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AUTOMATION IN SITE MANAGEMENT: A QUALITATIVE APPROACH

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ABSTRACT

This paper will address a new approach to construction management: Qualitative Construction Site Assessment System (QCSAS). QCSAS is essentially a site management software package. The objective of this system is three fold. Firstly, it aims to provide a holistic view of construction site to the project manager. It tries to achieve this by tracking essential factors like construction progress, construction quality, safety on site and resource requirement. Secondly, it assesses the condition of all factors on site in qualitative terms by using *fuzzy logic*. Thirdly, the system intends to achieve smooth information flow between various participants of site, i.e., the site supervisors, procurement officer, quality inspector, safety engineer, planning engineer and project manager with minimal effort and time wastage.

KEYWORDS

Construction Planning and Management, Information Technology, Site Management

1. INTRODUCTION

In early 1990's Information Communication Technology (ICT) has shown increasing importance for its possible applications in construction industry [1]. Complex systems have been developed to cater to the need of efficient planning and management of construction site. Systems involving visual techniques to obtain a bird's eye view of the construction site as the construction progresses have also been developed [2]. They are known as 4D dynamic construction management systems, which show development of site in 3 dimensions with respect to the 'fourth dimension', that is, the time. This aids the planning engineers by giving them better understanding of resource requirement and improves space utilization.

Several Knowledge Based Expert Systems (KBES) have also been developed for improved construction planning management. Systems such as 'Construction Planex', 'GHOST', 'SIPE', 'CONSCHED' and 'HISCHED' are briefly discussed in [3]. Most of these systems (with exception of 'Construction Planex' which deals with work and labor assignment) focus on scheduling. Reference [3] also discusses development of a KBES system for creating a productivity-adjusted schedule. However, in India, the primary tool used for construction planning and management remains MS Excel and MS Project [4]. Some leading construction firms in the country, such as M/s. Larsen and Toubro are using in-house custom-made software packages. But these do not cater to the actual *management* of construction site. They are used for centralized billing and inventory management.

Delays in construction and poor construction quality are problems that are regularly faced by construction industry in India. No study for delays in construction projects in India were found but the figures should be similar to that found by Ayman and Al-Momani in their study of public projects in Jordan, if not worse [5]. They found that out of

130 surveyed projects, 106 had run into delays. Out of these 52 projects were delayed because of change of orders, weather and site conditions. Other reasons should one way or other relate to some sort of mismanagement on construction sites. Thus there is a need for a construction management system that can help project managers fight these delays without compromise on quality and safety standards.

1.1 Failure of Previous Attempts

The concern to be addressed is that such systems have either not been developed or if they have been, the industry isn't using them. It is possible that certain hindrances such as fragmentation in construction sector, lack of computer and trained professionals, security concerns, legal implications are keeping the industry at bay when it comes to using ICT for project management [6]. After having discussions with site engineers, it is our belief that the application of systems have mainly failed because of following factors: (i) Complicated software packages require substantial employee training time (ii) Systems are black boxes and their recommendations (if any) are considered with a certain degree of distrust (iii) Lack of faith that machines can adapt and provide right advise for situations in a highly dynamic system like construction sites (iv) Cumbersome data input with little utility gained without using the advanced features

1.2 Requirements of Practically Applicable Construction Management System

Thus there is a need to develop a system that is easy to give inputs to, utilizes minimal time to give those inputs, can cater to interdependencies, is flexible and finally can manage both "hard" and "soft" data. Most importantly its reports must be easily understandable and useable [7,8].

Now it has been proposed that a force metaphor can be used to describe the comparison between planning versus actual construction progress [9]. A construction project is like a rolling ball on a curved plane. The actual path will depend on the curvature of the curve it rolls on. The curved plane may be defined by various constraints (predicted and unforeseen) on the construction site. Since there will always be unforeseen constraints, the actual path of construction progress can never be accurately predicted. Thus, the difference between the planned project schedule and actual construction progress is observed. This then brings an interesting corollary to our notice. If the actual progress cannot be predicted more accurately, then the emphasis should be more on improving monitoring of construction activities than on improving already existing advanced and fairly acceptable scheduling techniques.

