Evaluating aspects of power plant performance using Project Success Life Cycle Model (PSLCM)[1]

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Abstract

The Project Success Life Cycle Model (PSLCM) is aimed at ensuring that critical factors are considered when the success of power plant is measured. This model uses data envelopment analysis (DEA) to measure task, activity, process, product or firm input, output as well as process efficiency at any stage of project, product or business development. It integrates technical performance and financial performance measures so that projects in different industries can be compared objectively and inefficiencies in areas where resource availability is high can easily be identified.

This paper shows how integrating effective technical and financial performance measures (TFPM), data envelope analysis (DEA) and design of experiments (DOE), as well as the use of standard processes, can dramatically improve plant life cycle management through an integrated life cycle management model.

The outcome of the model is a success performance measure which incorporates project performance measure, product performance and corporate performance into a single value. This model will make it easy to compare projects, product and organisations performance in different stages of the life cycle.

Keywords: Life cycle management, Data envelop analyses, Performance measurement, life cycle model.

Introduction

Power generating plants require 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 in order to sustain the plant output over its intended life cycle. In addition, 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.

It is important for utilities to determine standard practice involved in the plant life cycle management process, which include the inputs and expectations of key stakeholders, as well as proposed methods to ensure process effectiveness. It is vitally important that

[1] How to cite this paper: Budeli, L. and Wichers, J. H. (2018). Evaluating aspects of power plant performance using Project Success Life Cycle Model (PSLCM); *PM World Journal*, Vol. VII, Issue XI (November).

the technical planning process must follow all the critical steps to ensure that an effective and efficient plan is achieved by establishing correct planning assumptions and inputs when developing the life cycle management plans. These include the planned operational life of the power plant, economic evaluation parameters, plant maintenance strategies, legislative and statutory requirements, as well as the future production regime, performance targets, primary energy requirements and quality. Power utilities require these inputs to integrate information systems into a database in which all project proposals, as well as finalised technical and life of plant plans are in place to avoid developing technical plans from zero bases every year. Financial targets are applied to sections over the period of the technical plan to optimise the plan within the available funding, while project proposals are prioritised according to approved ranking methodologies.

The power industry landscape continuously experiences disruptions mostly due to existing business models, systems and methods of operation and a blend of players and electricity subsectors. In developing countries, energy efficiency can be realized quickly because the potential for energy efficiency improvements are high. 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 from one plant to another. Real plant design constraint also limits power plant efficiency beyond the control of utilities, which is not necessarily a result of ineffective design or operation. Various factors are perceived to affect the efficiency of power plants. However, this study will focus on technical efficiency problems due to design and maintenance which is subdivided into:

- Plant design – the efficiency of a power plant is largely dependent on the basic plant design and how well it has been maintained.

- Deterioration – equipment deterioration over the years of operation could affect plant efficiency and performance significantly.

- Plant maintenance – comparing actual performance to design is important because equipment distorts, leaks, wears, fouls, corrodes and as calibrations drift, the plant becomes less efficient.

- Component availability – non-availability of certain plant components and equipment can affect efficiency, which requires maintaining proper cleaning of equipment to avoid degradation.

In this paper, a project success life cycle model (PSLCM) is developed to measure, control and manage power plant performance. The model is achieved by combining variance, process and system theoretical approaches which will offer a particularly significant opportunity to improve theory in light of the results. It can be argued that the insistence on exclusion of variables from process research unnecessarily limits the variety of theories constructed. In this research, the concept will be developed, key relationships identified, model developed and the study conclusions provided.

Development of concepts

The core concepts required for the development of the project success life cycle model (PSLCM) theory, relate to the improved detail understanding of life cycle management modeling and elements of success factor dependency in stages of the project, product and organizational life cycle.

Poole et al (2000-42) said that an approach is defined as a researcher's choice of the types of concepts and relationships used to construct the theory. In project management and systems engineering, there has been a growing interest in theory building. Below is the evaluation of the three theory building approaches according to Poole et al (2000-39-44):

- Variance approach - In terms of theoretical concepts, the variance approach focuses on properties of entities, often called variables or factors. It is assumed that these properties can have different values even though the property itself has a fixed meaning.

- Process approach - In terms of theoretical relationships, the process approach focuses on accounting for an outcome by reference to a sequence of events involving the focal actors. The process approach focuses on entities participating in events. If the entities can act, they are often referred to as focal actors

- System approach - It derives from a conviction that the world is comprised of wholes and interacting parts, not merely entities, properties, and events. The systems approach is based on the insight that the interrelations of certain components may result in an entity (system) with its very own properties. This approach looks at systems holistically, emphasizing the interrelations of the system's components, the properties and boundaries of the system and its environment.

Plant life cycle management components

Goodman and Ignacio (2000-21) specify that life cycle models may be used under specified conditions to establish and test a hypothesis and to discover effects. Blanchard (1998-3) asserts that models are often used to evaluate significant effects of inputs on outputs as part of process and sub process analysis, to determine the input levels required to achieve the desired results (outputs). Kemp (2004-57) holds that the power plant integrated life cycle management model formed on the basis of understanding project life cycle models, asset life cycle models, product (deliverables) life cycle models, and business life cycle models, can be used at a point of greatest leverage. This can be done by improving efficiency of the design process reducing design costs, reducing complexity (product, material, labour) and eliminating late engineering design changes.

Plant life cycle models are powerful tools in cost saving efforts by minimising variations in projects, processes, and sub processes, as well as tasks and activities which will improve overall efficiency and effectiveness. Blanchard (1998-4) believes that past practices have a significant impact on the overall cost of a system, creating an imbalance between cost and effectiveness. The complexities of many systems have been greater and with the ever-increasing emphasis on performance, while sacrificing other key design parameters such as reliability and quality. The overall effectiveness of a system is proportional to life cycle cost as shown in the figure below.

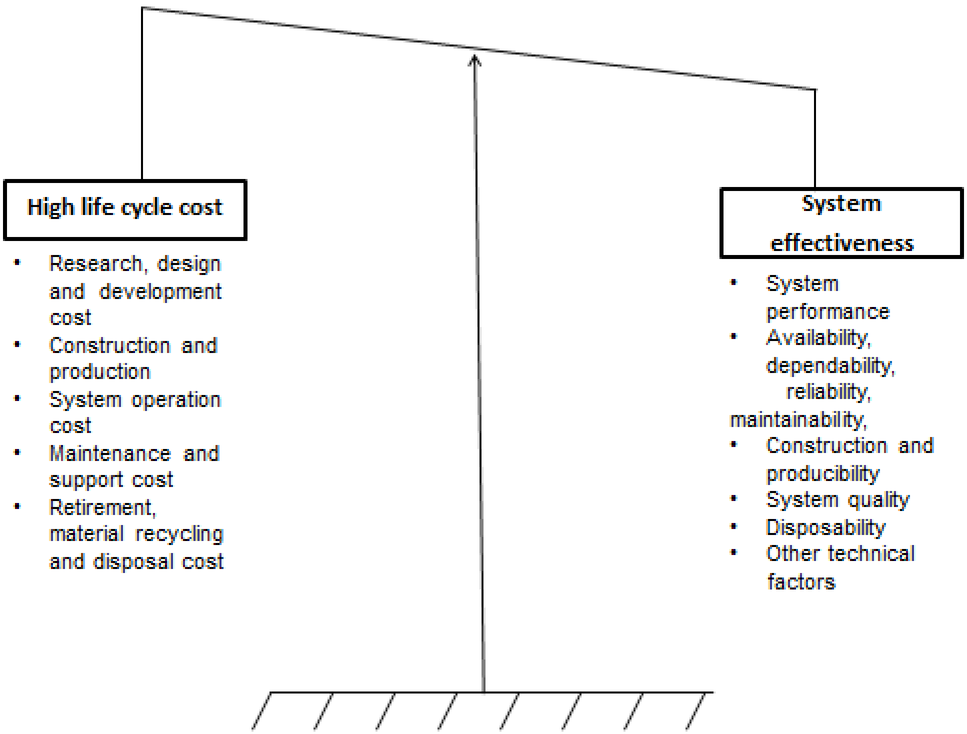

Figure 1: The imbalance between system cost and effectiveness factors (Blanchard, 1998-3)

There are three aspects of a process that should be analysed by an integrated plant life cycle model according to Blanchard (1998-12), namely:

- Inputs (factors, variables, process inputs): The types of variables are controllable, uncontrollable and interdependence (mixed) factors.

