THE POTENTIAL VALUE of 4D PLANNING IN UK CONSTRUCTION INDUSTRY

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ABSTRACT

Performance measurement has received considerate attention by both academic researchers and industry over a past number of years. Researchers have considered time, cost and quality as the predominant criteria for measuring the project performances. In response to *Latham (1994)* and *Egan reports (1998)* and to improve the performance of construction processes, the UK construction industry has identified a set of non financial KPIs. There is an increase utilisation of IT based planning in the construction industry and in particular 4D (3D+time). Literature review has revealed that there is an inadequacy of a systematic measurement of the value of such systems at both quantitative and qualitative levels. The aim of this ongoing research is to develop a systematic measurement framework for 4D based key performance indicators. Two major issues have been addressed in the research: the absence of a standardised set of 4D based KPIs and the lack of existing data for performance evaluation were addressed in this research. In this context, the objective of this paper is to establish the benefits of 4D planning through identifying and ranking a set of KPIs established on the basis of semi-structured interviews conducted with UK project managers. The ultimate objective of the research is to deliver an industry based 4D performance measures and to identify how project performance can be improved by the utilisation of 4D planning.

KEY WORDS

4D planning, Information technology, Performance measurement, Value, Visualisation

INTRODUCTION

This study is a collaborative research project between Centre for Construction Innovation & Research at the University of Teesside and Architectural3D. The aim of the study is deliver an industry based 4D performance measures and to identify how project performance can be improved by the utilisation of 4D planning.

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The industry based KPIs that were developed by the DTI sponsored construction best practice program are too generic and do not reflect the value of deploying IT system for construction planning and in particularly 4D planning. The objective of this research study is to overcome the presence of a generalised set of KPIs by developing a set of 4D based KPIs at project level for the industry. Information Technologies and their applications are proceeding at a pace and their influence on working practice can be noticed in almost every aspect of the industry. The potential of IT applications is significant in terms of improving organisation performance, management practices, communication, and overall productivity. 4D planning allows project planners to visualise and rehearse construction progress in 3D at any time during the construction process. According to *Dawood et al. (2002,* using 4D planning, participants in the project can effectively visualise and analyse the problems considering the sequencing of space and temporal aspects of the construction time schedule. The thrust for improved planning efficiency and visualisation methodology has resulted into the development of 4D planning. The Construction Industry Institute (CII) conducted research in the use of three-dimensional computer models on the industrial process and commercial power sector of AEC from 1993 to 1995 (*Griffis et al., 1995*). Major conclusions of the CII research is that the benefits of using a 3D technology include reduction in interference problems; improve visualisation; reduction in rework; enhancement in engineering accuracy and improve jobsite communications. *Songer (1998)* carried out a study to establish the benefits and appropriate application of 3D CAD for scheduling construction projects. The study focuses on the impact of 2D and 3D on the project schedule review. The above two studies lack well-established metrics that would allow the quantification of 3D CAD and 4D planning. This will ultimately lead to the required benefits of 3D and 4D over existing processes. In the absence of well defined measures at the project level, the priority of this research project is to establish a set of 4D based key performance indicators. This is of particular interest in the industry as any investment in advanced technologies needs to be fully justified.

The remainder of the paper discuss the research methodology adopted and research findings.

RESEARCH METHODOLOGY

This research has followed a well defined methodology for the identification and quantification of 4D KPIs based measures. The methodology compromises three interrelated phases:

- identify performance measures through literature review and authors experience in the application of 4D;
- conduct semi-structured interviews with project managers and planners to further identify the measures and their priorities.
- identify and collection data needed to quantify the measures and identify methods for continuous measurement as site operation progresses.

