PROJECT COST PERFORMANCE FORECASTING SYSTEM

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Abstract: Forecasting project cost performance is a paramount important to the project controls process in construction industry. In making profits, today's construction organization requires an ability to predict, well ahead of time, project performance. Thus, necessary and timely corrective actions need to be taken if project lagged of time or exceed budget. As a consequence, there have been many studies on this aspect which develop theories and methods to improve the forecasting system. Through a critical review of forecasting method approaches, a number of issues are highlighted that concern of the types of forecasting approach, forecasting project cost performance at completion, cost variances in project performance, other critical parameters of project performance to be incorporated along with cost and ineffective methods in generating reliable and timely results and therefore providing early warning of cost performance overruns. Also, it provides fundamental for forecasting system designed for adaptability in a challenging environment and focused throughout on the delivering successful project.

Keywords: Construction, Project Cost Performance, Forecasting.

1. INTRODUCTION

Forecasting performance is one of the most challenging tasks in predicting whether the project will be successful. In turn, this will depend on the ability of the project manager to predict, well ahead of time. In attempting to establish the reliable forecasting system, it is required to develop a forecasting tools which capable in dealing with variability existing in construction operations. As such, this has still been a burden to project manager to determine the accurate data as early as possible where the primary important of forecasting system is, it should be able to predict variance data at any future time and at completion and thus provide an early warning of performance overruns. Often, project variables differ from time to time throughout the construction operation which usually unacceptable to most stakeholder. Thus, a reliable forecasting system should provide project manager an accurate, unbiased, timely and stable system. In essence, however, accurate project performance forecasts are difficult to produce when considering the impact of some factors such as material delays, scope deviation, poor productivity, unforeseen scope changes, and adverse weather conditions. Most of the current systems are not designed to incorporate this input in the form of a judgmental input from the user and consequently could lead to inaccurate results.

The aim of this paper is thus to provide a critical summary of the status of forecasting system, highlighting the implications of the state-of-the-art for both research and practice. Consequently, key issues that have driven the development of the theoretical approaches are reviewed alongside the practical difficulties that arise when attempting to apply forecasting system in practice.

The paper begins by synthesizing the perceptions that surround forecasting system in order to state the fundamental goals of the approach. These goals provide a basis for assessing the development in forecasting standards, which are then, can be used as a datum for future research purpose. A detailed critical analysis of forecasting system is also presented and a number of issues highlighted that concern (a) the types of forecasting approach, (b) forecasting project cost performance at completion (c) cost variances in project performance

(d) other critical parameters of project performance to be incorporated along with cost, (e) ineffective methods in generating reliable and timely results and therefore providing early warning of performance overruns. Lastly, the paper concludes by presenting coherent recommendations on how forecasting management system can best be used in practice.

2. AN OVERVIEW ON FORECASTING SYSTEM IN CONSTRUCTION INDUSTRY

The nature of construction industry is to be profitable in extremely competitive environment. More specifically, the construction environment is continuously changing and resulted to uncertain variable in project data. As a consequence, Project Manager faced with performance problem in determining the accurate project performance. In attempting to gain better profits, Project Manager needs to make timely and informed decision. However, today's deficiencies in monitoring and control of project operation unable Project Manager to manage project effectively and resulted to major cause of project failure.

When controlling project performance, Project Manager should not only monitor cost and time variances for actual project progress, but also to properly establish the actual project status based on objective predictions of final project performance. At completion project performance can be predicted by comparing estimates of planned total budget and final duration with their respective most likely forecasted values (Ahuja et al. 1994). This, however, are necessary for Project Manager to determine if corrective actions are required to minimize the expected variances from planned performance Thus, forecasting is needed to predict the project performance at completion based on current performance.

2.1 Significance of Project Forecasting in the Construction Industry

In reality, the original estimates may be considered the first project forecast and, at the point of project completion, the latest updated estimate (last forecast) and the actual amount of what is being expended should be the same (Ward and Lithfields 1980). In controlling a construction project, Project Manager should understand the importance of using project baselines which serves as a benchmark. This is to ensure the project is running smoothly and early indication on deficiencies of project can be identified. Thus, necessary corrective action can be made in due time.

In current practice, project baselines or planned S-Curves is used to determine variances in cost or schedule and to measure the earned value. In this context, it explains why this method is widely used in construction industry to measure the performance of projects. One of the advantages of this method is that it can identify any cost and schedule variances at the end of the project. However, there is still lacked within this method of providing corrective action plans if negative variances is identified. Therefore, the needs of forecasting performance variances at completion is necessary to Project Manager in order to decide the suitable corrective action plans and the effect on final project performance.

