Critical Success Factors for Instrumentation and Control Projects Within the Power Industry in South Africa

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***Abstract* – Instrumentation and control projects entail an upgrade or refurbishment of a portion of the current process control system. The changes introduced present integration challenges to people, the plant and operating guidelines and procedures. The successful implementation of these time sensitive projects depends on factors such as change management effectiveness, stakeholder investment and competency of the project team. Project success factors identified across the lifecycle of the project enables the organization to filter down on challenges and risks contained within each project phase. The research identifies critical success factors specific to instrumentation and control projects within the South African power industry. The framework is developed through the descriptive analysis of feedback received from key stakeholders within the organization.**

***Keywords* – Business enterprise framework, critical success factors, instrumentation and control, power industry, TOGAF**

I. Introduction

The energy sector in South Africa has experienced unpredictability in generation and supply due to an imbalance between capacity and demand as well as ageing infrastructure [1]. Strategic initiatives such as the refurbishment of instrumentation and control (I&C) systems at aging fossil fired power stations were launched to safeguard the country's energy infrastructure [2]. The age demographics of the power generation fleet lies on average at around thirty years with most stations already exceeding half of their design life. These refurbishment projects address key challenges such as improving availability and reliability of assets, extending plant operating life and control system obsolescence [3,4].

A. The Instrumentation and Control Environment

Instrumentation and control refurbishments conducted on power plants prove to be challenging due to the uncertainty presented by the operational state of installed equipment and its subsequent systems. These projects result in modifications to the existing infrastructure resulting in changes to the plant and processes. The strategic management of I&C projects is often overlooked within the power generation industry, particularly due to the classification of the project. The introduction of strategy into the planning and execution of I&C projects provides economic and competitive advantages [4].
Business tools such as critical success factors (CSF) and balanced scorecards are available which enable organizations to strategically reduce project challenges and delays. CSF developed for each phase of the project enables the organization to filter down on change management risks contained within the different phases of the project lifecycle.

B. Research Objectives

The research study aims to establish critical success factors (CSF) for I&C projects executed within the power generation industry and investigate if there exists a relationship between the maturity level of the organization in terms of change management maturity and the identified critical success factors. The research study is contained within the power generation industry in South Africa with specific focus on identifying critical success factors for I&C projects that are implemented at coal fired power stations.

II. Literature Review

The literature review conducted provides an understanding of best practices and trends utilized within the areas of project management, success factors and process control. The understanding gained from the theoretical study was used to formulate the basis of the research work.

A. Process Control Lifecycle

I&C control systems have a useful life which resides between ten to fifteen years. Thus within a coal fired power station's operating life of forty to sixty years multiple I&C upgrades are required. Refurbishment projects stem from key necessities such as, the obsolescence of the installed technology or changes in operating, maintenance, engineering or regulatory requirements. Power utilities are required to either upgrade the process control installed base or face an increased risk to the plant due to the unavailability of spares, lack of original equipment manufacturers (OEM) support or competent persons available for the legacy technology [12]. The nature of I&C upgrades entails an extensive scope with replacement of all associated field instrumentation, cabling, control modules and human machine interfaces (HMI). Outage opportunities to implement the upgrade are often run on a tight schedule with marginal room for error. Pre-outage work, on and off the job training initiatives for affected personnel and replica simulators are some of the drives initiated to secure the success of the project [5].

B. Project Management and Project Success

Since the early 1950's the emphasis within the project management field has been to streamline the scheduling of project activities, with the notion that optimising the process would lead to successful projects. It was later understood that there are external factors to the project and organization which influence the outcome of the project [6]. Projects can be managed successfully and yet still be deemed a failure, as the focus is often placed on ensuring the project remains within the limits of time, cost and scope. These variables are described as the "Triple Constant" or "Project Management Triangle" [7]. Once a project is successfully executed within the defined variables, one may assume project management success has been attained. Project success however, is the extent to which overall objectives of the project have been met. Project success factors run throughout the lifecycle of the project and are to be measured and monitored accordingly. Both project management success and project success need to be distinctively driven throughout the lifecycle of the project. [8]–[10]. Adopting the project success methodology doesn't in itself prevent the failure of projects. Success factors need to be tailored specifically for each project with consideration given to the project environment, targets, stakeholders and organization. The ranking of the success factors continuously change over the lifecycle of the project, with some factors weighing significantly more than others depending on the project phase [11].