Three major construction projects in London (currently under construction and use 4D planning with a combined value of £230,000,000) were selected for study and data collection. Project managers and construction planners from the three projects were selected for interviews to further identify 4D KPIs and their priorities. Semi-structured interviews techniques were used to elicit information and knowledge from the project managers and construction planners. The Semi-structured interviews use a methodological procedure known as the Delphi technique for data collection. This technique is ideal for modelling real world phenomena that involve a range of viewpoints and for which there is little established quantitative evidence. The Delphi technique is therefore highly appropriate to the definition and subsequent ranking of a set of performance measures that can be mutually acceptable *(Hinks & McNay 1999)*. The next section of the paper describes the process of identification of KPIs on the basis of semi-structured interviews conducted with project managers. The subsequent section describes the research findings and ranking of identified 4D KPIs and future research activities.

Identification & Selection of KPIs

A study of the literature was conducted to develop a list of key performance measures. The development of the performance measure list has taken account of the performance measurement characterised by Rethinking Construction, the construction best practice program has launched the industry wide KPI for measuring the performance of construction companies *(CBPP-KPI-2004)*. The Construction Best Practice Program has identified a framework for establishing a comprehensive measurement system within both organisation and project level. Other literature sources include *Kaplan & Norton (1992), Li. et.al (2000), Chan et.al (2002), Cox et.al, (2003), Robert. et.al (2003), Albert & Ada (2004) and Bassioni et.al (2004)* and the authors knowledge in the construction industry for identifying other key performance indicators were also used. Once a list was complied the next task was to contact project managers and construction planners from the three construction projects and invite them for interviews.

The first task for the interviewees was to identify and select a set of key performance indicators and order them into a priority. The second task was to identify information needed to quantify each measure. Their input was considered to be critical in the success of this research. The concept behind conducting semi-structured interviews was to understand how mangers and planners perceive the measures and to identify practical performance measure that can be used to measure the value of 4D planning. The interview included both open and closed questions to gain a broad perspective on actual and perceived benefits of 4D planning. A due consideration has been given to the sources from where data has to be collected in a quantitative or qualitative way. So far eight semi-structured interviews have been conducted with senior construction planners.

Findings and Ranking of KPIs

Interviewees were asked to rank the identified KPIs. The ranking of the KPIs was done using a scaling technique. For the prioritisation process, each KPI can be graded on a scale of 1 to 4 (where 1= Not important, 2 = fairly important, 3 = Important and 4 = Very important) to measure its level of importance. The benefits of 4D planning will be quantified on the basis of prioritised KPIs. The measures will be further classified in Qualitative terms (rating on a scale) and Quantitative terms (measurement units) to have a detailed understanding of the cause and effect relationship. Table 1 gives the initial results of the analysis of the interviews related to ranking the measures. As can be seen in table 1, time and safety soured very high compared to other measures.

Table 1: Ranking of performance measures

KPIs	Ranking Score In Percentage (%)	Rank
Time	94 %	1
Safety	92 %	2
Communication	82 %	3
Cost	80 %	4
Planning Efficiency	70 %	5
Client Satisfaction	65 %	6
Team Performance	62 %	7
Productivity Performance	60 %	8
Quality	52 %	9

The list of 4D based KPIs and ways to measure them is given in table 2. Table 2 shows the 4D based KPIs in a priority list, the index in which each measure need to be quantified, ie for 'time' we propose to use 'Schedule Performance Index' and stages of the construction process in which the identified KPIs is most relevant. For example, 'Safety' has been considered a very important measure at 92% ranking score and the information needed to measure 'Safety Index' is: Number of accidents per 1000 man hrs worked and time lost in accidents per 1000 man hrs worked. Table 3 gives definition of the identified measures.