- Process conditions (levels, settings, quantity, rate): This aspect relates to process conditions best required to transform inputs into desired outputs.

- Outcomes (responses, output): Output characteristics, consistency and appearance are measurable outcomes influenced by the inputs and process.

According to Cadle and Yeates (2001-30), life cycle management models must focus on both the delivery portion of a project and the business value portion of a project. This is a holistic way of evaluating projects, which will easily measure project success. Barringer (1997-3) indicates that effectiveness can be best elaborated by the formula below:

$$\text{Effectiveness} = \text{Availability (A)} * \text{Reliability (R)} * \text{Capability (C)} * \text{Maintainability(M)} \dots \dots .. (1)$$

Where:

- Availability – the chance of the equipment or system to perform its duty
- Reliability – the system will operate for a certain period without failure
- Capability – the system can perform production activity to standard
- Maintainability – can be repaired with no excessive lost time

Purpose of using integrated models for optimisation

Goodman and Ignacio (2000-23) found that the use of different models, tools and technology by engineers and analysts, resulted in a large gap between system engineering activities in current practices of system development. This, in turn, resulted in inefficiencies and quality issues that were very costly to fix. Van der Walt and Knipe (2001-90) indicate that the need for an integrated model with analysis capability is evident. This requires measurement capabilities to be developed to bridge the existing gap through integrating modelling tools, process integration and design optimisation, and by developing capabilities to analyse realistic methods. This integrated approach will allow design teams, project management teams and operational teams to continuously analyse and trade off studies throughout the process and respond quickly to changes in requirements and design configuration.

Blanchard (1990-4) asserts that the model must also focus on interdependencies and their impact on the whole, while identifying factors and their level of impact (positive or negative). A system constitutes a complex combination of resources in the form of human beings, materials, equipment, software, facilities, data, and money. To accomplish various functions often requires large numbers of personnel, equipment, facilities and data.

The goal of asset manufacturing is to design the most reliable products or systems. However, limited information about the operating conditions, as well as operators' limited knowledge of equipment reliability is a constraint. To design highly reliable systems, the following factors must be taken into consideration:

- Firstly, the inherent reliability of the equipment or installation must be determined (design stage reliability).

- Secondly, the inherent reliability must be maintained and component life upgraded (process operation reliability).

- Thirdly, best practices must be adopted to prolong product and equipment life (maintenance operation reliability).

It is vitally important that there is continuous interaction between designers and operators through equipment life cycle, because their combined knowledge will lead to the overall availability and reliability of the installation. Early life cycle interaction planning based on industry success factors and constraint management strategy, will result in a balanced life cycle management strategy. The outcome will be a high return on investment (ROI) at an optimal life cycle cost (LCC). The figure below illustrates the basic engineering system.

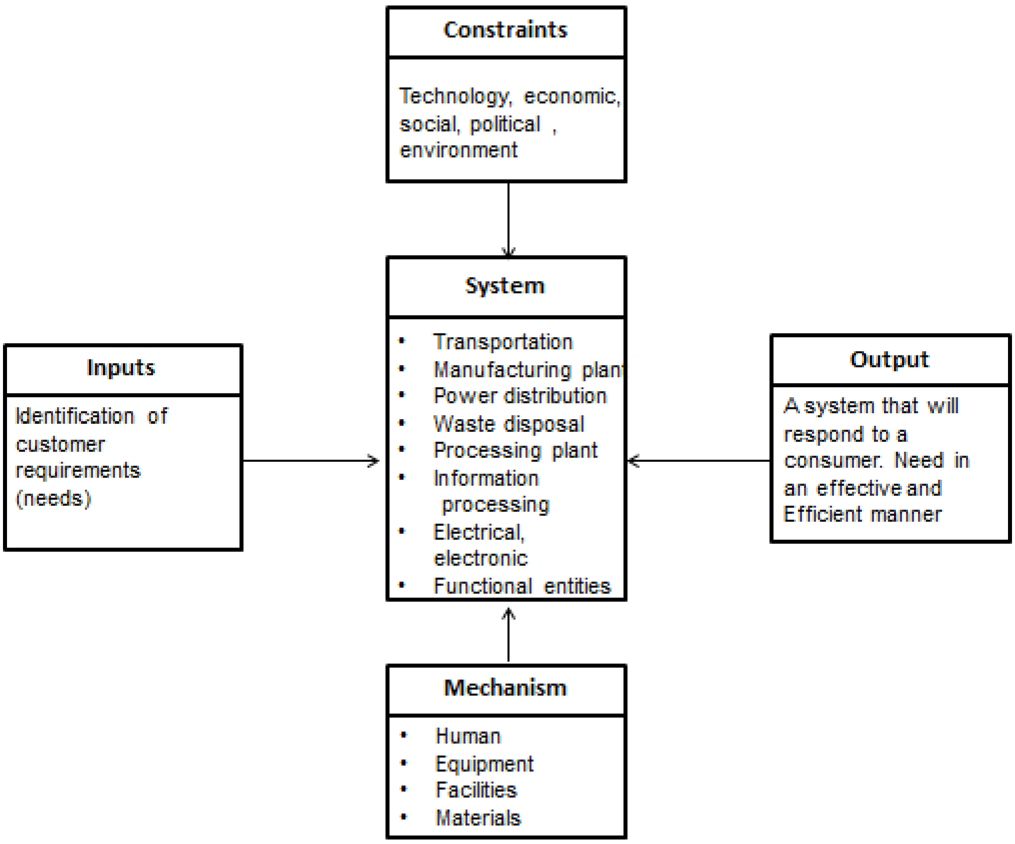

Figure 2: The basic engineering system (Blanchard,1998-4)

According to Goodman and Ignacio (2000-81), the key output of a technical planning process using a model, is to carry out a structured and defendable basis for allocation of limited resources to enable the delivery of sustainable performance in line with organisational expectations. These include safety, legal and statutory compliance, as well as sustainment or enhancement of projects to improve availability, reliability, capability and maintainability. As a result of these key outputs, costs from technical plans become key assumptions in plant life determination models. These provide control for investments and operational spending for the next business cycle. Burgelman, Maidie and Wheelwright (1996-256) suggest that the success of technical planning processes hinges on a detailed framework to prescribe the necessary activities and interventions required to achieve utilities' expectations. Frame (2003-210) indicates that the process input allows optimisation of limited resources to achieve the maximum output from a power plant.

Dicson (2000-34) holds that the model's basic focus is on comparing estimated, calculated, allocated and measured values in order to determine overall efficiency at any stage of a process. The major focus of PSLCM is to integrate different project inputs and outputs with different measuring units to a single efficiency value performed through a continuing verification of the degree of anticipated achievement of financial and technical parameters.

McGhee and McAliney (2007-61) point out that models are used to identify deficiencies that jeopardize the ability of the system to meet a performance requirement by selecting and identifying deficiencies that can jeopardize the ability of the system in meeting a performance requirement. This includes design parameters, performance parameters and process errors.

