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Staffing-Technology Fit in Construction Scheduling

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Abstract: Construction managers use scheduling methods to improve the outcome of their project. In spite of the many obvious advantages of the critical path method (CPM), its use in construction has been limited. Understanding the reasons why CPM is not used as extensively as expected could improve its level of acceptance in the construction industry. The link between construction scheduling methods and the capabilities of the scheduling staff has been an on-going concern in the construction industry. This study proposes a staffing-technology fit model to understand why CPM is not used as extensively as expected in construction scheduling. A staffing-technology fit model that aims to measure the extent to which a construction scheduling method matches the staff`s experience, know-how and capabilities. The model that is proposed is an answer to the lack of proper instruments for evaluating the extent to which scheduling methods are used in the industry.

Keywords: Scheduling, Critical Path Method, Task-Technology Fit, Technology Acceptance

I. Introduction

Construction managers routinely use scheduling methods to make sure their project is completed within the time specified in the contract. Several scheduling methods are available for use in construction projects such as bar charts, the critical path method (CPM), and linear scheduling methods (LSM). The scheduling method selected by construction managers depends on a number of factors including but not limited to size and complexity of the project, the degree of repetition involved in the project, and expertise available for the method used. CPM is by far the most popular method used in larger projects that do not exhibit repetitive characteristics. However, according to Galloway [1], even though CPM scheduling has been used for over half a century, its application in the construction industry has still not reached 100% acceptance.

The linkage between construction scheduling methods and the scheduling staff`s capabilities has been an on-going concern in the construction industry. Can the fit between the scheduling staff's expertise and the characteristics of CPM explain the reason why CPM is not used as extensively as expected?

The objective of this study is to investigate the staffing-technology fit in order to evaluate the extent to which CPM is used in the industry. The idea is to see how much the characteristics of CPM (technology) fit the abilities of the scheduling staff (staffing). By scrutinizing the staffing-technology fit in CPM applications, deficiencies which hinder CPM from being used widely in the industry could be found. Thereby, the ways to increase its level of acceptance could be developed later.

II. The Proposed Staffing-Technology Fit Model

A staffing-technology fit model in construction scheduling is proposed to measure the extent to which a technology functionally matches the staff`s capabilities in the construction industry. Figure I shows the staffing-technology fit model. The major features of this model are described in the following subsections.

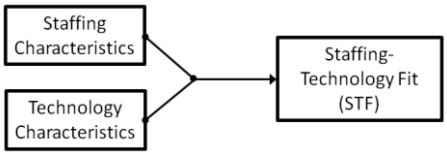

Figure I
Staffing-Technology Fit Model

A. Characteristics of Staffing

Individuals may use technologies to assist them in the performance of their tasks [2]. The characteristics of the staff could affect how easily and well schedulers utilize a scheduling method. The difficulty of scheduling may vary depending on the competence of a scheduler. Schedulers, who are more competent, well trained, or quite familiar with a particular scheduling system will be better able to successfully manage their work. Skilled and experienced personnel are absolutely essential to any scheduling system. Without their involvement, a scheduling system is doomed to failure. Also, schedulers who are willing to learn new or different scheduling systems will lead to improvement in their job performance. In order to measure the characteristics of the schedulers, questions regarding scheduling experience and motivation were developed as suggested in Goodhue and Thompson`s [2] study.

B. Characteristics of the Technology

Time management is an important function in delivering a constructed facility in a timely way. The many activities involved in the construction projects need to be scheduled to allow the contractor to complete the project within the allotted time in the contract. Scheduling and control can be achieved by using CPM, a dominant scheduling method that is mostly based on precedence relationships and the identification of the critical activities.

C. Staffing-Technology Fit

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Staffing-technology fit can be defined as the degree to which technology functionally matches the individual abilities of schedulers and managers. In the context of this research study, staffing-technology fit is the extent to which the accumulated expertise of the scheduling staff is CPM is sufficient to set up a network diagram, run COPM calculations, and interpret the outcomes.

The staffing-technology fit model shown in Figure I leads to three general propositions. The first two propositions deal with the technical capabilities of the scheduler and the characteristics of the CPM technology, respectively. The third, and most critical proposition, is that the capabilities of the scheduler and the characteristics of the CPM technology interact to define a relationship. Such interaction is the essence of what is meant by a "fit" relationship.