C. Critical Success Factors

Critical success factors are those elements considered critical in securing the overall success of a project. These success factors are specific to the project and influenced by the nature of the project, the environment and economic influences. The identified success factors are those which if positively influenced can increase the probability of success of the project [12], [13]. The application of the CSF approach within any organization provides one with a performance measuring tool which gauges if objectives have been achieved and provides a means to highlight critical elements that need to be addressed [14], [15]. Companies utilizing CSF to drive project success attain a streamlined approach to project execution with reduced impacts associated with project delays and scope changes. In summary the common theme found in literature material is that CSF are simply the most critical elements within a project which are an absolute requirement to be met, without which the project would be rendered a failure [16].

D. CSF Dimensions

Critical success factors can be classified into five distinct dimensions, as described by Rockart [17] in the figure below. These dimensions provide a general overview of the considerations one needs to take in account when defining the CSF and their subsequent measures.

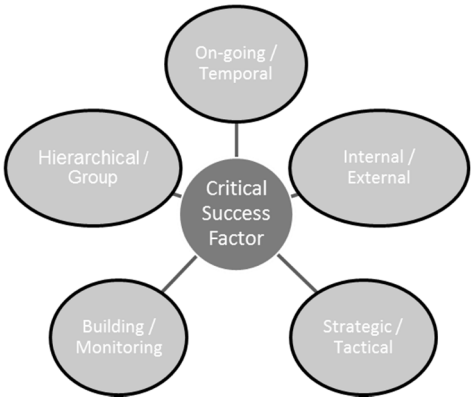

Fig. 1. CSF Dimensions [17]

Ongoing CSF are elements that are well known and established throughout all stages of the project lifecycle. Temporal CSF are factors which may arise within an organization for a brief period of time due to an abnormal condition causing some degree of jeopardy towards the execution of an initiative. Internal CSF are factors which fall within the direct control and influence of the organization, whilst external CSF are uncontrollable factors residing outside the organization that pose a hazard. Strategic CSF pertain to long term planning initiatives. Tactical CSF are factors which stem from short to medium term planning. Building CSF typically reside around expansion or change management initiatives and monitoring CSF are those linked to common deliverables, situations or functionalities that are currently present within an organization. Lastly hierarchy or group CSF are similar factors found to be a common occurrence across different organizations [17]. The utilisation of the five CSF dimensions offers the individual a global perspective of key factors that should be considered and managed through the project lifecycle.

E. CSF Frameworks

Jacobs and Barry [11], groups success factors into four dimensions which is aligned with the different project phases, feasibility, basic, detail and construction phase. The CSF deduced from these dimensions relate to the definition of project objectives, stakeholder involvement and integration, clear roles and responsibility and competence of all involved parties.

Gepp et al. [18], describes success factors in terms of financial, customer, process and growth perspectives. With the resultant success factors defined as conducting holistic cost calculations and resource allocation, integration of all stakeholders, management support, risk management, defining project goals, responsibilities and allocation of tasks, compliance with existing business processes, competence and training of affected employees, quality management, standardisation, modularisation and reusability of products.

Belassi and Tukel [6], assess the dimensions which influence the project, project manager, team members, organization and external environment. The factors that stem from these dimensions relate to the size, value and urgency of the project, competence and commitment of the team, top management support and project communication.

Busi et al. [19], focus on the internal and external dimensions, and highlight the success factors as the adherence to change management procedures, safety adherence, alignment to organizational strategy and the proper documentation of project decisions.

Ali and Kidd [20], identify seven dimensions as being execution strategies, decision takers, performance monitoring, sufficient resources, effective communication and defined project boundaries. The dimensions place emphasis on the importance of having committed and competent change management practitioners who can secure adherence to the change management process. Teamwork, management support, effective leadership and resource allocation are also highlighted as critical factors in securing project success.