Technical performance measure

According to Fewings (2005-93), technical performance measures (TPMs) are traditionally defined and evaluated to assess how well a system is achieving its performance requirements. Fewings (2005-65) point out that although TPMs generate useful information and data about performance, limited information is available in the programme management community on how to integrate these measures into a meaningful measure of the overall performance. According to Cooke-Davies (2002-193), individual TPMs may be combined to measure and monitor the overall performance of a system.

Day, Schoemaker and Gunther (2000-141) believe that the approach consists of integrating individual technical performance measures in a way that produces an overall efficiency index. Cope (2000-157) specifies that the computed index shows the degree of performance risk presently in the system. It identifies risk-driving TPMs, enables monitoring time-history trends, and reveals where management should target strategies to reduce or eliminate the performance risks of the system. Baca (2007-23) indicates that TPM is very useful to technical managers, mainly to ensure that inexperienced project managers focus holistically on project parameters rather than focusing on the triple constraint.

According to Nokes et al (2003-138), TPM involves a technique of predicting key performance parameter future values, based on current low-level assessments. According to Burke (2011-137), performance variances that can jeopardise the achievement of high-level requirements, must be identified quickly by continuous verification of actual, planned and anticipated values. Estimation errors result in tolerance bands due to variations above tolerance levels, which help to alert managers when the degree of expected variation is exceeded. The figure below illustrates the example of TPM identification (development) process.

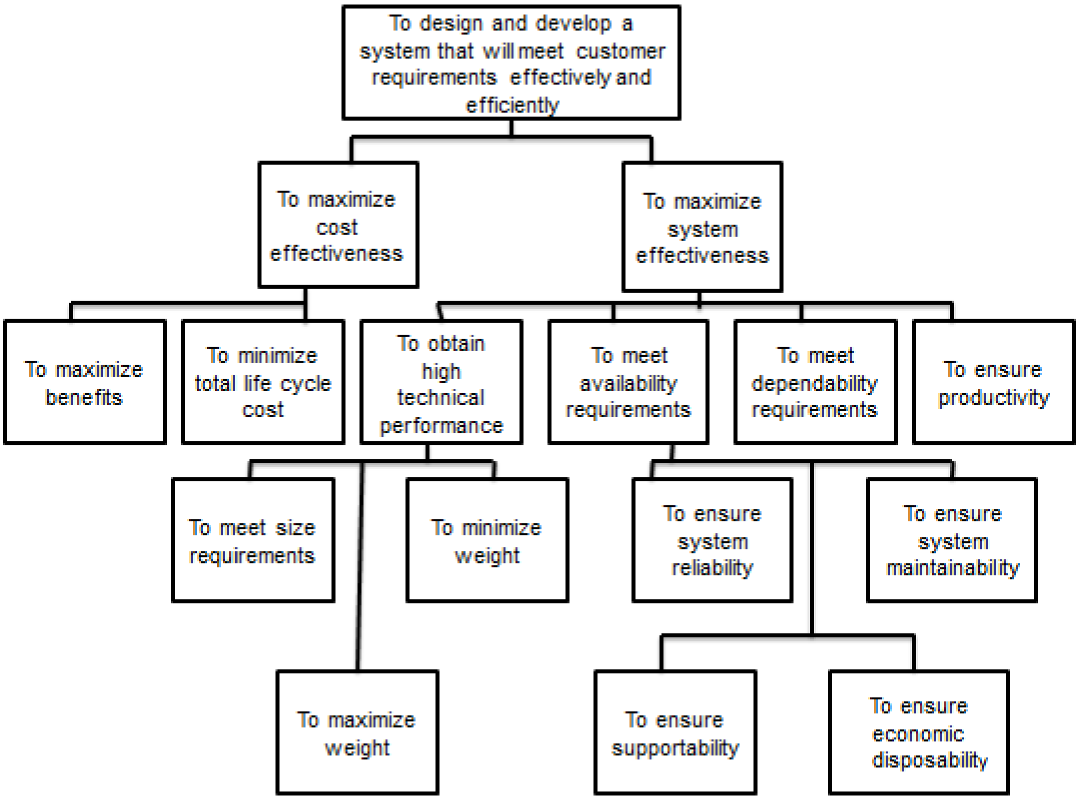

Figure 3: TPM development process according to Burke (2001-142)

Burke (2001-144) specified that the central limit theorem specifies that variance of the sum is equal to the sum of the variance on an individual distribution if a number of independent probability distribution is summated. The figure below illustrates the technical performance of a system at a specific point in time indicating threshold, variations and milestones.

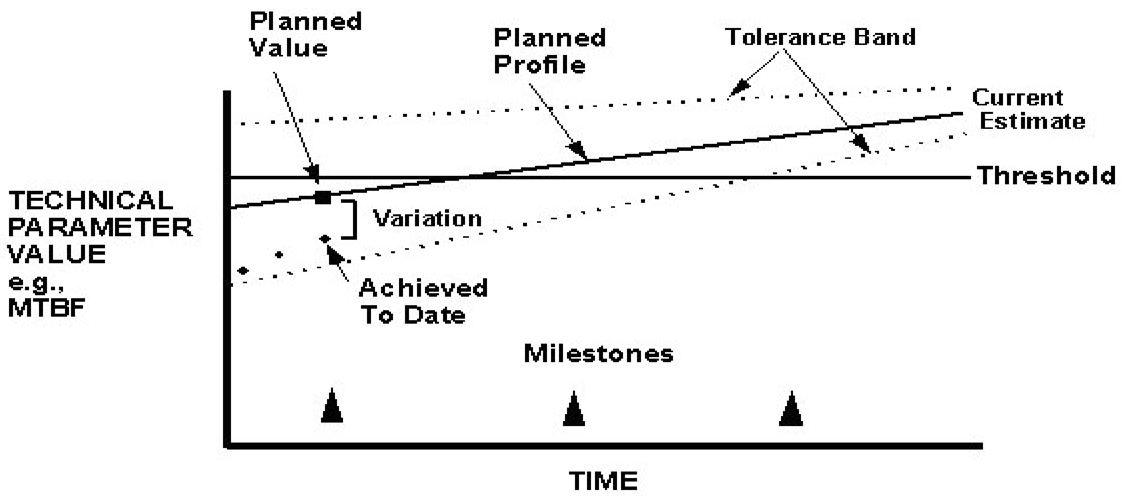

Figure 4: Technical measure profile illustration (Roedler, Martin and Jones, 2005-14)

In most utilities, the problems associated with project, product cost and time performance risks are evident. What managers often do not realise is that they are not dealing with risks, but with variations as shown above. The application of mathematical statistics, also known as statistical process control (SPC) to control process variations, is used to continuously improve performance by understanding input output process effects on the quality of the desired outcomes. Measuring different variables requires that all variables are converted into one unit so that they can mathematically be represented as a single unit.

Data envelop analysis (DEA)

Baurus (2007-286) asserts that DEA is a technique developed in operations research and management science for measuring the efficiency of decision making units (DMU) in the public and private sectors, by observing data on multiple inputs and outputs. Abbott and Avkiran (2001-64) said that the DEA methodology considers all resources used and services provided, and compares it with the best practice units. DEA can be used to offer variety of models that use multiple inputs and outputs to compare two or more processes. By utilizing the three efficiency calculation, it will be easy to identify all performance gaps from a process to the next process. The figure below illustrates how DEA can be used to identify performance gaps and benefits realisation.

