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Proposed Approach For Developing Process-based KPIs For Project Control During The Pre-project Stage

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Abstract
In recent years a great deal of attention has been made to measuring different aspects of construction project performance. Some of the tools used for this purpose are the Key Performance Indicators (KPIs). The main shortcoming of these however is that most of them are end product oriented and hence are of little use for controlling the project performance while it is in progress.
The pre-project stage in construction is where most of the decisions that greatly influence the project as a whole are taken. To be able to monitor and influence the performance of the process at the very beginning of the project is hence very beneficial. This paper describes a theoretical framework for developing KPIs to be used for project control in the pre-project stage. The theoretical framework is based on mapping the sub-processes within the pre-project stage and their main activities. The sub-processes and their activities are identified using literature and then validated by experts. A system dynamic (SD) approach to model the link between these and the project final objectives is proposed. The paper discusses the basis of the theoretical framework and the research methodology.

Keywords
Process, Control , Performance Indicators, Pre-project Stage, System Dynamics

1. Introduction

In recent years performance indicators are increasingly being used in construction as alternatives to traditional tools of time and cost to measure project performance. The aim of many of the existing indicators is to assess the overall project performance based on comparing it with targets that are usually established on best practice.
In general however most of the existing performance indicators can be characterized as being:

- used mainly for benchmarking purposes;
- end product oriented;
- mostly unrelated to each other.

There is a need therefore to develop process-based performance indicators that will allow controlling the construction process whilst the project is still in progress.

Project performance is a complex issue to measure. It is often the result of many elements and factors that interact with each other. In this sense it lends itself to the use of system thinking. A system is an assembly of components united by some form of regulated interaction to form an organised whole, see Mawdesley (1994).

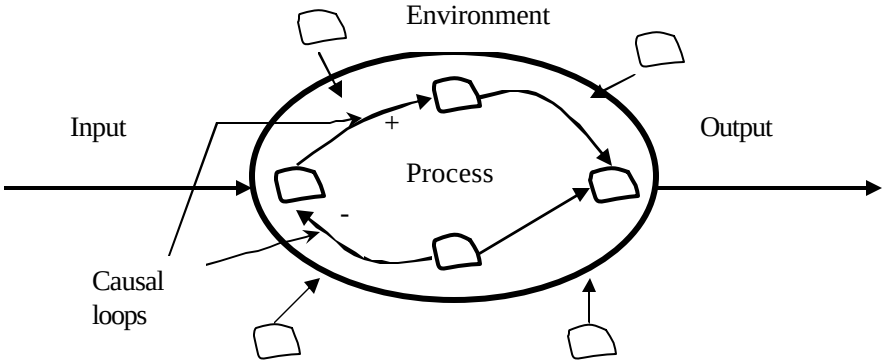

Figure 1: Concept of a system

Figure 1 shows the concept of a system. It shows that there is an input to the system where there is a process. This process is represented by the interaction of the elements. The elements utilise the resources available in order to convert the inputs to outputs. Outside the boundary of the system there exists the environment which influences the system. The environment is used in the diagram to describe the external conditions (i.e. situations, events, people) that will influence the system (Longman Dictionary, 1995) or as defined by Kendall and Kendall (1995):

"Anything external to an organisation's boundary is considered to be an environment"

The system has no control over the forces of the environment. In a construction project, for example, the project has no control or influence on severe weather conditions that may halt it completely or on fluctuating prices of materials that may result, in some cases, in a great loss to the contractor.

Resources of the system can be represented by all means available to the system to accomplish its objectives. Unlike the environment, the resources can be controlled by the system. In the construction, for example, management can use overtime or more resources to meet the project objectives. Similarly, money, information, equipment and tools are all resources which could be utilised.

The efficiency of the system is the result of the efficiency of the components and how these components interact with each other.

This paper examines the elements of the construction process within the pre-project stage, which is defined as a stage, where the idea of a project is taken from general set of ideas and requirements into a specific well-defined project. A proposed conceptual framework is based on process mapping of the main

activities within the stage. A systems dynamic approach is proposed to model the relationships between these elements and the final project objectives as a basis for developing a set of KPIs.

2. Controlling the construction processes

Project control involves the process of monitoring, assessing and comparing the values of the various activities within the process to ensure that they are in accordance with the expected values. Corrective action can be taken in case there is an evidence of lack of progress or identifying areas of poor quality (Mawdesley et al, 1997) and is part of overall control cycle and feedback loop. Feedback provides information about the necessity to make corrective action (Bennett, 1985).

Based on the definition of control stated above, it can be concluded that control aims not only at ensuring progress but quality of the project or the process as well. This is particularly relevant when using performance indicators for control. Performance should reflect the quality of work done and not only the amount being carried out compared to the plan. Quality can be defined as meeting the legal, aesthetic and functional requirements (Arditi and Gunaydin, 1997). Requirements in its turn are established specifications used to define the nature of a product or a process or service (Ledbetter, 1994). Therefore the process-based performance indicators are those that provide information both about the degree of completion and the degree to which the established specifications (or requirements) are met.