The list of factors and associated dimensions obtained through the literature study vary and are not grouped within a common criteria. This doesn't allow for an appreciation of an understanding of the interrelationship and interdependencies between the factors. Depending on the nature and environment of the project many of these factors may also not be applicable [6]. The above studies also lack the key dimensions as described by Rockart [17] and fail to address the requirements of an enterprise wide organizational environment.

F. Business Enterprise Frameworks

The Zachman framework illustrates the dimensions of key enterprise viewpoints, such as, What, How, When, Who, Where and Why against transformation objectives which are defined as identification, definition, representation, specification and configuration [21].

Spewak [22] expands on the business oriented approach to architecture planning which is defined in Zachman to provide additional viewpoints such as data quality, access to data, adaptability to changing requirements, data interoperability, sharing and cost containment.

The Treasury Enterprise Architecture Framework (TEAF) [23], [24] is another architecture framework that focuses on business processes in terms of products by translating the key viewpoints in Zachman against new key dimensions such as functional, information, organizational and infrastructure.

While the frameworks address many key viewpoints for enterprises they fail to define various CSF dimensions required within the project lifecycle phase. TOGAF [25] provides a comprehensive architectural development method (ADM) which can be iteratively applied to any enterprise seeking to manage and maintain their assets and associated risks. The framework allows for a holistic approach to be undertaken when executing any change within an organization by considering the impact to the organization, its processes, policies and staff. This framework is used as the foundation on which the critical success factors for I&C projects are identified.

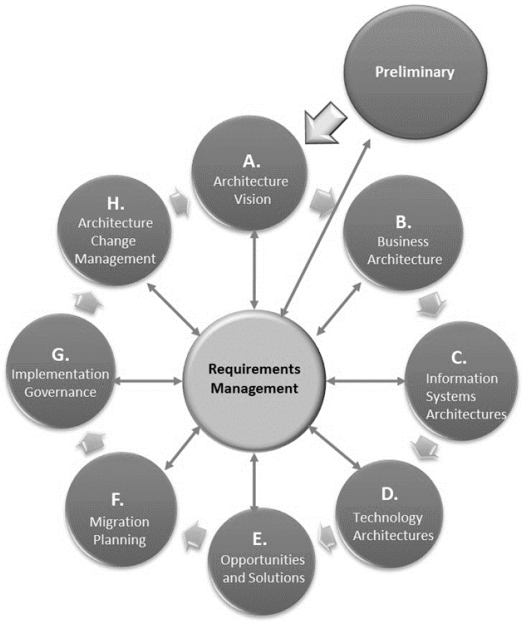

Fig. 2. ADM cycle in TOGAF showing different project phases [25], [26]

III. RESEARCH METHOD

An extensive literature review is conducted to support the problem statement and objectives. The review feeds into a conceptual framework to identify critical success factors associated within the different project phases. This framework is translated into a questionnaire to secure feedback from industry experts on the relevance of CSF within the different project phases. The results of the survey details the CSF unique to the South African context with key attributes reflective of strategic leadership and direction required to drive success of I&C projects. The survey approach was used to obtain the required data for analysis.

A. Questionnaire

The survey was distributed to sixty key persons with five years or more of experience and fulfilling critical roles within the organization. Individuals from operating, maintenance, engineering and the project management departments were approached. These individuals hold a range of positions from that of senior supervisors to management. This was to ensure that the respondents had

been sufficiently exposed to the organization's processes in order to provide an insightful reflection of current practices.

The survey is structured in the following manner.