If the CPM scheduling system does not enjoy a good fit between staff capabilities and CPM technology, then this attempt to using CPM is considered failed or unacceptable. An experienced scheduler can select an optimum level of detail, whereas insufficient knowledge of the scheduler may lead to poor schedule development. Thus, by examining to what degree the CPM scheduling system fits the capabilities of schedulers, the scheduling system can be judged to be acceptable or not.

Eight questions for measuring staffing-technology fit were set up for CPM, inspired from the study of Goodhue and Thompson [2]. These questions were set up to measure how staff capabilities meet the requirements of the CPM technology. The actual questions are presented in the following section.

III. Methodology

The methodology of the study is presented in Figure II. An exhaustive literature review was conducted to understand the characteristics of CPM scheduling. Similarly, technology acceptance theories were reviewed to propose a staffing-technology fit model to investigate the current situation. The questionnaire survey method was chosen for data collection because the unit of analysis is users of CPM. The study was confined to the professionals listed in the directory of the Construction Management Association of America (CMAA). The selection of the respondents was based on their experience in construction scheduling. A cover letter was emailed to the recipients, which emphasizes the intent of the study and acknowledges the confidentiality of the information that is requested. This letter also included a link to the questionnaire.

The eight questions described in the following section were identified as staffing-technology fit measures that affect the linkage between CPM and the capabilities of the staff involved in scheduling and control.

The first part of the questionnaire requires the respondent to indicate agreement or disagreement with eight questions on a scale of 1–5 (1=strongly disagree and 5=strongly agree). These eight questions attempt to measure staffing-technology fit in construction scheduling.

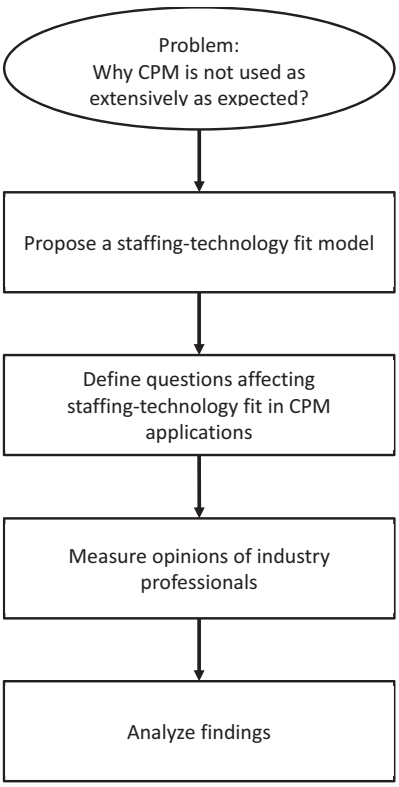

Figure II
Research Methodology

The second part of the questionnaire included three questions that inquired about demographic characteristics such as the experience of the respondents, and the type and characteristics of projects in which they were involved.

The online survey was designed through www.SurveyMonkey.com that provides tools for creating user-friendly surveys on the web. The reason for selecting an online survey tool was to obtain a wider sample of respondents as well as to reduce cost and time [3]. The statements that were part of the questionnaire are presented in the following section.

IV. Staffing-Technology Fit in CPM Applications

In this section, eight statements S1 to S8, were categorized as staffing-technology fit measures that have an effect on the linkage between the capabilities of the scheduling staff (staffing) and CPM (technology).

S1. The schedule provides information that is useful to all project participants.

Although the schedule provides useful information, this information differs based on the recipient`s position. According to Galloway [1], many owners require detailed construction schedules as a means of monitoring the progress of work. The actually performed work is commonly compared to the schedule to determine if construction is proceeding satisfactorily. Thus, owners prefer a scheduling method that they find easy to understand and that can provide a near-term look ahead.

On the other hand, contractors want to optimize resource utilization, meet deadlines, and archive project records for reference on future projects. They are responsible for project delays. Thus, a scheduling method is preferred that can predict bottlenecks that may result in delays, and that can compute the earliest and latest possible start and finish times for each activity in order to complete the project in the shortest possible time.

Meanwhile, construction managers coordinate the activities through the entire project, communicate with other participants, and respond to schedule-related issues. Managing a project involves managing risks that include additional work, changes to the project, and unanticipated events, all of which can have a serious impact on the work schedule.

To sum up, participants in the construction project require information that is useful to them depending on their position and function in the project organization. The more a scheduling method satisfies these needs, the higher utilization occurs.