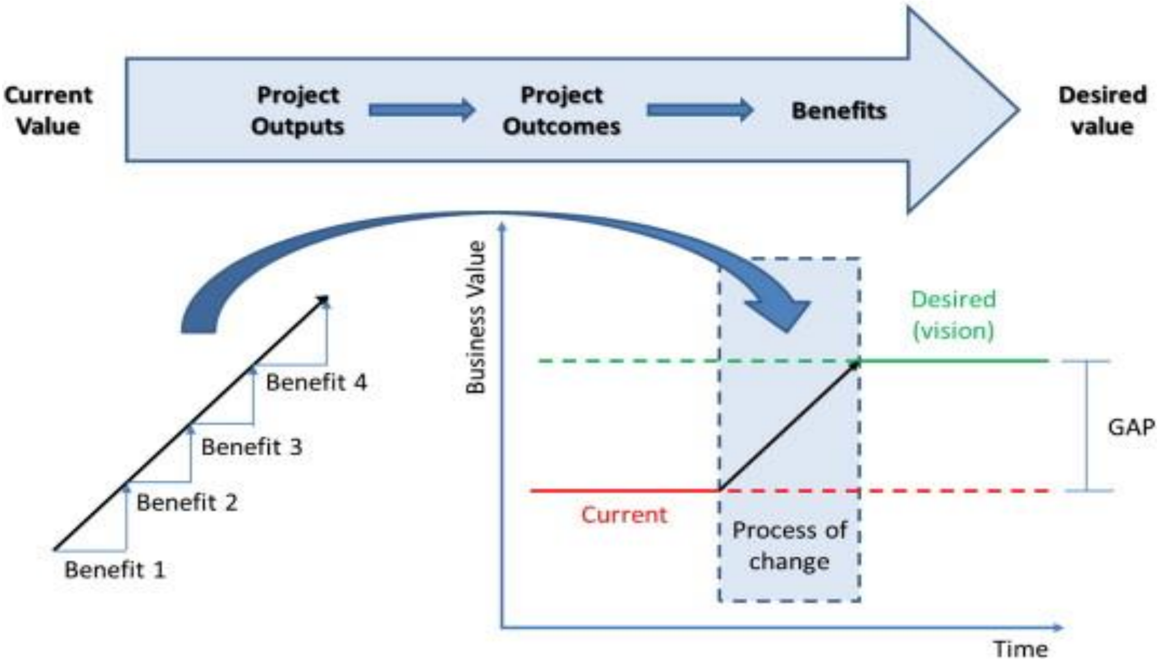

Figure 5: DEA identifies performance gaps and benefits realisation (Burke, 2001- 20).

Frame (2003-144) believes that efficiency and project management are subjects explored extensively by the scientific community and are also relevant to any company. Verzuh (2012-24) indicates that the cost of engineering projects includes engineering design, and procurement of material and equipment required, as well as human hours worked, premises and tools usage. The cost can also be attributed directly to the project or a general proportion of completion time.

Taylor and Watling (1987-157) indicate that engineering project costs normally vary inversely proportional to the completion time, starting at minimum possible completion time of the project. This is determined by technical parameters that can be achieved by using more resources, allow overtime, reduce manufacturing periods of materials and using advanced technology.

Process interdependency

Stein (1997-160) asserts that the design experiment objective is to illustrate the impact of specific changes to the process input in order to normalise, minimise or maximise the outcome by manipulating the input. Design experiments are used to determine the impact of a specific input on a process, individually or collectively. By varying factors on different levels and recording the impact of the results, it is possible to understand the impact of each variable within the process and the degree of its results. The analysis of inputs, as well as the results, determines the level of input needed to arrive at the optimal results, by first determining the quality characteristics to be examined and the desired effect. Understanding the level of goals and factors, is achieved through brainstorming, as well as a cause and effect investigation.

According to Schieg (2002-24), determining variation among treatments is completed by adding the square of each observation, commonly referred to as the sum of squares, followed by distributing variations among different types that can occur, comprising:

- Grand mean effect - variations caused by items under a test
- Effect of factors - variations caused by individual factors within an experiment
- Reputational error effect - variations caused by the number of trials performed.

The important part of the experiment is determining the importance of the factors achieved by determining the minimum significance variance required for a measurement to be considered significant. The total variation, which is a variation that has occurred among all treatments, is determined by adding squares of each observation.

Develop key relationships

Analoui and Karami (2003-122) point out that measuring performance is an important function of any engineering model and having an appropriate performance measure facilitates communication of a definite arrangement for moving towards achieving business goals and targets. Beriha, Patnaik and Mahapatra (2011-210) believe that developing operational excellency assists companies to improve their global competitiveness. The figure below indicates efficiency and variations in a process.

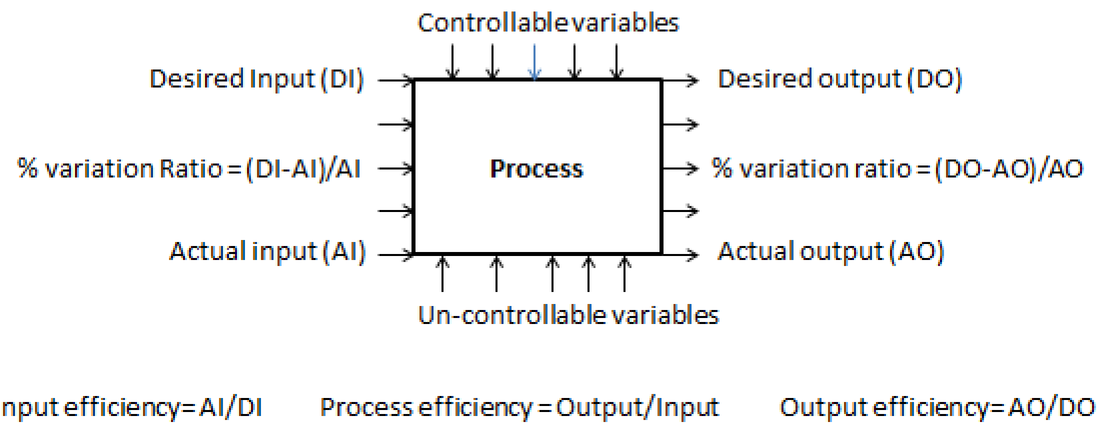

Figure 6 Efficiency and variation in a process

In complicated process with multiple inputs and output which are also interdependent, the process efficiency can be calculated as follows.

$$Process\ effitiency\ = \frac{Weighted\ Sum\ of\ Outputs}{Weighted\ Sum\ of\ Inputs} \ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

To evaluate actual inputs to desired input, the input efficiency can be calculated as follows:

$$Input\ effitiency\ = \frac{Actual\ Input}{Desired\ Inputs} \ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

To evaluate actual output to desired output, the output efficiency can be calculated as follows:

$$Output\ effitiency\ = \frac{Actual\ Output}{Desired\ Output} \ldots\ldots\ldots\ldots\ldots\ldots \text{(4)}$$

This can be achieved by managing all organisational resources in line with their objectives. The weighted input efficiency can be calculated as follows:

$$E_k = \frac{\sum_{j=1}^{M} u_j\, O_{jk}}{\sum_{i=1}^{n} V_i\, I_{ik}} \ldots\ldots\ldots\ldots\ldots\ldots \text{(5)}$$

Where:

$V_i = weight\ for\ input\ i$
$U_j = weight\ for\ input\ j$
$E_k = Efficiency\ of\ a\ DMU\ (0\%\ to\ 100\%)$

The PSLCM problem solving method aims to maximise system effectiveness by managing multiple constraints (impact of variability), while being flexible to address the challenges at hand. The overall efficiency of a project management process can be calculated as follows:

$$PMS(\mu) = \frac{u_1 X_{1j+}\ u_1\, X_{2j}+\cdots}{v_1 a_{1j} + v_2 a_{2j} + \cdots} \ldots\ldots\ldots\ldots\ldots\ldots \text{(6)}$$

Where:

$PMS(\mu)$ = Project management success efficiency

u_1 = Weight given to output 1

X_{1j} = Amount of output 1 from unit j

v_1 = Weight given to input 1

a_{1j} = Amount of input 1 to unit j

The overall efficiency of a project deliverable can be calculated as follows:

$$PPS(\mu) = \frac{u_1 Y_{1j} + u_1 Y_{2j} + \cdots}{v_1 b_{1j} + v_2 b_{2j} + \cdots} \text{.. (7)}$$

Where:

$PPS(\mu)$ = Project product success efficiency

Y_{1j} = Amount of output 1 from unit j

b_{1j} = Amount of input 1 to unit j

The overall efficiency of a corporate success can be calculated as follows:

$$OS(\mu) = \frac{u_1 Z_{1j} + u_1 z_{2j} + \cdots}{v_1 c_{1j} + v_2 c_{2j} + \cdots} \text{.................................... (8)}$$

$OS(\mu)$ = Organisational success efficiency

Z_{1j} = Amount of output 1 from unit j

c_{1j} = Amount of input 1 to unit j

This is the final value that is used to compare project performance at all stages of the life cycle, assisting the organisation to easily identify inefficiencies.

