1	6	< 0.005
Residual	1.96	4	0.49	
Core total	17.96	7		

Most of the statistics homework required to support the earlier decision has been finalized, but a final step is taken for utter protection alongside specious results by checking the assumption underlying the analysis of variance (ANOVA).

Predictive equation modelling response

This is a good place to provide details of PSLCM tested in the analysis of variance (ANOVA) because this model is a mathematical equation used to predict a given response using the linear model equation below:

$$\gamma = \beta_0 + \beta_2 X_2 + \beta_3 X_3 + \beta_{23} X_2 X_3$$

Where

Y = Predicted response
β_0 = intercept
β_1 = Model co-efficient for the input factor
X = Input factors

Fitted model for project performance with three factors which are project efficiency, system effectiveness, and return on organisational benefits, in coded form is:

$$Performence\ (Y1\ (pred)) = 50.58 + 11.8(X\ ) + 9.525\ (Y) + 12.35(Z)$$

The actual performances are compared to the predicted performance and depict the residual value. The figure below indicates predicted performance and residual values for each performance (difference between actual and predicted)

Table 24 Actual vs predicted values for performance

Project	X	Y	Z	Actual(PS)	Predicted (PS)	Residual
1	-1	-1	-1	28.26	16.9	11.36
2	1	-1	-1	36.49	40.5	-4.01
3	-1	1	-1	38.09	36	2.09
4	1	1	-1	50.09	59.3	-9.21
5	-1	-1	1	41.01	42	-0.99
6	1	-1	1	58.46	62	-3.54
7	-1	1	1	65.15	60.7	4.45
8	1	1	1	87.09	84.25	2.84

Variation fitted model code:

$$Variation(V\ pred) = 1.16 - 0.47(X\ ) - 0.615\ (Y) - 0.876(Z)$$

The figure below indicates predicted variation and residual values for each variance (difference between actual and predicted)

Table 25 Actual vs predicted values for variation

Project	X	Y	Z	Actual(PS)	Predicted (PS)	Residual
1	-1	-1	-1	3.99	3.56	0.43
2	1	-1	-1	2	2.18	-0.18
3	-1	1	-1	1.58	1.89	-0.31
4	1	1	-1	0.58	0.95	-0.37
5	-1	-1	1	0.94	1.37	-0.43
6	1	-1	1	0.18	0.43	-0.25
7	-1	1	1	0.02	0.2	-0.18
8	1	1	1	0.01	0.36	-0.35

At this stage, we have eight data points. Calculating half normal will be done exactly like we did it earlier. 100 %/8 = 12.5 % for a full normal plot. For a half normal 12.5/2 = 6.25%. The figure below indicates normal a plot of residuals for performance.

Research findings

The research findings for each research hypothesis as outlined in the research hypothesis, are analyzed in the following paragraph.

Hypothesis 1

H_0 : There are no critical success factors which are influential to avoid failures in African power plant project and programs

H_1 : There are critical success factor which are influential to avoid failures in African power plant project and programs.

This research identified critical success factors and critical constraint/delay/failure factors that have an impact on the project management process, product management, and the organization (this includes policy constraint). The research findings of this study were compared to similar research in developing countries, particularly those in the BRICS group, namely Brazil, Russia, India, China, and South Africa. Results showed that, irrespective of the fact that countries are exposed to different socio-economic, political, and natural environments, similar problems are relevant to project stakeholders.

The T-test primary results showed that there is generally an agreement between consultants, engineers, contractors, and owners with a certain degree of difference in how the groups evaluated the relations between the project critical success factors, critical constraint/delay/failure factors, and the influence of each project critical success factor on avoiding each critical failure factor.

The test result showed strong agreement between consultants, contractors, engineers, and owners on perceptions regarding critical project success factors and critical constraints/delay/failure factors. The difference has been observed on –

- The direct and indirect suppliers' awareness of project (S5)

Contractors and engineers agreed with each other more than any of the other groups, which can be a result of the degree of involvement by both parties which may be more frequent than the other groups.

From the above results H_1 : It can be accepted that - there are critical success factors which are influential to avoid failures in African power plant project and programs.

Hypothesis 2

H_0 : There are no failure factors that currently exist in the African power industry which can assist to expose the fundamental problem affecting project delivery performance

H_1 : There are failure factors that currently exist in the African power industry which can assist to expose the fundamental problem affecting project delivery performance

Individual ANOVA tests were performed to determine both individual perceptions about the influence of the five critical project success factors relative to each of the critical failure factors. The results on critical success factors that are more influential to prevent failure as using standards to drive quality of output (S2) and pre-project planning must be thoroughly considered (S4).

The significant difference in the least influential factors was on failure factors regarding inappropriate communication (F4) and waiting time for approval by consultants (F2). Overall, all groups agreed regarding the most influential success factors that are important in avoiding failure factors. The difference in opinion among owners could be a result of believing that most problems are management generated (top-down).

From the above results $\mathrm{H_1}$: It can be accepted that - there are failure factors that currently exist in the African power industry which can assist to expose fundamental problems affecting project delivery performance.

Hypothesis 3

$\mathrm{H_0}$: Applying the project success life cycle model (PSLCM) cannot assist power utilities to focus and invest in the right resources needed for the success of the project

$\mathrm{H_1}$: Applying the project success life cycle model (PSLCM) can assist power utilities to focus and invest in the right resources needed for the success of the project

The goal of an integrated life cycle management system is to measure, monitor, and control processes accurately, focusing on process output and correcting it before the next process so that the negative impact on other processes can be minimized. This is performed by always comparing the process output to the desired output and by calculating the variance, which will be used as a feedback signal to determine the error to be corrected to bring the system or process back to the original or desired response/value.

Differences are found in both success factors and delay factors, mostly relating to labor laws (policy constraints) that are affecting efficiency in one country, but not in the others, thus indicating that there are factors caused or aggravated by environment, culture, and political conditions. This is the research key findings:

- The research has demonstrated that there is a strong positive correlation between the successes of a project and its product (deliverable). This is because it is accepted that if the project is a success, its product is also expected to be delivered successfully.
- The research has demonstrated that there is a weak correlation between project product success and organizational success. This is mostly because external constraints beyond the organization’s control, such as market forces, economic growth, and market profitability, play a major role in realizing value for an organization

- The research also shows a moderate correlation between project success and organizational success. Projects are used to take advantage of technology advancement or deficiencies in the current system, which is an opportunity to improve efficiency while reducing costs for the organization.

The integrated life cycle management model has information on output conditions through calculating input efficiency, process efficiency, and output efficiency, which make it better equipped to handle process or system changes/disturbances in conditions that may reduce its ability to complete the desired task. The main characteristics of PSLCM are:

- To reduce variability by continuously calculating system input-output and process efficiency.
- To enhance robustness against external disturbances to the processor system.
- To produce a reliable and repeatable performance.

From the above results $\mathrm{H_1}$: It can be accepted that - applying the project success life cycle model (PSLCM) can assist power utilities to focus and invest in the right resources needed for the success of the project.

Conclusion

In conclusion, the findings of this research indicate that life cycle management performance can be improved by focusing on identified success factors and delay factors. The consensus of expert opinion in other studies substantiate this sentiment, explicitly that critical factors of success in project and programs are crucial to improve overall organizational performance. PSLCM develops a mathematical equation based on project input and output data that is used to mathematically calculate predictable values making it easy for a project performance to be compared against itself as different resources are allocated for a project. This also addresses the issue of overcapacity and under-capacity in projects.

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