Construction process consists of many stages that are interrelated. For the purpose of this work the process is depicted by three main stages, namely pre-project, design and construction. This research is concerned with the pre-project stage and the activities and output for this stage have been mapped using literature and a number of pilot studies. This is done as a basis for developing KPIs as control tools and to establish the interrelationships between the activities and outputs within a stage and those of the other stages. The process is seen as a dynamic system consisting of many elements that interact and change with time. The performance of the system at any one time is the product of its performance in the past, the action taken as well as its performance at present.

3. System theory applications

The importance of systems theory lies in the overall view to any problem under study. Such views stimulated researchers in different disciplines to approach their problems in a systemic manner.

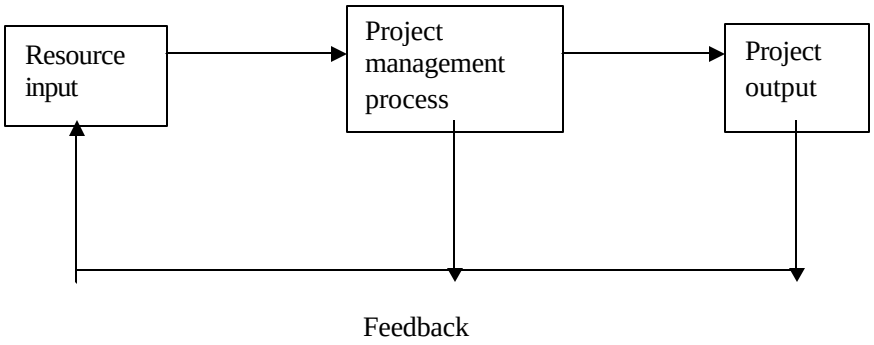

Figure 2: A system approach to project evaluation (based on Anbari 1985)

Many researchers have attempted to apply the theory to their work in various areas. In construction for example Anbari (1985) adopted the system approach to study various elements of project evaluation. He

viewed a project as a total system which transforms input into output by certain processes, and where there is feedback. Such feedback will provide a mechanism that will assure that goals and objectives set for the project are met. His view is shown in Figure 2.

The study viewed the process as the management of six subsystems. These subsystems are: scope, time, cost, quality, human resources and communications. Each of these subsystems has its own inputs, process, outputs and feedback. For example, scope management can be considered as a subs ystem with inputs such as goal settings and documents.; its process is change control and all necessary supporting documentation. The output includes the final closeout and acceptance of the project while the feedback is a periodic evaluation.

Evaluation of each subsystem of the process will be based on its meeting the objectives of that subsystem, its interaction with other subsystems and whether it is meeting the objectives of the project as a whole. In order for the project to be successful, Anbari suggested that evaluation needs to be done prior to the beginning of the project, at regular intervals during construction and during its conclusion.

Rodrigues and Pilcher (1998) claimed that existing project management techniques are inadequate for analysing modern complex technology projects especially where there are effects by multiple client actions. They discussed the practical use of 'system dynamics' (SD) models to evaluate the impact of client behaviour in projects. The system dynamics model they developed is focused on three major roles: estimating, risk analysis, progress monitoring and diagnosis. The models were developed based on studying the interaction of the software design tasks using influence diagrams that lead to the development of a number of cause-effect relationships.

The authors proposed what they refer to as a System Dynamics-based Project Management Integrated Model (SYDPIM). SYDPIM uses SD models to support the planning and monitoring functions; the model is based on continuous calibration of the SD models to replicate past behaviour and to capture the plans. Within the planning function the models are used to estimate the project outcome and to help identify better planning alternatives (ensuring that the plan is based on realistic assumptions). In monitoring, the models are used to uncover several metrics about the project status, and as a diagnosis tool to help identify possible causes for observed deviation. The model developed was validated on a software project mainly to investigate how schedule adjustments should be managed and negotiated with the client so that the effects of introducing requirement changes during the later design stages can be minimised.

Shaddad and Pilcher (1984) developed what has been referred to as a causal model for project productivity. The model is mainly a schematic descriptive model that shows and tries to explain the inter-relationship between managerial variables and the system performance of projects in the construction industry. Within the model, the construction project management activities are seen as a system that consists of seven sub-systems. The model is concerned with illustrating the influence of the management activities on system productivity at the project level, the main input to the model is the management activities variables and the output is concerned with the end result variable "system productivity variable". The model introduces a number of factors that affect productivity and classify those factors in a reasonable manner.