Table 2: 4D based KPIs in order of priority

Ranking	KPIs	Index	Performance Measures	Stages of Construction
1	Time	Schedule Performance Index	(i) Schedule Performance	Pre-construction and Construction
2	Safety	Safety Index	(i) Number of accidents per 1000 man hrs worked (ii) Time lost in accidents per 1000 man hrs worked	Construction
3	Communication	Communication Index	(i) Number of meeting per week (ii) Time spent on meetings per week	Pre-construction & Construction
4	Cost	Cost Performance Index	(i) Cost Performance	Pre-construction and Construction
5	Planning Efficiency	Hit Rate Index	(i) Percentage of activities completed per week (ii) Number of milestones delivered	Construction
6	Client Satisfaction	Satisfaction Index	Qualitative measure (Scale 1-5)	Pre-construction & Construction
7	Team Performance	Team Performance Index	Qualitative measure (Scale 1-5)	
8	Productivity Performance	Productivity Index	(i) Tonnes of Concrete used per day / m^3 (ii) Tonnes of Steel used per day/m^3 (iii) Number of piles driven per day (iv) Number of pile caps fixed / day	Construction
9	Quality	Rework Index	(i) Number of changes (ii) Number of error (iii) Number of corrections (iv) Number of request for information generated (v) Non-Programme activities (vi) Number of claims (vii) Number of process clashes spotted due to sequencing of activities	Pre-construction
			(i) Number of changes (ii) Number of error (iii) Number of corrections (iv) Number of request for information generated (v) Non-Programme activities (vi) Number of claims (vii) Number of process clashes spotted due to sequencing of activities	Construction

The analysis of semi-structured interviews has identified following 4D based KPIs:

Table 3: Definition of the identified measures

Measure	Definition
Time	It can be defined as percentage number of times projects is delivered on / ahead of schedule. The timely completion of project measures performance according to schedule duration and is often incorporated to better understand the current construction performance. Schedule performance index (Earned value Approach) has been identified to monitor the performance of schedule variance.
Safety	It can be defined as a measure of the effectiveness of safety policy and training of the personnel engaged in activities carried out on site. Safety is a major concern for every construction company, regardless of the type of work performed. Safety is measured quantitatively through Time lost as a result of accidents per 1000 man hrs worked, Number of accidents per 1000 man hrs worked.
Communication	Information exchange between members using the prescribed manner and terminology. The use of a 4D interface allows the project team to explore the schedule alternatives easily and assist in deploying 4D approach. Communication can be quantified in terms of number of meetings per week and time spent on meetings (Hrs) per week.
Cost	Percentage number of times projects is delivered on/under budget. Cost performance index (Earned value Approach) has been identified to monitor the performance of cost variance.
Planning Efficiency	It represents the percentage progress of construction activities scheduled to be performed on a weekly basis. It is measured as number of planned activities completed divided by the total activities planned to determine the project progress on a weekly basis.
Client satisfaction	Client satisfaction can be defined as how satisfied the client was with the finished product/facility. Usually measured weekly/monthly or shortly after completion and handover.
Team Performance	Ability to direct and co-ordinate the activities of other team members in terms of their performance, tasks, motivation and the creation of a positive environment.
Productivity Performance	This method measures the number of completed units put in place per individual man-hour of work. Some of the identified productivity performance measures are; number of piles driven/day, number of piles caps fixed / day, tonnes of steel used / day and tonnes of concrete used / day.
Quality	Quality has been represented here in terms of rework. Rework can be defined as the activities that have to be done more than once in the project or activities which remove work previously done as a part of the project.

	By reducing the amount of rework in the pre-construction and construction stages, the profits associated with the specific task can be increased. Rework can be represented in terms of number of changes, number of error, number of corrections number of request for information to be generated, non-Programme activities, number of claims and number of process clashes spotted due to sequencing of activities.

Future Research Activities

This paper report on the first stage of the research project. The current and future research activities will include:

- continue the interview process to further confirm the 4D KPIs and methods of data collection
- establish a methodology for continuous and incessant data collection and calculation of the KPI indices for the three identified construction projects.
- compare the KPIs indices above with industry norm and identify what are the improvements or otherwise in the construction processes that can be resulted or for using 4D planning.
- Identify specification for 4D planning in which all the supply chain can actively engaged in the development and updating of construction schedules. Current practices of using 4D planning identified through the interviews suggest that there are varying views between the trade contractors and the main contractors. The main trade contractors' concern is that there is no confirmed value of using 4D over their own planning system and the detailed information in which 4D planning needs might not be available or very costly to and time consuming to collate it.