Project success life cycle model (PSLCM) development framework

The PSLCM approach appreciates that there are hardly any similar problems in complex and dynamic power plant environments. This makes it difficult to solve non-standard problems using conventional ways and for the traditional project management approach that focuses on planning to solve complex problems in a restricted way. According to Roedler, Martin, Jones (2005:16), for a mission to be considered a success, it should perform in three areas:

- Meet or exceed business performance requirements

- Meet or exceed system performance requirements
- Meet or exceed project management requirements.

Atkinson (1999-15) holds that although there are interdependencies in a project, its product (deliverable) and its contribution to the organisation, there is no theory that confirms that project success results in product success, which will lead to organisational success (although some projects have failed, they produced a product that exceeded expectations and generated more revenue for their organisation).

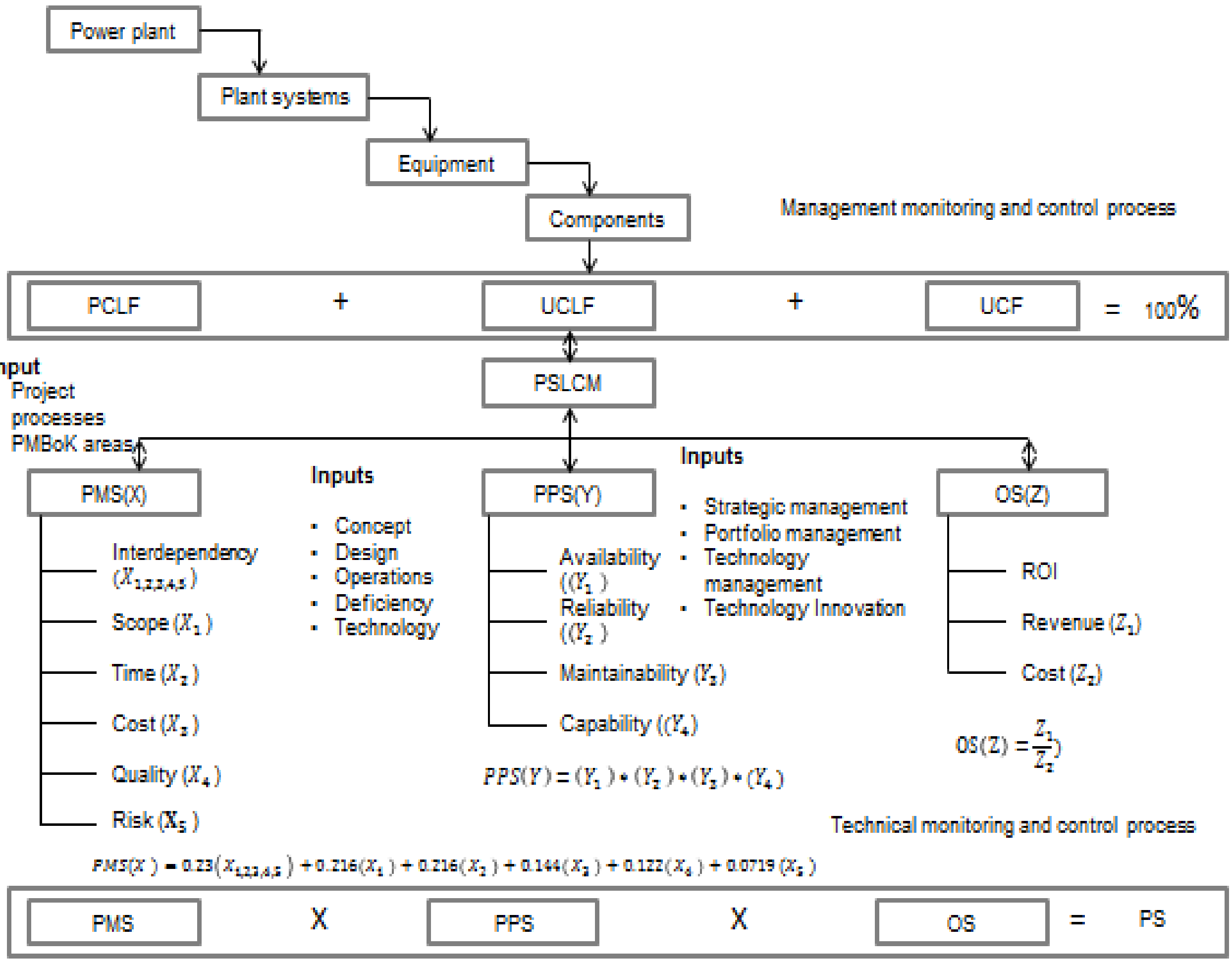

Figure 7 PSLCM development framework

Power plant life cycle management data collection method

PSLCM requires real data from system and subsystem interdependencies, aimed at achieving its multiple goals by producing a web of interlinked relationships, where every project in an organisation contributes to its strategic/corporate plan. The figure below illustrates how basic overall monitoring produces data that is used with the PSLCM to evaluate performance and interdependency effectiveness.