3.0 AN OVERVIEW ON PREVIOUS RESEARCH

In investigating the requirements for an effective forecasting system, a detailed critical analysis of literature review on the significant topic is conducted. Some important issues related to the accuracy and early prediction of final project status is discussed. As such, many research efforts were made to develop methods to forecast project status at completion. Most of the developments were focused specifically on predicting estimate at completion and duration at completion. The paper has noted that few methods in the literature were undertaken to develop such forecasting system, namely that: (1) Earned value methods, (2) Deterministic methods, (3) Stochastic and probabilistic methods, (4) Advanced computing

methods, (5) Methods based on artificial intelligence and fuzzy logic and (6)Method based on behavioral theories and judgmental forecasting.

3.1 EARNED-VALUE BASED METHODS

Earned value is a method for managing projects based on the regular comparison of actual project costs to planned cost and to completed work. This method analyse completed works to determine the cost to date and compare with the revenue to date. The advantage of this method is where corrective action can be implemented at early stage if the figures are found not promising to deliver successful project. These forecasting techniques, based on linear trend analysis, are very popular in the industry and are being used by many construction organizations. Indeed, the forecasting techniques employed in current project management systems, such as Primavera and Artemis applying simple regression analysis to forecast cost and schedule performance. Previous study on earned value based method is briefly discussed as follows:

Seiler (1983) recommended forecast techniques for predicting cost and schedule performance. The estimate at completion is assumed to be the same level of cost efficiency experienced to-date continues in the future. The study argues that at later stages of progress the future cost and schedule performance efficiency need to be modified based upon known conditions being experimented by the project. He suggested modifying the CPI and/or the SPI by estimating a line of "best fit" through the monthly data points on the trend line.;

Eldin and Hughes (1992) presented a detailed discussion of the use of unit costs to forecast the final cost. The study stated that an accurate forecast of final cost is based on applying unit costs to quantities using two approaches. The first approach is using the cumulative to-date unit cost to estimate future unit costs. The second approach is assuming that the current-period unit cost is the best available estimate for future unit costs; **Christensen et. al. (1992) and Christensen et al. (1995)** provided a comprehensive review of 25 studies that dealt with estimate at completion (EAC) formulas and models. The EAC formulas were classified into three categories: index, regression, and other (e.g. formulas based on heuristics). The study briefly reviewed comparative and non-comparative EAC research conducted over a period of sixteen years and made the following conclusions: (1) the study showed that no one formula or model is always best. Attempting to generalize from a large and diverse set of EAC formulas is dangerous, (2) the study did not establish the accuracy of regression-based models over index-based formulas. Additional research with regression models is needed, (3) the study concluded that the accuracy of index-based formulas is a function of the system, and the stage and phase of the project. In addition, averaging over short periods (e.g., 3 months) is more accurate than averaging over longer periods (e.g., 6-12 months), especially during the mid stage of the project when costs are often accelerating;

Brown (1996) slightly modified the EAC proposed in **Christensen et. al. (1992)** to correct for variance in future cost performance rates by introducing Forecasted Cost Performance Index for the remainder of the budgeted work to be performed; **Fleming and Koppelman (1994)** proposed a constant budget model. The model assumes that all cost overruns can be absorbed through corrective action by the project end date and that the final cost will be equal to the original budget. The major drawback is that the assumption implied by the model could apply to a very small number of projects and in most cases the actual cost at completion will differ from the budgeted cost; **Shtub et al. (1994)** developed the constant performance efficiency model, which assumed that the cumulative cost and schedule performance indices (CPI and SPI) remain unchanged or constant throughout the remaining project duration. Fleming and Koppelman (1999) and Zwikael et al. (2000) suggested that this model is better that the other earned-value based models;

Al-Tabtabai (1996) forecasted the performance at completion by considering eight influencing factors to impact the project performance index. The factors are performance of

management, cash flow situation, material and equipment availability, labour availability and productivity, weather and other environment influences, amount of rework, extra-work, and work difficulty, percentage of work completed, past project's performance trend. Since the index contains many subjective factors, its accuracy is highly dependent the quality of judgments and the ability to capture project specific data. This limitation can be overcome to a certain extent by selecting well-experienced professionals in the construction industry as domain experts for knowledge representation;

Fleming and Koppelman (1999) proposed the schedule performance efficiency model that assumed that the forecasted final cost (EAC) is a function of both the Cost Performance Index (CPI), and the Schedule Performance Index (SPI). However, research carried out by Zwikael et al. (2000) showed that this model is inferior to the model where EAC is function of the CPI only.

