Key Performance Indicators: Advances in Construction Projects Performance Measurement

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Abstract
The last two decades, performance measurement in the construction industry has shifted towards a more holistic and integrated assessment of the overall construction project success, with the implementation of appropriate Key Performance Indicators providing essential information for project monitoring and construction management processes control. This paper attempts a critical literature review of recent trends on performance measurement systems developed for construction projects, focusing on the development and application of related Key Performance Indicators, by presenting some of the most significant published studies in construction and project management journals. The two main objectives of this review is first to examine whether the issue of sustainability is addressed in the presented studies, and in what extend, and second to inspect if these studies are considering performance evaluation throughout the construction project Life Cycle. After a short report on the most applied modern performance measurement frameworks in construction and the creation and evolution of Key Performance Indicators, a succinct presentation of the reviewed studies is following, summarizing and reporting their basic features in an extensive table. Finally, concluding remarks and comments are given.

Keywords
Key Performance Indicators, Performance Measurement, Life Cycle Assessment, Sustainability Criteria

1. Introduction

Performance Measurement (PM) has gained significant attention during the 1990s among academics, researchers and professionals in most of the economy's sectors. The new trend quickly expanded in the construction industry, with more and more construction engineering organizations adopting Performance Measurement Systems (PMSs) (Bassioni et al., 2004). A rough distinction in the application of PMSs in construction is at a macro level, that is the industry, and at a micro level, that is the construction project. Although PM in construction initially used to focus on project performance, strictly following the classical “Iron Triangle” approach in terms of time/cost/quality, the evolution over the last decades has led PM objectives to extend to construction firms and to the project stakeholder level. Meanwhile, performance at the construction project level incorporated the evaluation and assessment of the overall project success in a more holistic and integrated manner, viewing the construction project as a product.

Project performance evaluation throughout the entire life of a project has been a concern for academics and researchers since the last two decades. Jugdev and Muller (2005) concluded that views on project success have changed over the years from limited definitions restricted to the implementation phase of the project, to definitions reflecting appreciation of success over the entire project and product Life Cycle (LC). Yet, in the case of construction projects, most of the PMSs, theoretically or empirically developed, do not seem to take into consideration the entire LC of the project, the process of which includes conception and feasibility studies, engineering and design, procurement, construction and operation or utilization. Related literature and various definitions (Kibert, 1994; Ritz, 1994, Shen et al., 2007) suggest five major phases to compose a construction project's LC, namely: *i) Inception:* an initial pre-project phase where the project idea is born and its primary objectives are defined, including also opportunity and feasibility studies leading to investment decisions, *ii) Design:* involves the preparation of detailed construction drawings and analytical designs of structural, electrical or other systems, supplemented by contract documents and written conditions containing legal requirements and commitments, *iii) Execution:* the phase of the actual construction of the project, including the pre-construction stage where various subcontractors are recruited and the project site is organized and the actual construction stage, where the various physical activities are undertaken, *iv) Operation:* the time period upon which the completed project will function as a product and will be used by the project's stakeholders (clients, end users, neighbors etc.) and *v) Demolition:* the final stage of the project's LC, indicating the termination of the project's life by the decomposition of its basic structures and facilities.

Sustainability performance across a construction project's LC is a critical aspect in achieving the primary goal of sustainable development, while the impacts of construction activities on it can be considered in three main dimensions: *social, economic,* and *environmental*. Various management approaches have been developed (Kibert, 1994; Hill and Bowen, 1997) and lists of sustainability performance factors were formulated (Shen et al., 2007) to assist and improve sustainability performance in construction projects. However, specific sustainability measures and indices are not often included in the PM process implemented in construction projects.

Taking into consideration these two recent trends of LC analysis and sustainability in construction projects' PM, the aim of the paper is to present a thorough literature review and a critical reporting of published studies, during the last two decades, on PMSs developed strictly for construction projects. The two main objectives are on the one hand, to examine whether the issue of sustainability in construction projects is addressed in the developed PMSs, and in what extend, and on the other, to inspect if the presented PMSs for construction projects are considering performance evaluation and project LC analysis. For the selection of the presented studies, major and highly-ranked project or construction management journals were considered.