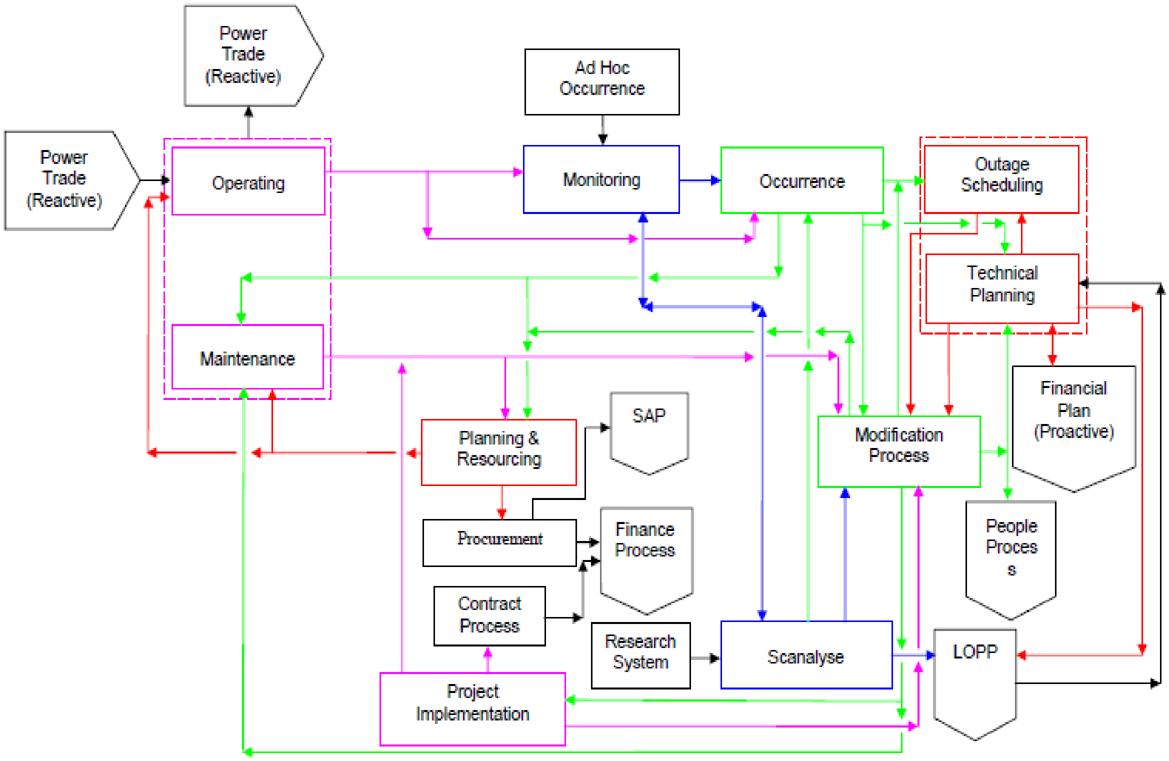

Figure 8: PSLCM system and processes monitoring

Each process input and output connects the entire process flow to understand the overall effect of each sub-process. Due to the increasing need for power, there is an increasing demand on plant availability and efficiency, while older systems from former technology fail to meet these requirements. Resource project interdependencies, knowledge interdependence and technology interdependence must be considered to maximise the benefits of life cycle management. This takes place when something else is developed from existing knowledge as a result of advancement in life cycle management, which is due to collaborations that surge strategic interaction towards the strategic direction established by the organisation. The two PSLCM processes are:

- Proactive processes – these processes are well planned processes that the organisation follows to deliver projects and products and power plants that always meet and exceed customer expectations. It includes business plan processes, life of plant plan (LOPP) management, technical plan processes, outage plan processes and project execution processes.

- Reactive processes – these are not so planned processes that are followed as a results of current system deficiencies , obsolescence or advancement in technology which include operating processes, maintenance processes, plant monitoring process, resource planning and scheduling processes, and the deviation process.

The diagram below illustrates the process interdependency management of the PSLCM processes.

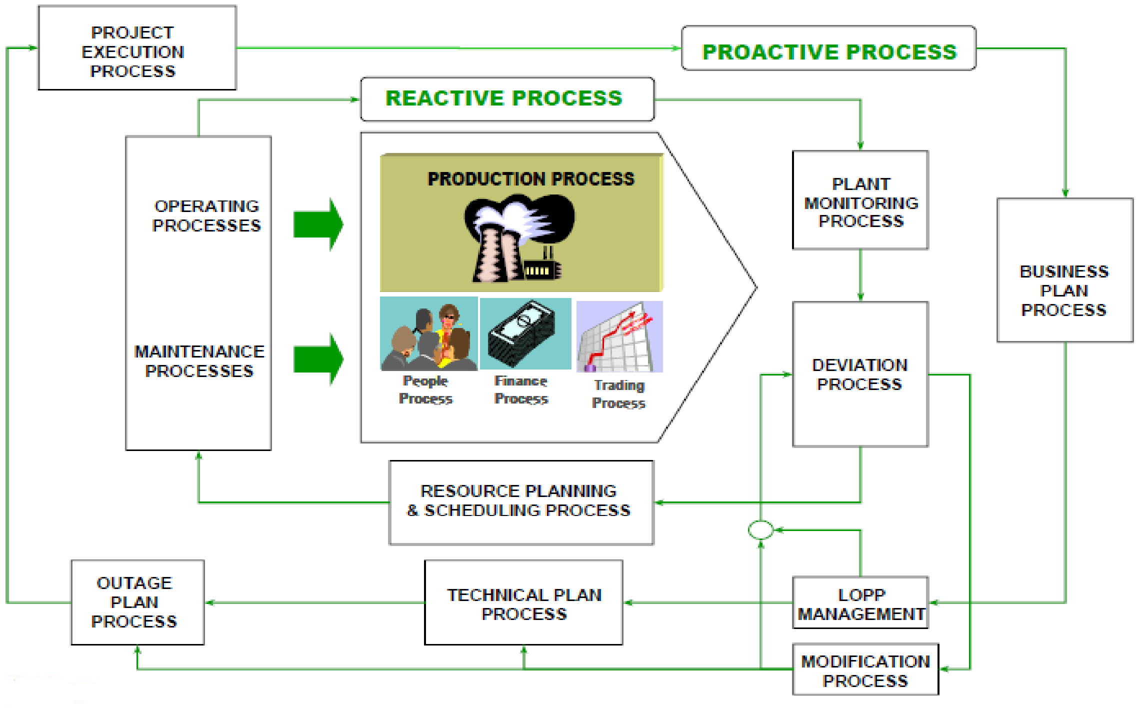

Figure 9: PSLCM process interdependency management

From the above, it could be deduced that plant success (PS) through the life cycle is directly proportional to project management success (PMS), project product success (PPS) and organisational success (OS) indicated by mathematical relationship below:

$$\mathbf{PS\ (Y) = X(PMS) * Y(PP) * Z(OS)} \ldots\ldots\ldots\ldots \textbf{(9)}$$

Where:

$$\mathbf{PMS(X_1) = 0.23(X_{1,2,3,4,5}) + 0.216(X_1) + 0.216(X_2) + 0.144(X_3) + 0.122(X_4) + 0.0719(X_5)} \ldots\ldots\ldots\ldots \textbf{(10)}$$

PMS = Project management success

$X_{1,2,3,4,5}$ = Factors interdependency

X_1 = Scope

X_2 = Time

X_3 = Cost

X_4 = Quality

X_5 = Risk

$$\mathbf{PPS(Y)} = (\boldsymbol{Y_1}) * (\mathbf{Y_2}) * (\boldsymbol{Y_3}) * (\mathbf{Y_4}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textbf{(11)}$$

PPS = Project product success

(Y_1) = System availability

Y_2 = System reliability

Y_3 = System maintainability

$Y_{.4}$ = System capability

$$\boldsymbol{OS(Z)} = \left(\frac{Z_1}{Z_2}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textbf{(12)}$$

OS = Organisational success

Z_1 = Capital/Revenue

Z_2 = Costs (LCC)

Substituting equation (7), (8), and (9) into equation (6):

$$\boldsymbol{PS\ (Y)} = [\mathbf{0.23}(\boldsymbol{I}) + \mathbf{0.216}(\boldsymbol{S}) + \mathbf{0.216}(\boldsymbol{T}) + \mathbf{0.144}(\boldsymbol{C}) + \mathbf{0.122}(\boldsymbol{Q}) + \mathbf{0.0719}] * [\boldsymbol{A} * \boldsymbol{R} * \boldsymbol{M} * \boldsymbol{C}] * \left[\frac{Z_1}{Z_2}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{13})$$

Therefore, change in input output efficiency can be calculated as follows;

$$\Delta_{\mu} = \left(\frac{\Delta\_\mu O_i}{\Delta - \mu i_i}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textbf{(14)}$$

Where:

$\Delta\_\mu O_i$ = Change in efficiency input of a variable
$\Delta - \mu i_i$ = Change in effitiency output for a variable