Anbari (2003) proposed three (3) different scenarios in developing EAC as follows:

- when current analysis shows that the assumption underlying the original estimate are flawed, or no longer applicable due to changed conditions affecting the activity, work package, or project;
- when current analysis shows that past performance is not a good prediction of future performance; and
- when current analysis shows that past performance is a good predictor of future performance.

3.2 Deterministic Methods

The deterministic approach estimates cost and schedule using the most likely values. More specifically, it has been found from literature that deterministic methods are more commonly used by construction organizations because they are based on simpler models (Crandall & Woolery, 1982). Many of the deterministic forecasting methods use performance trend analysis.

Teicholz (1993) proposed a method that uses the sliding moving average (SMA) and to-date cost data to forecast the final cost of a construction project. The proposed method was compared to two existing methods and was found to be superior in terms of accuracy, timeliness, and consistency. The limitation of this research is that the results that were derived from the analysis of projects performed by a single construction company. In addition, the proposed method forecasted cost only without considering other performance parameters or linking cost data to schedule data.

Wheelwright (1995) evaluated various subjective and deterministic mathematical methods and concluded that there is no single deterministic forecasting method that is accurate and superior for all projects and under all circumstances. However, the study stated that some simple techniques, such as the moving average, might produce better forecasts than complicated techniques. **Dawood and Molson (1997)** developed specifications for a strategy that forecasts construction costs through integration of cost indices forecasts and construction plans. The forecasting module predicts the cost indices for six quarters ahead and uses various forecasting techniques like: Simple Moving Average, Single Exponential Smoothing, Exponential Smoothing and Decomposition Method. It was concluded that the Decomposition technique has produced better results compared to other techniques and it is capable to handle judgmental feedback to tune the final forecasting figures. Cost forecasting in this research is limited to predicting future expenditures at early stages of project design and before construction starts.

3.3 Stochastic and Probabilistic Methods

The probabilistic approach assumes variability of cost and duration of activities.
Farghal and Everett (1997) used learning curves to predict the time or cost to complete the remaining cycles of the work in progress. A learning curve is generated by plotting the hours or cost required to complete one cycle as a function of the cycle number. The study used historical data for 60 construction activities from several published sources. Compared to other standard cost forecasting methods using linear projection of to-date actual costs (where estimate to complete is derived by multiplying the unit cost to-date by the remaining quantity), the proposed learning curve method is shown to be more accurate. The proposed method is only applicable to predict future performance of repetitive activities where learning effects are present.

Barraza et at. (2004) studied a new methodology; using the concept of stochastic S curves (SS). This method enables Project Manager to forecast the at-completion project cost and schedule performance as well as at each 10% increment of project progress. The principle objective of this method is using simulation approach to generate the stochastic S curves based on the variability in cost and duration of activities. The method enable one possible S-curve be generated for each simulation iteration. Distributions of possible values of at-completion budgeted cost and at-completion schedule duration can be analysed at 100% progress. Using the simulation method, stochastic S-curves providing cost and time distributions can be obtained at any percent of work performed. The key objective of this method is to estimate at-completion performance variations in order to obtain the need for corrective action.

3.4 Advanced Computing Methods

Al-Tabtabai (1998) developed a framework called PAFEX (Performance Analysis and Forecasting Expert System). The framework consists of two (2) modules; first module is a diagnostic expert system to analyse the project performance; second modules deals with forecasting project performance by adopting artificial neural network. The system attempted to forecast construction performance in terms of cost and schedule using artificial neural networks and introduced the application of expert systems to represent the forecasting process of a construction project manager expert. The expert knowledge was acquired by interviewing a group of scheduling experts. The experts were asked to identify factors that could impact the cost and schedule performance at the completion of the project.

Isidore and Back (2002) integrated range estimating and probabilistic scheduling techniques through the development of a new procedure called the multiple simulation analysis technique (MSAT). It was developed to analytically quantify the complex interactions between the probabilistic cost and schedule data such that high confidence values for both parameters could be selected. The study indicated that choosing a schedule value with a high confidence level does not guarantee that the associated cost estimate, corresponding to the selected schedule value, will also have the same level of high confidence. (MSAT) combines discrete event simulation, regression analysis, and numerical analysis in order to model the relationship between the stochastic cost estimate and schedule data. The model will allow decision-makers to select highly probable schedule and cost estimates thus leading to accurate and reliable forecasts.