S2. The schedule generates graphics that are easy to understand by all parties in the project.

The graphical format enables all parties in the project to better visualize the plan of action and to more easily communicate the plan to the group involved with the project. Typically, a Gantt chart shows activities displayed against time with horizontal bars. Thus, the duration and order of each activity can be illustrated at a glance. Percent completion graphs and production rate graphs in network diagrams also help to visualize the project. The use of graphics also allows the group members to visualize the obstacles in the project. The plot can display what is wrong with the progress of an activity, and can detect potential bottlenecks in the future thereby, it allows to keep a smooth and efficient flow of tasks and resources [4].

S3. The degree of detail that the schedule provides coincides with the needs of the project manager.

A certain degree of detail allows project managers to effectively manage their projects [5]. The level of detail varies from low density (e.g., executive summary) to high density (e.g., detailed schedule). To be specific, the level of executive summary emphasizes major project activities, milestones, and key deliverables for the entire project. It is used to summarize the project schedule in reports and other documents when a more detailed schedule is not required. However, most of all projects require an execution schedule for day to day coordination of the project's work. Although the typical level of detail in the execution schedule is sufficient for managers to use without further detailing, project managers often require more detailed schedules for their own purposes [6]. A short term schedule which breaks down into the activities of the execution schedule is needed to coordinate day to day work in specific areas. The advances in project scheduling software tools allow a high degree of integration and interconnection between different levels of the schedules due to the development of computerized technologies.

S4. Schedulers are familiar with and have access to a software package.

Typically, as projects get larger and more complex, scheduling software becomes more important because software packages allow schedulers to define many phases and tasks, and then to assign the labor, materials and resources required to complete each task and phase. Schedulers need to be familiar with such software packages [6]. Having access to a software package affects the selection of a scheduling system. The nature of construction requires that schedulers spend time in the field. While in the field, schedulers want to stay connected to their software applications. Also, there is a substantial need for improved collaboration between project participants at anytime from anywhere, through the Internet. Web-based construction software packages make that possible with the cost and ease of implementation benefits.

S5. The schedule requires little time and effort to produce.

Badiru and Pulat [7] wrote that a network's degree of complexity is usually a good indicator of the time spent during scheduling and planning. If a scheduling method is easy to use and user-friendly, the schedule requires less time and effort to produce.

S6. There is enough training for project managers and their staff on how to use the system.

Although scheduling systems have been used in the construction industry for decades, many contractors do not fully know how to use these tools effectively [8]. Therefore, on-the-job training (OJT) is required to all project parties [9]. This can be offered through vendor training, technical society meetings, specialty conferences, invited guest lecturers, external seminars, in-house seminars presented by external vendors and/or in-house personnel, and many other formats. Training on how to use the scheduling system improves the productivity of project participants. To be specific, inexperienced schedulers who have a background in scheduling methods cannot develop realistic plans, whereas those with substantial construction experience but are short on planning theory tend to result in basic scheduling errors. In both cases, training gives a chance to make up for their weakness. Also, the training on the scheduling system represents a part of an overall integrated project information system that would provide reliable data and decision-making aids for improving the productivity of construction managers [10]. In addition, staff training on how to use the system should be provided in case scheduling software is required from an outside source [6].

S7. Project participants can effectively communicate with each other on the basis of the schedule.

Communications are, in general, the basic means through which managers interact with the project counterparts [11]. These following studies reflect the principal role of communications in ensuring the effectiveness of construction projects. Walker [12] indicated the use of bi-directional communications as a means of improving quali-

ty in construction. Rwelamila [13] emphasized the critical role of the construction manager in communicating with multiple participants in the project. Jergeas and Hartman [14] recommended keeping good records and communications as a means of avoiding claims and disputes in construction projects. Coble and Snow [15] and Mackanzie, Gibb and Bouchlaghem [16] found that communications have a significant effect on the safety records of projects, both in the design and construction phases. Communication among project participants on the basis of the schedule is necessary to clarify roles and responsibilities, obtain and disseminate information, resolve conflicts, and negotiate agreements on a variety of project-related issues. They can understand the day-to-day objectives of the project and then, reduce uncertainty and disagreement [6]. Current computing technologies provide construction professionals with access to rapidly evolving communication pathways. This access has profound implications for the construction industry in several areas, such as intra-office communications, client relations, design coordination, and site management [17].