Conclusions

There are many benefits from the use of 4D planning tool. However, there is very little quantification of the benefits done. The evaluation of 4D planning in the construction management literature has not been addressed seriously from a performance basis. The evaluation and justification of 4D planning is crucial to promote the value embedded in it. The study has developed five key performance indicators consistently perceived as being highly significant at project level are: Time, Safety, Communication, Cost, and Planning Efficiency.

It is often said that "you can't effectively manage what you do, if you don't measure it". The quantification of 4D value proposition will convince the clients to invest in and implement the emerging 4D planning technology. Therefore industry will gain in an improved understanding of the capabilities of 4D as an efficient planning tool.

References

Al-Meshekeh, H.S., and Langford, D.A. (1999). "Conflict management and construction project effectiveness: A review of the literature and development of a theoretical framework." *J. Construction. Procurement.,* 5(1) PP.58-75.

Albert, P.C.C. and Ada P.L.C. (2004). "Key Performance Indicators for Measuring Construction Success." Benchmarking: *An International Journal,* vol.11, No.2, pp. 203-221.

Bassioni, A.H., Price, A.D.f., and Hassan, T.M (2004). "Performance Measurement in Construction." *Journal of Management in Engineering***,** vol. 20, No. 2, pp 42-50.

Chan, A.P.C. (1996*). "Determining of project success in the construction industry of Hong Kong."* PhD thesis, University of South Australia, Australia.

Chan, A.P.C., David, S. and Edmond, W.M.L. (2002). "Framework of Success Criteria for Design/Build Projects" *Journal of Management In Engineering*, Vol. 18, No 3, PP 120-128.

Construction Best Practice Program- *Key Performance Indicators* (CBPP-KPI-2004), (available at http://www.dti.gov.uk/construction/kpi/index.htm

Dawood N., Eknarin S., Zaki M., and Hobbs, B. "4D Visualisation Development: Real Life Case Studies." Centre for Construction Innovation & Research, University of Teesside, Middlesbrough, UK.

Egan, J. Sir (1998). *Rethinking Construction*: *The Report of the Construction Task Force to the Deputy Prime Minister.* Department of the Environment, Transport and the Regions, Norwich.

Griffs, Hogan., and Lee. "An Analysis of the Impacts of Using Three-Dimensional Computer Models in The Management of Construction." Construction Industry Institute. *Research Report* 106-11, September 1995.

Hinks, J. and McNay (1999). "The creation of a management-by-variance tool for facilities management performance assessment." *Management Facilities,* vol.17, No. 1-2, pp. 31-53.

Kaplan, R.S. and Norton, D.P. (1992). The Balanced Scorecard -- Measures that Drive Performance. *Harvard Business Review*, Vol. 70, No. 1: 47-54

Latham, M. Sir (1994). *Constructing the Team: Final Report of the Government/Industry Review of Prcurement and Contractual Arrangements in the UK Construction Industry.* HMSO, London.

Li. Heng., Irani. Zahir., and Love, P. (2000). "The IT Performance Evaluation in the Construction Industry." Proceedings of the 33rd Hawaii International Conference on System Science.

Naoum, S. G. (1994). "Critical analysis of time and cost of management and traditional contracts." *J. Construction Management*, 120(4), 687-705.

Robert, F.C., Raja, R.A., and Dar, A. (2002) "Management's Perception of Key Performance Indicators for Construction." *Journal of Construction Engineering & Management,* vol. 129, No.2, pp. 142-151.

Songer, A. (1998). "Emerging Technologies in Construction: Integrated Information Processes for the 21st Century." *Technical Report,* Colorado Advanced Software Institute, Colorado State University, Fort Collins, CO 80523-1 873.

Yin, R. K, *"Case study research design and method."* 2nd edition, Sage publication Inc, CA 1994.