- Introductory Phase
- Consent and Profiling
- Objective 1: Assessment of Organizational Maturity

B. Data Analysis

Data collected is summarized with the aid of descriptive statistics which allows the researcher to describe patterns, occurrences and any outliers with the aid of a handful of indices [27]. The respondent feedback from a questionnaire are transformed into results which reveal the key insights with the use of the below five steps [22]:

1. Preparation and cleansing of the data prior to analysis
2. Checking the reliability of measurement scales
3. Analysis of the data at the descriptive level
4. Analysis of the data at the inferential level
5. Drawing conclusions

Step 1 and 2 secures that invalid responses cannot be submitted. Step 3 identifies the averages, gaps and outliers. Outliers are tested using the skewness test. This provides highlights differences in responses. Step 4 focuses on reviewing the relationship between organization maturity and the occurrence of the identified ADM CSF from the respondents. The ANOVA (Analysis of Variance) single factor is used to test the difference in mean scores between three or more groups. The success factors identified across the nine project phases were evaluated against the prescribed CSF, in order to deduce areas of largest deviation.

IV. Case Study

The responses received per ADM phase is analyzed with the use of descriptive statistics to reflect the range of priorities given to the success factors. Further analysis to provide insight on the response received per department is carried out. Finally the ANOVA test was used to determine if a relation existed between the organizational change management maturity and the highlighted CSF.

A. Determination of CSF

The graph reflects the responses received from the targeted audience for the preliminary project phase. The results indicate capability assessment, change request and business principles as the highest rated CSF, with business principles being the only success factor which coincides with the prescribed TOGAF model during the preliminary phase. This reflects that the respondents generally do not consider key architecture definitions as important during this phase.

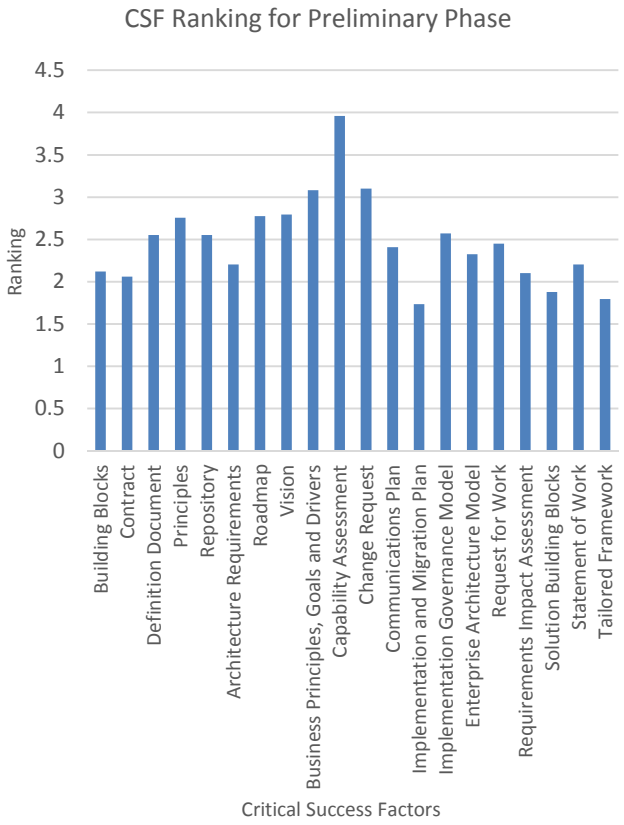

Figure 3. Overview of responses for preliminary phase

In order to determine any anomalies within the responses, the skewness test is carried out and summarized in the below table. The results show significant skewness with deviation above '1' for the prescribed success factors which is indicative of irregularities within the responses.

TABLE 1
SKEWNESS RESULTS FOR ADM CSF

Critical Success Factors	Skewness
Architecture Principles	1.020816245
Architecture Repository	1.031369695
Architecture Requirements	1.087584702
Business Principles, Business Goals and Business Drivers	1.209431216
Tailored Architecture Framework	1.106190223

The difference in stakeholder views on the critical success factors that need to be focused on and secured during the preliminary project phase is further illustrated in the figure below.