4. Proposed approach

A process can be defined in many ways but for the purpose of this paper the definition of a process by Cheung (2004) is to be adopted. Cheung defined a process as "a system or a subsystem consisting of interrelated components that have a common purpose and share a set of goals". Therefore, to be able to control any process it is necessary to control the interrelated elements of a process and their alignment to

project goals. The interrelated elements in the construction process can be interpreted as the outputs within each stage that have influence on each other in one way or another.

It is assumed that when the process is under control then the effect or the output is predictable (McGeorge and Palma, 1997). To know whether the process has achieved the desired effects it is important to relate the outputs of the activities and sub-processes to each other and to the project goal. If the inputs or the information available to an activity are inconsistent, insufficient or wrong then there is a great chance that the process and its outputs will also be deficient since the inputs of the following sub-processes forms the outputs of previous ones.

In this research the authors propose a System Dynamics (SD) approach whereby all of the main process elements are linked to each other as a system. Establishing the links and influence of the various outputs within the construction process on each other and on the project goals will help identifying the appropriate control required. Such links are determined on the basis of a number of KPIs that are developed using the information from the process outputs. A representation of the proposed systems model is shown on Figure 3.

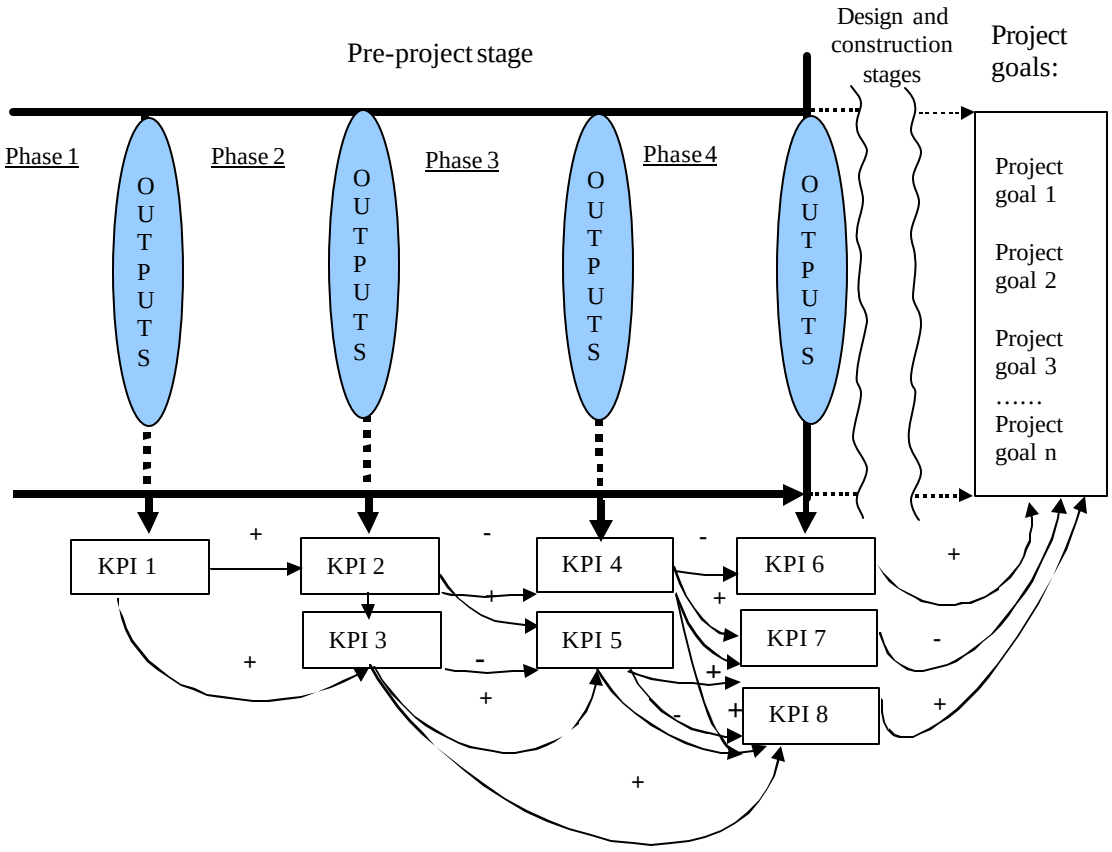

Figure 3: Systems model for controlling the processes and their outputs within the pre-project stage

The theoretical framework shown in Figure 2 provides a basis for a systems model of the construction process, where process outputs are identified and used as a basis for the development of KPIs.

According to Maskell and Baggaley (2004) performance indicators must shift from the traditional orientation, which aims at the results and their main causes. The causes that will lead to the desired processes must be identified beforehand, designed and then controlled during the process. This new focus therefore must be concerned with identifying the causes and the effects within the process and linking them to the main goal of the stage and that the entire project.