3.5 Methods using Artificial Intelligence, Expert Systems and Fuzzy Logic

Nay and Logcher (1986) presented an artificial intelligence (AI) system that forecasts time and cost variances at the work package level. **Boussabine and Elhag (1999)** developed a subjective model to predict cash flow at the project level. Statistical results from 30 case

studies were used to develop the fuzzy membership functions for each evaluation period. Three linguistic terms: "Low", "Medium", and "High" were used and to describe the scope of each evaluation period. The current cash flow status was described in terms of "Pessimistic", "Moderately Optimistic", and "Optimistic".

Ng et.al. (2001) established a computer based model that has a cash flow forecasting ability. The model was developed into a program that can be used to predict future trend of cash flows in a projects. In this study, the internal rate of return (IRR) and capital requirement are used to indicate the performance of cash flow. It is stated by the author that the results from actual data showed that the model gives a good prediction of IRR and capital requirement of projects.

Knight and Fayek (2002) proposed a fuzzy logic model to predict cost overruns/under runs in engineering design projects and consequently forecast profit. Fuzzy binary relation was used to model the relation between thirteen project characteristics and eight risk events on one hand, and the cost overruns resulting from any combination of project characteristics and risk events on the other hand.

Skitmore et. al. (2003) established a forecast model for actual construction time and cost prediction. This study was conducted with 93 Australian construction projects actual data. In order to develop the model, forward crossvalidation regression analysis were used and several factors were identified i.e. client sector, contractor selection method, contractual arrangement, project type, contract period and contract sum. The model provide practical tools for clients and contractors to predict the actual construction time and cost based on the risk and uncertainties of different client sector, contractor selection method, contractual arrangement and project type.

Li (2004) developed an indicator-based fuzzy forecasting method to forecast the project cost and duration at completion as well as at interim future points. The method utilized the fuzzy inference process and the principle of GMP (Generalized Modus Ponens) type reasoning. The model used thirteen terminal indicators as input variables to predict future cost values. Two performance indicators were utilized to predict the project duration of a control object. The developed system could generate reports at three levels: project, control-object, and individual resource.

3.6 Methods based on Behavioral Theories and Judgmental Forecasting

Hill (1970) introduced a set of judgmental forecasting techniques like the Delphi technique. The Delphi technique is a means for elicitation of opinion in order to obtain response from a group of experts. It uses the rule that "several heads are better than one". The deficiencies in judgmental forecasting have been widely criticized. In most cases, such forecasting is carried out in a naive fashion and the results are often quite unreliable.

Diekmann and Al-Tabtabai (1992) introduced the social-judgment theory approach to forecast project performance. This new approach uses judgment, rather than purely mathematical methods, and is concerned with building a model of the cognitive system to predict the future based on a set of information (cues). The social-judgment method uses multiple regressions to represent the person's judgment as the dependent variable and the values of the cues as the independent variables. The judgmental analysis was applied to the forecasting of project cost and schedule performance at the construction work package level. Forecasts of judgments were developed for the following types of variances quantity-usage variance, labor-productivity variance, labor wage-rate variance, materials price-rate variance, equipment cost variance and work-package schedule variance. What differentiates this method from the earned-value based techniques is its way of predicting the future by not only considering the current status but also other factors that might impact the future outcomes. The major disadvantage is that it is heavily dependent on the judgment and expertise of the

project managers. If the input information were not reliable, the model would not produce satisfactory results.

3.7 Miscellaneous Methods

Khosrowshahi (1988) developed a mathematical model for use by the client and the contractor to forecast the project costs and revenue. The model is capable of generating a satisfactory forecast quickly and easily at any time of the project. While the model demands little input from the user, it does allow the user to develop a solution. The model parameters can be adapted, without modifying the structure of the mathematical expression, to meet the requirements of specific users with specific project characteristics.

Mazzini (1991) applied the Momentum Theory, an alternative approach to cost analysis founded on the dynamics of spending, for cost analysis, forecasting, and control. This new technique involves a multi-step process to transform historical data into the characteristic momentum patterns. The resulting patterns, and the future course of spending they produce, allow the cost analyst to accurately forecast the future.