Substituting equation (14) into equation (13)

$$\boldsymbol{PS} = \left[\mathbf{0.23}\left(\left(\frac{\Delta\boldsymbol{\mu O_i}}{\Delta\boldsymbol{\mu i_i}}\right)\boldsymbol{i}\right) + \mathbf{0.216}\left(\left(\frac{\Delta\boldsymbol{\mu O_i}}{\Delta\boldsymbol{\mu i_i}}\right)\boldsymbol{S}\right) + \mathbf{0.216}\left(\left(\frac{\Delta\boldsymbol{\mu O_i}}{\Delta\boldsymbol{\mu i_i}}\right)\boldsymbol{T}\right) + \mathbf{0.144}\left(\left(\frac{\Delta\boldsymbol{\mu O_i}}{\Delta\boldsymbol{\mu i_i}}\right)\boldsymbol{C}\right) + \mathbf{0.122}\left(\left(\frac{\Delta\boldsymbol{\mu O_i}}{\Delta\boldsymbol{\mu i_i}}\right)\boldsymbol{Q}\right) + \mathbf{0.0719}(\left(\frac{\Delta\boldsymbol{\mu O_i}}{\Delta\boldsymbol{\mu i_i}}\right)\boldsymbol{r}\right] * \left[(\left(\frac{\Delta_{\boldsymbol{\mu o}_i}}{\Delta\boldsymbol{\mu i_i}}\boldsymbol{A}\right) * \left(\frac{\Delta_{\boldsymbol{\mu o}_i}}{\Delta\boldsymbol{\mu i_i}}\boldsymbol{R}\right) * \left(\frac{\Delta_{\boldsymbol{\mu o}_i}}{\Delta\boldsymbol{\mu i_i}}\boldsymbol{M}\right) * \left(\frac{\Delta_{\boldsymbol{\mu o}_i}}{\Delta\boldsymbol{\mu i_i}}\boldsymbol{C}\right)\right] * \left[\frac{\left(\frac{\Delta_{\boldsymbol{\mu o}_i}}{\Delta\boldsymbol{\mu i_i}}\right)\boldsymbol{R}}{\left(\frac{\Delta_{\boldsymbol{\mu o}_i}}{\Delta\boldsymbol{\mu i_i}}\right)\boldsymbol{C}}\right] \ldots\ldots\ldots.\ldots\ldots\ldots\ldots\ldots\ldots..\ldots..(\mathbf{15})$$

The above equation monitors both efficiency and effectiveness of a system and its processes.

Project success life cycle model (PSLCM)

The model representing the above formula has a holistic view of life cycle performance measurement and applies system thinking and process thinking simultaneously, 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 proposed integrated model is indicated in the figure below (summary of model).

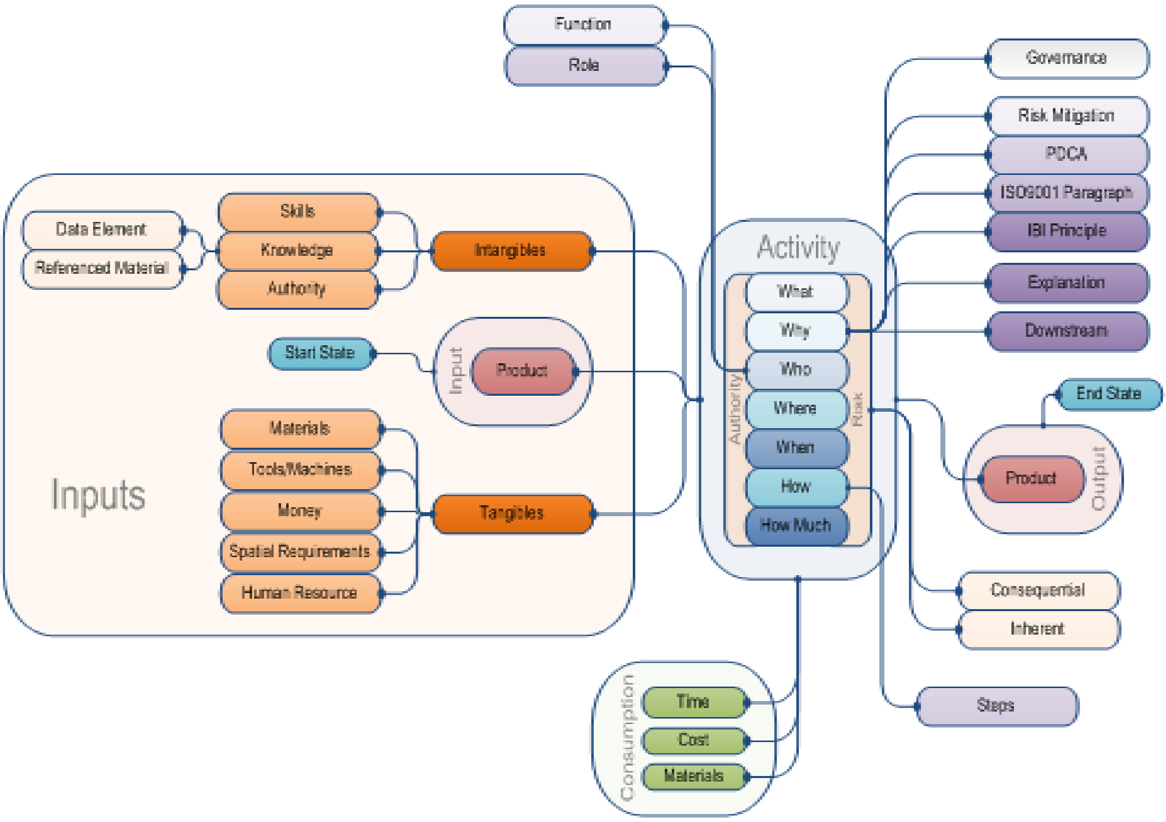

Figure 10: Project success life cycle model (PSLCM)

The PSLCM problem solving method aims to improve team competencies and adaptive ability to bring about the required transparency and a detailed understanding of how elements of the system affect system effectiveness. The existence of a system, its interaction and interdependency, is rooted in the connectivity of one element with others, which constitutes a network that must be dealt with as a whole.

Systems scenario analysis and planning provide a way for engineers to systematically integrate political, economic, and socio-cultural aspects of complex, large-scale engineering systems into the understanding of the operation and evolution of these systems. It also enables consideration of how emerging technology may change the way engineering systems operate and change over time (life cycle). Developing the intellectual dexterity and agility of engineers regarding how different perspectives and interpretations of science and technology, especially risk and how risk is managed and communicated, along with the ability to communicate clearly the overarching goal of the system, can minimise the impact of constraint present in engineering systems. The figure below indicates the PSLCM stages.