2. Performance Measurement in Construction

2.1. Contemporary Performance Measurement Frameworks Applied in Construction

The gradual abundance of traditional PMSs during the past thirty years, led to the development of numerous models and frameworks for implementing PM, aiming to bridge the gap between financial and non-financial measures and considering several other critical aspects, like quality management, customer and employee's satisfaction, processes optimization etc. Yet, not all of them experienced wide implementation in construction. The *European Foundation for Quality Management (EFQM) Excellence Model,* the *Balanced Scorecard (BSC)* and *Key Performance Indicators (KPIs)* are considered to be the most frequently used by a number of researchers (Bassioni et al., 2004; Yang et al., 2010).

The *EFQM Excellence Model*, a non-prescriptive framework developed in 1989 in Europe, has emerged as a major tool in the development of continuous business improvement, aiming to improve performance and to enable the assessment of excellence. (EFQM, 1999). The model consists of five enabler's criteria, dealing with how the various activities are undertaken and representing the management of the organization, and four sets of results criteria, focusing on what results an organization have achieved. Despite its original mission as a business quality and excellence model, the EFQM Excellence Model has been used ever since as a PM framework (Bassioni et al., 2004) and has been adopted by many construction companies. *BSC,* introduced in the early 1990s by Kaplan and Norton as a new comprehensive PMS, comprised a framework that can translate a company's vision and strategy into a coherent and linked series of measures and sub–measures, allowing an organization to measure and evaluate its performance through four distinct perspectives: Financial, Customer, Internal Process and Learning & Growth Perspective. Although BSC intended to serve as the basis of a typical PMS, it was further promoted as a strategic management system, organized on a cause-and-effect relationship base between the four perspectives (Kaplan and Norton, 1992;1996). Yang et al. (2010) considered BSC as the most frequently used PM framework in construction industry. *KPIs* constitute performance metrics of processes critical to the company's success and indispensable for benchmarking and project monitoring. Such models, developed generically, have been widely applied in the construction industry, establishing a system for the continuous performance improvement, in order to eliminate inefficiency and maximize cost effectiveness and productivity **(**Cha and Kim, 2011).

2.2. Key Performance Indicators in construction industry and projects

During the 1990s two landmark reports, published by Sir Michael Latham (1994) *"Constructing The Team"* and by Sir John Egan (1998) *"Rethinking Construction"* respectively, set out specific targets for performance level improvement in the construction industry, in terms of project performance, productivity, profitability, client satisfaction and quality & safety. In response to these two reports, the Construction Best Practice Program (CBPP), a government funded organization, was established in the U.K., launching the first KPI Programme in 1998. CBPP developed a first set of 10 headline KPIs in November 2000, serving as a measure of the overall state of a company's health, roughly classified into three categories: *economic, respect for people* and *environment.* On project performance, KPIs provide information regarding *construction cost, construction time, predictability cost, predictability time, defects, client satisfaction for product* and *client satisfaction for service*, while company performance is addressed from the perspectives of *safety, profitability* and *productivity* (CBPP, 2002). These headline KPIs were further classified as: i) operational indicators, used to measure specific activities and ii) diagnostic indicators, providing information on why certain changes may have occur in the headline or operational KPIs (KPI Working Group, 2000).

CBPP was soon acknowledged as the leading organization in the production of KPIs for the construction industry and its merging with the *"Rethinking Construction"* movement created in 2004 the Constructing Excellence (CE) Programme of the U.K (CE, 2006). CE compares pilot projects of the "Rethinking Construction" movement, from the KPI viewpoint, verifying the need for the introduction of a PMS in the construction industry, for the improvement of its competitiveness and management's efficiency. In the case of the U.S, the importance of performance assessment in increasing competitiveness and growth was acknowledged in the early 1990s. The Benchmarking & Metrics Programme (B&MP) of the Construction Industry Institute (CII) is another widely known construction initiative for PM, aiming to provide the construction industry with a common set of metric definitions and performance norms (Costa et al., 2006). B&MP reported a first collection of performance data in 1996 and its current review includes a set of indicators classified in the categories of *budgeted & actual cost, planned & actual schedule, facility capacity, outcomes, accident data* and *impact factors*. Its goal is to set performance standards in the construction industry using a consistent PM algorithm and to develop assessment tools in order to promote construction performance (CII, 2001).