There are several previous attempts at developing better models for construction planning and management. These include models that cater to monitoring dependence relationships, planned/actual construction activities, revision of plans and tracking actual schedule [10]. These features are without doubt important for monitoring construction activities.

Various recommendations have been made through other models. Use of independent interfaces has been strongly advocated [11]. Also, it is advised that systems should work in three different layers:" Tactical layer" (the strategic core of the system), "Operational layer" (where the simulation takes place and results are compiled) and finally "Interface layer" (where the results are displayed and inputs are taken) [12].

A certain phenomenon of *dilution* in information has been noted on site. This dilution is of two types and for the sake of convenience can be termed as "forced dilution" and "natural dilution". Natural dilution in information occurs when information is passed up the hierarchy and small aberrations aren't reported at the top level as a result of averaging out various factors while moving up. Forced dilution occurs due to poor communication between senior management and site engineers. It can be either because of intent to conceal information or because a subordinate decides that the information is not worth bothering his senior about. While *natural dilution* is an acceptable and one might say, even required process in reporting, *forced dilution* may more often result in serious concerns not being informed to the senior managers. A good system should be able to avoid forced dilution but keep natural dilution in reporting.

2. PRESENT STUDY

Keeping in view the discussions in section 1, a fresh approach was adopted for creating a practically applicable system. After some discussions with site engineers, it became clear that there are certain practices that engineers on site are averse to. Engineers need to see the consequence and ultimate value addition of any practice they are asked to do. Also, the system should be simple to use and should require minimum training. To tackle this, it was decided that the site management system should be qualitative in nature rather than quantitative.

Human communication is essentially qualitative in nature. Ironically, in a lot of cases qualitative phrases are more accurate way of passing information than quantitative figures. For example, saying that the quality of formwork is “good” gives immediate and correct understanding of what is intended to be communicated. In contrast, saying that quality of formwork is “7 out of 10” is not only abstract, but also requires significant amount of work by an organization to develop standards in figures for them to be interpreted. Thus, forcing qualitative entities to be dealt with in a quantitative manner creates a redundant cycle as shown in Figure 1 below.

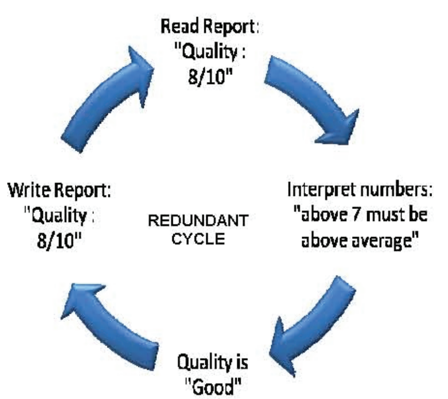

Figure 1 Redundant Cycle of Communication

This cycle brings forth another realization that not only should the data inputs be qualitative (because that’s how humans communicate) but the reports should also be qualitative. By making the input and output of the system in qualitative terms, the problem of time wasted on initial training and readability of reports would have simultaneously been addressed.

In addition, the time for data input should be as less as possible so that the site engineers can focus on getting work done. The reports for construction progress should be in real time and similar to time-impact analysis. That is to say that two parallel construction schedules will be maintained. One will track the current progress of schedule and adjust itself accordingly. Using this schedule, the project manager can track delays in actual project and shift in critical path (if any). The other schedule will remain same as the original and will show which activities have exceeded their assigned time. The system should be entirely flexible and should allow changes at “operational layer”, thus allowing user to set standards that he wishes to follow at the construction site. Finally, it should produce an “easy to navigate” and readable report of the entire construction site. In final reporting it should be able to avoid *forced dilution* in information so that there isn’t any loss of important information but *natural dilution* is allowed to occur so that not every small problem on the site has a serious effect on the overall report.