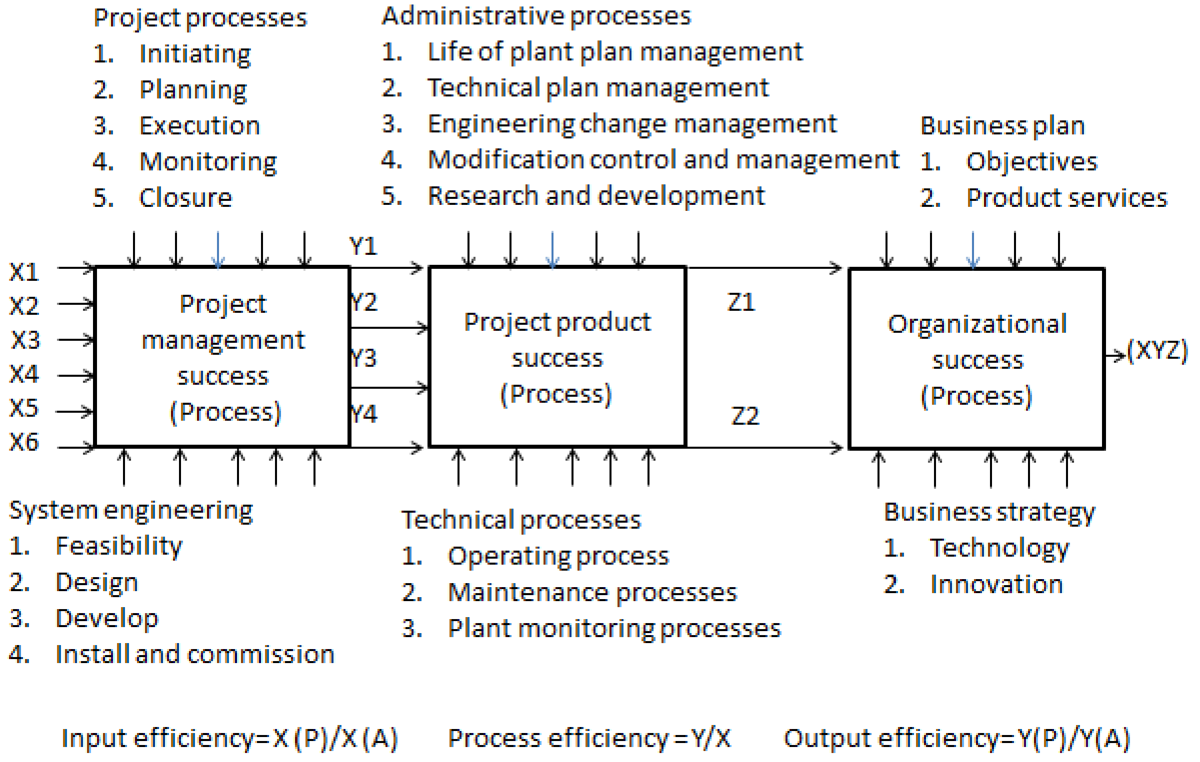

Figure 11: PSLCM stages

By understanding the input output relationship in system and processes, the most influential variables of success x (input) on the response y (output) can establish 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 uncontrollable variables' effects are minimised. The results of running all combinations of the selected factors at two levels (high and low) are shown in table below.

Table 1: Factorial experiment table simulating inputs/outputs

Projects	X1	X2	X3	X1X2	X1X3	X2X3	X1X2X3	Performance(Y1)	Variation(Y2)
1	-1	-1	-1	1	1	1	-1	21.80	7.63
2	1	-1	-1	-1	-1	1	1	39.04	6.11
3	-1	1	-1	-1	1	-1	1	51.91	5.76
4	1	1	-1	1	-1	-1	-1	63.86	6.07
5	-1	-1	1	1	-1	-1	1	60.29	6.94
6	1	-1	1	-1	1	-1	-1	65.53	9.73
7	-1	1	1	-1	-1	1	-1	53.16	4.20
8	1	1	1	1	1	1	1	42.17	3.96
Effects (Y1)	**5.86**	**6.11**	**11.14**	**-5.38**	**-8.74**	**-21.3**	**-2.73**	**49.72**	
Effects (Y2)	**0.00**	**-2.6**	**-0.18**	**-0.30**	**0.94**	**-1.65**	**-1.22**		**6.30**

The figure below shows the Pareto chart, which indicates the effects on variable performance to the overall output. The few factors on the left are identified as the vital few while all other on the right are considered the trivial many.

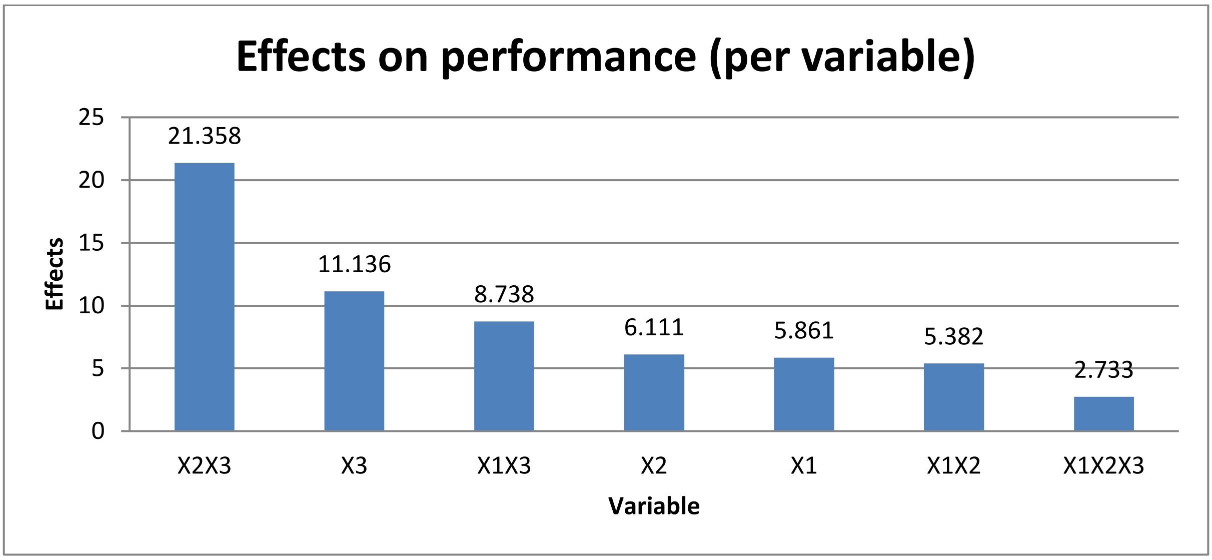

Figure 12: Pareto chart for variables affecting project success

The model simulation goes a long way towards identifying hidden problems down the line, allowing timely decision making in a project, which will definitely improve project success. Simulating variation goes a long way towards identifying project constraint so that solutions can be easily provided by reusing existing processes in different ways. The model forces all stakeholders involved in a project and product to focus beyond their direct responsibilities.

Conclusion

In this article, the model used to measure, control and manage overall life cycle success of projects, product and organisations, has been developed and presented. The method can be easily applied to projects were operating hours are directly related to profitability and to the availability of the equipment. The method integrates financial and technical variables in order to calculate performance and variability by calculating input efficiency, output efficiency and process efficiency. This method makes it easy to identify the process that is affecting the project, its product or the organisation, thus making it an effective tool for continuous improvement. This method gives a single score which summarises performance of all critical variables, while considering the importance of each success criteria.

This model ensures that project stakeholders look beyond their immediate responsibility, thus forcing all stakeholders to work together for the benefit of the whole. This allows problems and opportunities to be exploited at any stage of the life cycle, including operations and maintenance. The model also discovered that the interdependency of elements is of outmost important for the system mission and must receive the highest attention. All project knowledge areas can be compared to determine the project teams that are continuously improving their performance or acquiring valuable experience, making it easy to duplicate good practices within an organisation.

The need for life cycle management tools as a result of deterioration of the energy market, requires decision support for finding an optimum between operational performance, financial performance and risk exposure, focusing on informed decision making rather than technical performance only. The condition and performance of assets drive decisions to meet corporate objectives, initial targets and regulations. This model provides predictions in meeting requirements and provides a warning of deviations that have an impact on the system's mission. Incorporating the financial and technical measurement systems resulted in the development of a holistic measure, appreciating the importance of each measure variable in the overall contribution to performance. This will make it easy to compare tasks, activities, projects, process and asset performance at any given point throughout the plant life cycle.

Recommendations

It is recommended that the:

- Power utilities utilizing this methodology must fully understand the desired impact the project is going to make on the organisation (be clear about the purpose of the project). This is because the benefit cost relationships are both important for the performance calculation monitored throughout the system's life cycle.
- project life cycle model (PSLCM) be applied in the manufacturing sector, because it will increase data availability, which makes it easy to accurately measure holistic performance and to identify inefficient areas. In today's competitive word, PSLCM will go a long way towards guiding investment in the organisation while reducing equipment life cycle cost, eventually reducing manufacturing cost.

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