Although KPIs, especially those of CBPP, proved very successful in introducing the topic of PM to the construction industry, they have been criticized as merely lagging indicators with limited use for internal management decision making, since they do not give insight for post event performance improvement (Bassioni et al., 2004). According to Beatham et al. (2004), KPIs are rarely incorporated into a proper PMS since they do not offer a real opportunity for organizational or performance change and they are more suited for cross-industry benchmarking purposes.

3. Presentation of related studies

Chan et al. (2002) modified the generic success criteria to develop an assessment framework for Design and Build (D&B) projects. Adopting the view that project success criteria change with time, they analyzed project success from the three conceptual phases of a construction project: the pre-construction, the construction and the post-construction phase. In their study, a list of success criteria for design/build projects, appearing in previous studies, was incorporated and categorized as objective and subjective measures. Their objective measures were described as hard and tangible and included *Time* and *Cost*, measured in the pre-construction and the construction phases, *Health & Safety*, considered in the construction phase, and *Profitability*, measured in the post-construction phase. On the contrary, subjective measures were termed as soft, intangible and less measurable, including *Quality* and *Technical performance*, assessed and measured in the pre-construction and the construction phase, *Functionality*, considered in the post-construction phase, *Productivity*, considered in the construction phase, *Project participants' satisfaction*, assessed in all three phases, and finally *Environmental sustainability*, measured in the post-construction phase. For each one of the objective and subjective criteria measures, common and widely applied KPIs were proposed.

Cox et al. (2003) acknowledged the necessity of identifying common indicators, for construction executives and managers, in measuring projects' performance and investigated management perceptions of quantitative and qualitative KPIs utilized in construction. They generated an initial set of perceived KPIs, through literature research, and conducted a survey in order to administer them to construction projects. Performing statistical analysis of the collected responses, in order to determine common KPIs by construction sector and by management or experience level, they concluded that the reported KPIs generally differ according to management's perspectives. Nevertheless, they identified six top rated indicators, including: *Quality control, On-time completion, Cost, Safety, Cost/Unit* and *Units/Man-hours*, reported as the most significant and useful by every construction sector.

Following the Chan et al. (2002) study, Chan and Chan (2004) developed a conceptual framework for evaluating success and measuring performance of construction projects. A set of KPIs, measured both objectively and subjectively, was collected through a comprehensive literature review and based on earlier research and their validity was tested with three case studies. Nine KPI categories in total were selected and divided into two groups, representing the objective and subjective criteria respectively, according to the calculation methods of the proposed KPIs. The first group, implementing mathematical formulas to calculate the respective values, included the categories of *Time, Cost, Value & Profit, Health & Safety* and *Environmental performance*. The second group, incorporating subjective opinions and personal judgement of the stakeholders, included *Quality, Functionality, User expectation & satisfaction* and *Participants' satisfaction* of various stakeholders. Similar KPIs with the ones reported to the Chan et al. (2002) study, were proposed for the nine success criteria.

Yeung et al. (2007), arguing that KPIs can serve as a benchmark for PM in construction partnering projects, developed a comprehensive performance evaluation model of partnering projects in Hong Kong. Utilizing a previously developed KPIs' conceptual framework, they applied the Delphi technique conducting a four-round questionnaire survey with a large number of construction experts, in order to rank and address weighs to the initial indicators list. Their results revealed seven top-weighted KPIs, including: *Time/Cost/Quality performance, Top management commitment, Trust & Respect, Effective communications* and *Innovation & Improvement.* In addition, a composite partnering Performance Index

(PI) was derived to provide an integrated assessment of partnering projects' performance. In a consequent study, Yeung et al. (2009), following an identical procedure and applying the same Delphi technique, formulated a model to assess the success of relationship-based construction projects in Australia. Eight KPIs were selected this time, excluding *Top management commitment* and adding *Safety performance* and *Client's satisfaction* in the previous list of KPIs, and a PI has been also derived. In both studies, the developed indices were composed of a set of lagging KPIs and could be used to measure, monitor, and improve the performance of construction partnering and relationship-based projects.