3. OVERVIEW OF THE SYSTEM

The QCSAS system works with two modules running in parallel and in co-ordination with each other [13]. One system deals with critical path and scheduling of activities. The other deals with the core function of QCSAS, which is to make decisions about the daily conditions of the site. They interact in together to make an effective tool for site management as shown below in Figure 2. There are essentially 6 core members on the site who deal with the QCSAS system. We will refer to them as site officers. They include the project manager, the planning engineer, site supervisors, quality engineer, site safety engineer and inventory in charge/ procurement officer.

To begin with, the planning engineer of the site will develop the initial hierarchical model for the construction site. He will also submit the pre-decided list of activities with their optimum times and quantities. Once he does that, the system will generate the original critical path. This stage of work on QCSAS will be referred to as the initialization stage. The system recognizes two types of variables: qualitative and quantitative.

Qualitative variables: These variables are all those whose reports can be directly be submitted in linguistic form using fuzzy logic, that is, in words like "good", "bad" or "average". These include construction site quality and construction site safety. Fuzzy logic is used to express all conditions in qualitative terms. This allows engineers on site to easily communicate with the software, thus reducing the cost and effort in training the personnel. For example, it is easier and ironically more accurate for a quality inspector to state that the quality of concreting is "good" instead of stating that the quality of concreting is "7 on a scale of 1 to 10". For example the quality of concreting may have following states: Excellent, Good, Average, Concern and Poor. The quality engineer may input the choice that is appropriate in his judgment. Provision is also provided for giving comments in case the need arises to explain the situation. It is also possible that certain variables are quantitative in nature. For example progress cannot be measured in terms of qualitative expressions. Such data is normalized in by using a pre-defined graph (referred to as a template), a "target" value and a pre-defined equation. For example, let the target be to complete concreting of 15 meters length of first lift of a concrete wall and the template of the standards for construction progress set by the project manager is as shown in Figure 2.

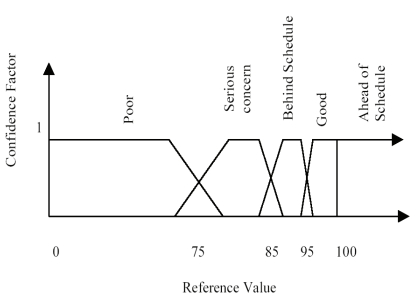

Figure 2 A Sample Template for Setting Standards for Progress

The pre-defined equation for this input module is shown in Eq. 1. If the total target achieved is 13 meters length then the reference value becomes 86.67, which implies that the progress is "Behind Schedule".

$$\text{Reference Value} = \frac{\text{Input Value}}{\text{Target Value}} \times 100 \qquad (1)$$

The templates, target values and the normalization equations will be different for different type of base variables.

Quantitative variables: These variables are those whose inputs can be given in numbers more conveniently. They include resource requirements on site and construction progress

The next stage of the QCSAS is daily processes. The daily process has two sub-sections. The first is '*Updating of the Hierarchical Model'*. Under this section, the site supervisors, quality engineers, safety engineers and procurement officer manage their section of the hierarchical model. They make changes to it by adding new variables that are to be monitored and deleting those that aren't being monitored anymore. The targets for quantitative variables are also updated in this process. This way, the planning engineer doesn't have to bother with keeping track of what all is going on the site and take the pains for updating the entire model. The second sub-section is *'Submitting Daily Reports'*. This involves submitting the status of qualitative variables and values of the quantitative variables. The total process shouldn't take more than 15-20 minutes per site officer daily. As the site supervisors submit the construction progress, QCSAS updates the critical path and saves it as the current critical path. As a result, the project manager should have a compiled report for the previous day within an hour of the beginning of the day. The final stage is the report generation.

4. WORKING OF THE SYSTEM

Some variables are inherently quantitative (i.e., "hard") in nature. These variables include those measuring progress of construction on a site and resource requirements on site. The values are entered in form of numbers and their status is also obtained by comparing the submitted values with pre-decided numerical target values. For example, it may be decided that the target for concreting for a particular day is 40 cubic meters. The value submitted for the concreting achieved that day may be 37 cubic meters. From this it may be concluded that the status of the work is "on time". Thus both the submitted value and the target value for deriving the status of the variable are in numerical form. It is noteworthy that though the variable is dealt with in quantitative terms, the final conclusion is always qualitative in nature, i.e., it is a human expression and not some mathematical identity.