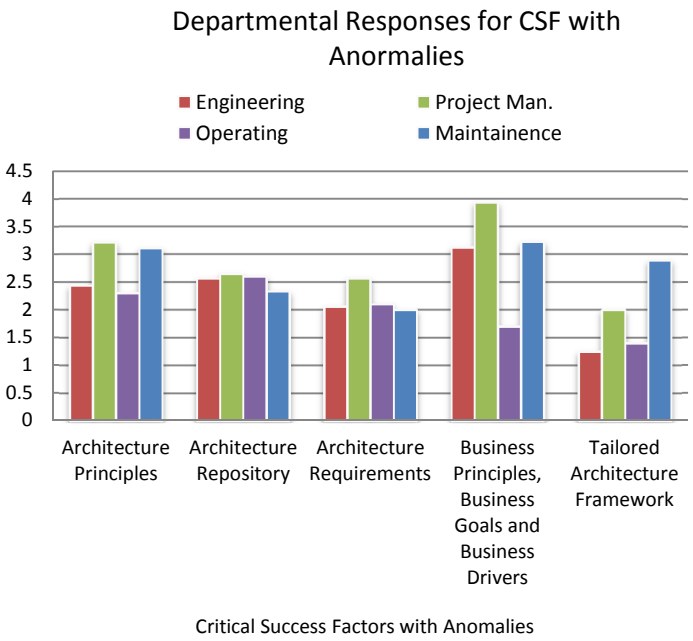

Figure 4. Overview of responses for preliminary phase with anomalies

B. ANOVA Test

The ANOVA test is used to test the relationship between maturity level and the occurrence of ADM CSF which is hypothesized as follows:

H1: Maturity level to execute change management I related to the occurrence of ADM CSF in I&C projects.

MSTG= 119.31 MSTE= 0.88, Fo = 1.45 At alpha = 0.05, F critical = 3.1375 Since F 0 > F critical we accept the hypothesis H1 that the there is a relationship between the maturity level rating and the occurrence of ADM. The results of the ANOVA test is summarized in the table below.

TABLE 2
SUMMARY OF ANOVA TEST

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	119.31	31	3.849	3.1375	1.94E-08	1.458845
Within Groups	1845.02	1504	1.227	NA	NA	NA
Total	**1964.33**	**1535**				

V. CONCLUSION

The responses from the engineering and operations role have shown to introduce a considerable disturbance in alignment within earlier phases while contributing to clear alignment in the execution phases. The project manager and maintenance manager roles remain consistent in their ratings. This highlights a need for organizational awareness of architecture, business, and information and technology strategies particularly within the engineering and operations roles.

The recommended CSF across all the project phases are summarized in the table below.

TABLE 3
CSF PER PROJECT PHASE FOR I&C PROJECTS

Project Phases	CSF
Preliminary Phase	Architecture repository, principles, requirements, business principles and tailoring.
Vision Phase	Architecture building blocks, definition document and requirements
Business Architecture Phase	Architecture requirements and roadmap
Information Architecture Phase	Architecture definition document and roadmap
Technology Architecture Phase	Architecture roadmap and building blocks
Opportunities and solutions phase	Architecture requirements and solution building blocks
Migration planning phase	Architecture requirements and roadmap
Implementation governance phase	Architecture contracts and solution building blocks
Change management phase	Architecture requirements and requirements impact assesment

The results of data analysis supports the requirements of the research objectives and reveals the following:

- Alignment towards the ADM factors were evident in execution phases such as opportunities and solutions, migration and planning, implementations governance and architecture change management.
- Each phase reveals roles that were better aligned to the ADM phases that others. The emphasis of alignment is more prevalent in earlier phases of the project lifecycle when establishing architecture, business, information and technology strategies.
- A clear relationship between organizational change management maturity and the capability to manage I&C projects was established based on the outcome of the ANOVA test.

Further expansion on the survey to include the influence of demographics of age, work experience, position within the company and an evaluation of current business practices used within the organization was not part of the research scope. The research study can be further extended by determining an evaluation criteria which assists in aligning the project team's understanding of the

required deliverables. It is also recommended to consider power stations independently from the enterprise and to rather treat it as an enterprise system of systems containing a host of product and business systems. In order to successfully integrate between product systems and enterprise systems a common reference framework is to be generated, reflective of the differences between the terminologies, methods, requirements and criteria within the two systems [28]. This research therefore concludes with the recommendation to apply the above consideration during the implementation of the proposed CSF framework for I&C based systems.

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