Li (2010) build an indicator-oriented PMS based on BSC, aiming to evaluate international engineering projects in a more comprehensive and accurate way. Considering the two aspects, results and processes, of the overall performance evaluation process of an engineering project, he made necessary amendments and modifications to the classical BSC in order to adjust it as an engineering-project-oriented PMS, including non-financial and qualitative indicators. Stating that international engineering projects differ substantially from domestic ones, and as a result performance indicators should be modified accordingly, he established a set of 1st class and 2nd class KPIs under the SMART principle, based on related literature. The 12 selected 1st class KPIs for the four BSC perspectives of his model were: i) Finance: *Profit potentiality, Finance operating conditions* and *Finance stability*, ii) Customer satisfactory degree: *Owners/Government & public satisfactory degree*, iii) Inner-business process: *Quality/Progress/Cost control* and *Internal communication & cooperation*, iv) Study & Growth: *Staff case, Project's innovative capability* and *Knowledge management*. He also proposed a total of 51 2nd class KPIs, with some of them having significant influence on international engineering projects.

Cha and Kim (2011) attempted to develop a framework to be used as an effective PMS for building construction projects in South Korea, focusing on the construction phase from the perspective of the construction company. They collected a number of potential indicators through a thorough literature review and case studies, which in turn were reviewed and revised by construction projects experts, resulting to 8 performance categories and a preliminary set of 27 KPIs. In order to inspect the initial list checking the validity of the candidate indicators and examine their measurability and representativeness, they conducted two preliminary survey investigations, carrying out in-depth interviews with selected experts. From this procedure, 6 categories serving as performance criteria, namely: *Cost*, *Time*, *Quality*, *Safety*, *Environment* and *Productivity*, and 18 final indicators were screened out. Based on the finalized 18 KPIs, Cha and Kim conducted an extensive survey in order to verify the established PMS and to quantify the individual project performance indicators, by calculating a weight for each indicator.

Ikediashi et al. (2012) developed a set of KPIs for measuring performance of D&B projects in Nigeria, aiming to examine their importance on performance outcomes and to ascertain the agreement level among key stakeholders on them. In their study, an initial set of 12 quantitative and qualitative indicators were firstly identified through literature review and were then rated with the descriptive research approach using a structured questionnaire and a four point Likert scale. The questionnaire respondents represented construction stakeholders such as client/contractor-based organizations. Their findings identified 8 KPIs consistently perceived as highly significant, which were: *Job cost reporting, Time performance, Resource management, Cost per Unit* and *Rework/Quality control* from the quantitative indicators and *Quality of work, Health & Safety* and *Motivation* from the qualitative indicators. The same 8 KPIs were found to be the most relevant and important indicators, although not in the same descending order.

Yeung et al. (2013), acknowledging that the basic problem with KPIs in construction management is their "lagging" nature, formulated a benchmarking model to evaluate performance of construction projects in Hong Kong, incorporating both leading and lagging KPIs. After compiling a list of 20 leading and lagging KPIs based on a two-stage, comprehensive literature review, they conducted a questionnaire survey with industrial practitioners, analysing the survey results with the Reliability Interval Method in order to determine the relative importance and weightings of the various KPIs. Their results identified 10 top-weighted KPIs, which were in descending order: *Safety/Cost/Time/Quality performance*, *Client's*

Table 1: Studies developing and implementing Performance Measurement Frameworks and KPIs for construction projects