4. THE BASIS OF DEVELOPING FORECASTING SYSTEM

From the review of previous researches explained earlier, this paper provides the basis in developing forecasting system as follows:

- The importance of accuracy need to be highlighted where averaging short period of time (e.g., 3 months) is more accurate than averaging over longer periods (e.g., 6-12 months), especially during the mid stage of the project when costs are often accelerating.
- If earned value based method is used, cost performance indices and schedule performance indices should be taken into account in developing forecasting system.
- If subjective parameters are adopted in forecasting system such as performance of management, cash flow situation, material and equipment availability, labour availability and productivity, weather and other environment influences, amount of rework etc., well-experienced professionals in the construction industry should be selected as domain experts for knowledge representation.
- The forecasting system should be designed to indicate cost and time at any percent of work performed in order to estimate at completion performance variations to obtain the need for corrective action.
- The forecasting system should consider adopting probabilistic approach rather than deterministic approach. This is because probabilistic approach provides variability and probability of schedule and cost values which are consistent with the construction performance probabilistic nature. These approach allow decision-makers to select highly probable schedule and cost estimates thus leading to accurate and reliable forecasts
- The forecasting system should be able to provide early warning of performance overruns during the first quarter of a project so that corrective action can be taken to prevent further decline
- The forecasting system should consider the impact of future corrective actions on future performance
- The forecasting system should consider the input of human subjective judgment. In this case expert's opinion and judgment from construction projects. However, proper and reliable input information is necessary to generate forecasting model to produce satisfactory results.
- The forecasting system should produce realistic and meaningful revised schedules

- The forecasting system should be able to analysed effectively by incorporating actual data observed from past projects. This will improve on the accuracy of cost and schedule to model the dynamic and probabilistic nature of construction performance
- The forecasting system should incorporate other critical parameters such as safety, quality, client's satisfaction, team's satisfaction along with cost and schedule during forecasting process
- The forecasting system should simple and less expensive method that can be implemented by any parties involve in construction projects

5. DISCUSSIONS

Given the critical review on literature as explained above, forecasting is an essential system and should be part in project control procedure. One view is that benefits forecasting should indicate early warning about the project deficiencies to Project Manager. In this case, this will depend on the effectiveness of forecasting tools suitable for the practical use. Being in the construction industry, very dynamic and complex, past performance is not always an accurate prediction of the future. Thus, there is a need for a system to model the dynamic and probabilistic nature of construction performance. Indeed, from Neil (1987) studies indicated that few contractors are comfortable with sophisticated forecasting techniques but, if contractors wish to improve the quality of estimates, Vergara and Boyer (1974) suggested that they must utilize methods that are consistent with their probabilistic nature. Hence, this clearly shows from the literature review, why the probabilistic approach is much more appropriate in forecasting project performance than deterministic approach.

Most of the reviewed papers based their forecasting methodologies on the "linear trend" concept. This concept has been argued by Ward and Lithfield (1980) stating that straight line assumption is incorrect where project progress continually subject to change. The majority of the earned-value based forecasting methods assumed that past performance would continue throughout the remaining duration of the project. However, these methods lack in considerate the impact of future corrective actions on future performance. Ward and Lithfield (1980) have studied that implement forecasting by purely decided using previous performance will constitute incomplete forecasting technique. As such, in attempting to generate realistic forecasting Ward and Lithfield (1980) also suggested to consider the strategy for the work performance for subsequent progress period. In addition, Willis (1987) indicated that a forecast should rely on past performance predictions as long as the pattern of changes in the environment is steady.

Specific issues that also arise as a result of this research are the accuracy of project data and being unbiased. It is argued that these forecasting tools should be subjective and expert's views to be considered during the process. As a consequence, a study by Diekmann and Al-Tabtabai (1992) using the social judgment theory predicted future performance based on a set of cues, which were derived from human subjective judgment rather than objective mathematical methods. However, this method requires the input of highly experienced and knowledgeable project managers to produce satisfactory results. Following to this, another study by Al Tabtabai (1998) include expert's judgment and intelligence in the analyzing and forecasting process. This method using an artificial intelligence and expert system mitigate the existing forecasting approach by providing the advantage of ability to model the complex nonlinear mapping which is required in the decision –making process. Moreover, this method may produce realistic and meaningful revised schedules which can be generated systematically at any stage of the project.

6.0 CONCLUSIONS

Accounting for each of the methods explained above, it is clear that there is still a need for innovative research in the area of forecasting systems. There is still lacking of many aspects in forecasting methods implemented by today's Project Managers.   In a challenging construction industry nowadays, to have accurate forecasting methods require an approach that would cater subjective data and consider experts' experience and knowledge.   In conclusion, it is important to have forecasting tools that have a relatively simple and less expensive method that can be implemented by any parties involve in construction projects that could provide with early warning about potential performance variances.

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