Meanwhile other variables such as construction safety and construction quality are inherently qualitative (i.e., "soft") in nature. The quality of work will always be described as "good", "bad" or "average". These are already in form of human expression. Thus their submitted value is itself the status of the variable and is always in qualitative terms. More details can be found elsewhere [13]. It is apparent from the above discussion that for us to make sense of status (or condition) of any given variable we must convert it into a qualitative judgment. In further sections, it will be discussed how QCSAS achieves this.

4.1 Hierarchical Model

QCSAS is designed to understand a site in form of hierarchy. All aspects of the construction site are viewed as *variables* by QCSAS. If there is any aspect of construction site whose status is wished to be obtained or monitored by engineers on the construction site, it will be entered into the QCSAS system as a variable.

To begin with, any project manager would like a system like QCSAS to tell him about the overall conditions of the site. Let us say that the "overall condition of the site" is a variable and name it as "Main Report". Now, it is apparent that there are several aspects of the construction site that need to be monitored to actually derive the "overall condition of the site" or the "Main Report". For this purpose we would want to monitor "Construction Progress", "Construction Safety", "Construction Quality" and "Resource Requirements" on the construction site. The model of the construction site is now beginning to take shape of a hierarchy tree as shown in Figure 3 below. These variables may then further have more children as new levels are developed. The hierarchical model will have different levels. The top most level is that of the "Main Report" variable. The construction site can now be further developed by adding more sub-variables and developing new levels.

The existence of variables on the hierarchical model is dynamic in nature. That is to say, that only those variables, which are being monitored, exist on the model tree.

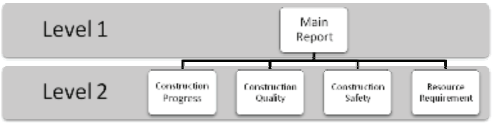

Figure 3 Hierarchical Model of Construction Site

The second level of the *variable tree* is also known as the Parent Tree. This is so because all subsequent variables under this level will have specific nature will be identified with the type of Parent tree under which it exists. For example, all variables under the Parent Tree "construction progress" will be progress type variables and will be concerned with progress of the work on a construction site.

All variables can be classified into two broad categories of variables: parent variable and end variable. The parent variables are the ones that have "children" under them. They have following properties: (i) They have sub-variables or "children" under them. (ii) Their status is derived from combining the status of all its children (iii) They are always qualitative in nature since they represent the combined status of their children (iv) No one need be directly responsible for these variables since they need no direct input from the engineers on the construction site.

The end variables, on the other hand, have the following properties: (i) They have no sub-variables or "children" under them (ii) They can be qualitative or quantitative in nature depending on what type of variable they are (iii) Their status is submitted if they are qualitative in nature or their values are submitted if they are quantitative in nature (iv) They must have someone assigned to them who will be responsible for entering their status or numerical data

5. GENERAL DISCUSSION

The prototype of QCSAS was tested on Delhi Metro Rail Corporation Construction Site under M/s. Larsen and Toubro Ltd. The site planning engineers found the system to be a novel approach towards Information management on site and suggested improvements such as inclusion of a module of making bill of quantities, automatic updating of inventory requirements as per on-going construction work and resource-leveling in critical path.

Since QCSAS, deals in qualitative terms the technical training required for an engineer is minimal. However, the effectiveness of the system depends largely on how motivated the project manager is to imply this system of site assessment. This calls for educating the site officers about the importance of making daily reports for 15-20 minutes. Therefore some level of adjustment is required in cultural and people processes.

6. CLOSING REMARKS

The paper presented development of Qualitative Construction Site Assessment System (QCSAS). The system is based on a qualitative communication on construction site. This is a completely new method of operations in field of information dissemination on a construction site. For any construction industry to adopt QCSAS, they must slightly change their strategic framework for site assessment. The change in strategy should give the project manager more support to use a qualitative system QCSAS for internal assessment of site conditions without interference from higher echelons in the industry.

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