Author(s) (Year)	Approach	Theoretical framework adopted	Project type	Implemented methodology	Life Cycle phases involved	Sustainability focus	Framework Notions			
							Dimensions/ Perspectives	Performance Criteria	Performance Indicators	
Chan, Scott & Lam (2002)	conceptual	multi-dimensional KPI	Design & Build	• literature – bibliography survey	•Design •Execution •Operation	• Social • Environmental	• Past: pre-construction • Present: construction • Future: post-construction	•Objective Time, Cost, Health & Safety, Profitabil. •Subjective Quality, Technical performance, Functionality, Productivity, Participants Satisfaction, Environm. sustainability	•Time/Cost overrun •Unit cost •Conformance degree to standards/technical specifications	•Construction time/speed •Injury/Accident rate •Total net revenue–Total cost •Resource input÷Given task •Sound/Air level
Cox, Issa & Ahrens (2003)	empirical	KPI	general construction	•literature review •questionnaire survey	•Design •Execution	• Economical • Social	-	-	•Quality control •Cost •Safety	•On-time completion •Cost÷Unit •Unit÷Man-hour
Chan & Chan (2004)	conceptual	KPI	general construction	• literature review • survey analysis	•Execution •Operation	• Social • Environmental	-	•Objective Time, Cost, Value & Profit, Health & Safety, Environmental Performance •Subjective Quality, Functionality, User expectation /satisfaction, Participants' Satisfaction	•Construction time/speed •Net Present Value •Environmental Impact Assessment score •Conformance degree to technical specifications	•Time variation •Unit cost • Per cent NETVAR •Accident rate •Number of complains •Participants satisfaction level
Yeung, Chan, Chan & Li (2007/2009)	empirical	KPI	partnering relationship-based	• conceptual KPI framework • Delphi survey technique with construction experts	•Execution •Operation	• Economical • Social	-	-	•Time/Cost performance •Trust & respect •Safety Performance •Innovation & improvements	•Top management commitment •Quality performance •Effective communications •Client's satisfaction
Li (2010)	conceptual	BSC KPI	international engineering	• literature – bibliography survey • SMART principles	•Execution •Operation	• Economical • Social • Environmental	• Finance • Customer satisfactory degree • Inner-business process • Study & Growth	-	•Profit potentiality •Finance stability •Government & public satisfactory degree •Internal communication & cooperation	•Finance operating conditions •Owners satisfactory degree •Quality/Progress/Cost control •Staff case •Project's innovative capability •Knowledge management
Cha &Kim (2011)	empirical	KPI	residential buildings	• literature review • interviews with selected experts • case studies	•Execution	•Social •Environmental	-	• Cost • Time • Quality • Safety • Environment • Productivity	•Defect frequency •Rework rate/frequency •Time savings •Safety to Cost ratio •Safety education •Site dangerousness	•Cost efficiency/effectiveness •Construction cost predictab. •Schedule efficiency/predictab. •Non-conform./Accident rate •Constr. waste/Recycling rate •Management/Labor productiv.
Ikediashi, Mendie, Achuenu & Oladokun (2012)	empirical	KPI	Design & Build	• literature review • questionnaire survey	•Design •Execution	• Economical • Social	-	-	•Job cost reporting •Quality of work •Resource management •Rework÷Quality control	•Time overrun •Health & Safety •Cost÷Unit •Motivation
Yeung, Chan, Chan, Chiang & Yang (2013)	empirical	KPI	general construction	• literature review • questionnaire survey • RIM weighting assessment	• Inception • Design • Execution • Operation	• Social • Environmental	-	-	•Safety/Cost performance •Planning effectiveness •Functionality	•Time/Quality performance •Client's/End users satisfaction •Communication effectiveness •Environmental performance
Langston (2013)	conceptual	KPI	general construction	• PMBOK knowledge areas • theoretical tetrahedron model	• Design • Execution • Operation	• Social • Environmental	-	• Scope • Cost • Time • Risk	•Value •Speed •Complexity	•Efficiency •Innovation •Impact
Maya (2016)	conceptual	BSC KPI	building	• previously developed model • application in a number of building projects	•Execution	• Economical • Social	• Financial • Customer • Internal process • Learning & growth	-	•Profitability •External/Internal customer satisfaction •Planning effectiveness	•Cumulative profit •Productivity •Human resource management •Human resource development

satisfaction, Effectiveness of communication, End-user's satisfaction, Planning effectiveness, Functionality and *Environmental performance*. They finally compiled a Composite PI to serve as a tool for evaluating and improving construction projects' performance at different stages of the project LC, namely the pre-planning, planning, designing, construction and commissioning phases.