Once the process-based KPIs are selected and their assessment is developed, they can be used to compose the causal loops that are required to form the transition equations in a systems dynamics approach. The assessment of performance of any part of the process and the project as a whole would be carried out on the basis of assessing them with respect to two main criteria, progress (i.e. % completion) as well as quality.

5. Research methodology

The proposed research methodology to establish the appropriate process-based KPIs and to use them as part of a systems model consists of three main steps namely:

1) identifying outputs relevant for project managers and their importance within any project stage;
2) defining KPIs based on these outputs;
3) defining the end project goals;
4) establishing the causal relationships between the defined KPIs and that of the project goals as part of transitions equations that will be used by the systems model;

The first step has already been carried out by splitting the pre-project stage into four main phases: project idea, initiative, feasibility and project definition phases to establish the so called control points during the construction process. The identified phases are defined as follows:

- project idea phase – the phase where the idea of the project is taken from the general set of ideas to the identified client requirements;
- initiative phase – the phase where project needs are defined based on the client requirements;
- feasibility phase – the phase where project 'alternative' options are analyzed and the preferred option is chosen;
- project definition phase – the phase where the preferred option is developed and the decision to proceed with the project is made.

Within each of the above phases the main outputs have been identified based on a comprehensive literature review which has been complemented by knowledge gained through a number of interviews with experts in the Dutch construction industry.

During the interviews the theoretical process model of the pre-project stage was introduced and explained with definitions of the various sub-processes. The phases of the theoretical model of the pre-project stage were outlined as explained above. The main purpose of the interviews was to provide answers to the following questions:

1) whether the theoretical framework represents the real construction process in the pre-project stage;
2) whether the identified outputs are representative of the phases within the pre-project stage and
3) which elements of outputs are important, affecting performance and essential to be controlled.

The list of the main outputs for each phase of the pre-project stage based on the results of interviews is shown in Table 1.

The defined outputs form a basis for identifying and later developing the appropriate KPIs to control the pre-project stage. The KPIs are expected to provide information about the degree of completeness and the degree of quality achieved during the process.

A list of project end goals relevant for all construction processes will be composed and the link between them will be established. All this information will be verified by experts to ensure that all important issues are included. It is suggested that experts be asked to provide scores on the importance of links (cause-effect) between the KPIs and the project end goals so that weightings for the various relationships in the transition equations are determined. This can be done in the form of filling out these scores on a matrix showing the relationships between all the KPIs themselves and between them and the project goals.

Table 1: The outputs of the each phase in the pre-project stage

Project idea	Initiative	Feasibility	Project definition
• Key objectives in strategic terms • Outline problem (need, opportunity) • Analysis of client needs • Analysis of client restrictions • Analysis of client requirements • Location analysis • The consensus between the interests of stakeholders' involved	• Global time based on client requirements (CR) • Global cost based on CR • Resources available • Specific issues of the project based on CR • Global specification of the project • Project constraints based on the client requirements • Environmental analysis • Stakeholders' analysis • SWOT analysis • Market analysis • Correspondence of results of analyses with CR • Participation of several stakeholders in analyses • Approval of project needs by stakeholders' involved	• Choice of the procurement method • Resources required • Choice of location • Global life cycle costs • Global project specification • Milestones of time • Milestones of cost • Methods of meeting project needs • Deliveries for each stage • Risk analysis • Spatial analysis • Correspondence of results of analyses with CR • Evaluation criteria for choosing alternatives • Costs & benefits of alternatives • Financial capabilities, alternatives and trade-offs • Interaction between the alternatives, costs and stakeholders • Choice of the best alternative • Check the alternative on site, legal and environmental issues • Participation of several stakeholders in analyses • Approval of project needs by stakeholders' involved	• Special work items • Specification of the end product • Time constraints • Cost constraints • Deliverables at the end of following stages • Info required for each stage (legal aspects) • Project control plan • Project management plan (incl OBS and RAM) • Risk management plan • Financial plan • Communication plan • Acquisition of property • Temporary provisions (building site, traffic…) • Provision of info required for all stakeholders • Approval of project needs by stakeholders' involved

6. Conclusions

The use of new performance measurement system and in particular the key performance indicators is gaining popularity in the construction sector. However, most of existing KPIs are end-product oriented, used for benchmarking purposes only and don't relate to each other.

To overcome some of the main shortcomings of the present use of KPIs, this paper describes a theoretical model as a basis for developing process-based KPIs for control purposes. The assessment of KPIs in the model will not only be based on measuring the progress of a particular process or output but also their quality.

The research also proposes the use of systems dynamics approach to model the process and to link the developed KPIs with each other and the project end goals.

The research methodology for developing process-based KPIs for process control has been described. It aims at establishing the interrelationships the process-based KPIs will have on the project goals.

The main focus of the paper has been the pre-project stage whereby the project is being defined and the decision to proceed with the project is being made.

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