Langston (2013) attempted to develop a 3-D project performance integration model, at different LC stages, including the 10 existing PMBOK's knowledge areas and advancing an 11th one of environmental management, to upgrade the importance of sustainability. Comprising four core project constrains (scope, cost, time and risk), suitable for objective measurement, he proposed six primary, generic KPIs integrated in a framework in the form of a tetrahedron, where the base reflected the classical "Iron Triangle" and the apex represented risk. The four constraints were placed in the four vertices of the tetrahedron and the six KPIs were represented by the edges of the model, expressing the relationships between the constraints. The proposed KPIs were defined as *Value, Efficiency, Speed, Innovation, Complexity and Impact* and could be measured as ratios of the four constraints, while an overall KPI in the form of a project success index was also derived. Although the proposed model was considered relevant to any project type, Langston demonstrated its application by an example of a hypothetical residential/infrastructure project.

Maya (2016) examined the application of a balanced and integrated PMS in order to serve as a tool to measure and manage Syrian construction projects performance, selecting BSC as a framework and utilizing a number of performance goals and a balanced set of indicators, focused not only on results but also on processes. Depending on a previously developed BSC model, in order to use indicators suitable for the building environment in Syria, and reserving the proposed strategy map of the model, she ended up with 8 final KPIs: *Profitability, Cumulative profit, External/Internal customer satisfaction, Productivity, Planning effectiveness* and *Human resource management/development.* The BSC Designer Software was employed as a MIS for performance measurement and management, aiming to support the application of all the BSC's elements, such as objectives, measures, goals and initiatives. To demonstrate a comprehensive application of the proposed model, the largest construction company and main contractor for public Syrian construction projects was selected as a research case study, while four building projects, under construction at that time, were chosen as a sample among the company's projects.

The context and the characteristics of the previously reviewed studies are summarized in Table 1.

4. Comparison of reported studies and discussion

Table 1 reports the basic features of each study and more specifically the approach followed, the adopted theoretical framework, the construction project type, the implemented methodology, the project's LC phases involved and the emphasized sustainability areas. The table also presents the main structure of the framework developed in each study, namely dimensions or perspectives implemented, performance criteria included and the proposed performance indicators. In terms of approach, the studies reviewed are as much conceptual as empirical, referring mostly to general construction or building projects. The selected KPIs basically originated from literature review, combined in some cases with questionnaire surveys with construction experts, implementing techniques like the Delphi method to address weights.

LC analysis of the presented studies suggests that PM in construction projects is drifting from the narrow limits of the Execution phase, representing the construction itself, and is gradually extending to the Design and Operation phases as well. Nevertheless, the majority of the studies seem not to examine the entire LC of a construction project, from Inception to Demolition. Regarding the sustainability aspects emphasized, the social dimension of the "triple bottom line" is the one distinctly appearing in all the reviewed studies, basically expressed with KPIs measuring users', or public in general, satisfaction level. Economical or environmental dimensions are alternately addressed in different studies through relevant indicators of financial viability or environmental impact. However, very few studies appear to deal equally with all three sustainability dimensions.

The previously reviewed studies manifest that recent trends in construction projects' PM, as well as the related KPIs proposed, involve in a much higher level, on the one hand LC analysis and on the other sustainability-focused criteria and indicators. Such trends represent the consideration of sustainability principles and the increasing need to develop KPIs as tools to integrate sustainability criteria into the management of construction projects. Conclusively, modern PMSs developed for construction projects can be considered as holistic approaches in performance evaluation, including the above features.

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