Therefore, communicating on the basis of the schedule makes project participants understand the day to day objectives of the project, and, reduce uncertainty and disagreement. When these elements are properly addressed and interrelated, user benefits can only be maximized and the scheduling system is accepted.

S8. Project managers can respond to schedule-related issues promptly.

Among a number of tasks that project managers are faced with, planning and controlling of project activities is the most critical [18]. They should respond promptly to the schedule-related issues such as contractual compliance, reasonability of job logic, and activity durations [19]. In particular, project managers can manage the projects well with the construction scheduling software.

V. Data Analysis and Discussion

The data obtained from the survey were analyzed using the Statistical Package for Social Science (SPSS 22.0 for Windows). The findings are organized and presented around each of the designed research questions presented in the previous section.

A. Data Collection

The questionnaire was designed for response over a web link distributed to the potential respondents. From the end of February 2015 to the end of March 2015, 13,313 e-mails were sent out; 3,451 e-mails were bounced back because junk mail filters blocked the e-mails. Also, 642 potential respondents were out of the office or had left their job. A total of 656 completed responses were received for data analysis over a period of 4 weeks. The rate of response was 7.1%.

B. Profile of the Respondents

Of the 656 respondents, more than half indicated that they had an experience in building construction (e.g., commercial, residential, educational, etc.) (64%) and civil works (e.g., roads, bridges, tunnels, etc.) (55%) while fewer had experience in industrial construction (e.g., power plants, refineries, etc.) (27%).

Concerning project size, 61 % of the respondents had been involved in projects over $50 million. Also, the average number of their years of experience in the construction industry was 23.1 years. All respondents stated that they were familiar with CPM. Given their extensive experience, especially in large projects, the respondents appear to be well qualified to answer the questionnaire administered in this study.

C. Analysis of Mean Scores of Staffing-Technology Fit in CPM Applications

The results presented in Figure III show that professionals` opinion regarding staffing-technology fit tended to "agree" relative to all statements except for S5 and S6. In other words, respondents mostly agree that (1) CPM satisfies the requirements of all project participants who need information that is useful to them depending on their position and function in the project organization(S1); (2) several well-designed software packages are commercially available for schedulers' use (S4); (3) CPM is not only a scheduling tool but also a control tool (S8); (4) CPM allows a good degree of detail in the schedule (S3); (5) CPM provides ease in communication between project participants (S7); and (6) CPM presents graphics that can be of great value to users (S2). The literature supports these findings.

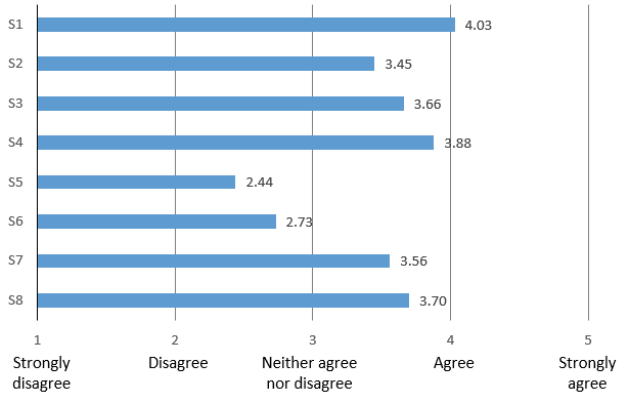

FIGURE III
MEAN SCORES OF CPM APPLICATIONS

On the negative side, respondents mostly agree that CPM schedules require much time and effort to produce. Indeed, in the study conducted by Tavakoli and Riachi [20], it was found that one of the major concerns of top management regarding implementation and application of CPM was the excessive work to develop logic among activities and assign durations to activities partly because of the difficulty to make accurate predictions about the future. Figure III also shows that there are not enough training opportunities for project managers and their staff to learn how to use CPM. Tavakoli and Riachi`s [20] work also indicated that the main reason behind unsuccessful CPM applications was the lack of support from employees who

were presumably not knowledgeable enough. To accomplish a successful implementation of CPM, all levels of users should be trained well.

VI. CONCLUSION

CPM is considered to be a powerful scheduling and control tool in construction. It has been used for many years in many projects. Yet, CPM use in construction has not been as extensive as expected. This study proposed a staffing-technology fit model to understand why CPM in construction is limited. A questionnaire survey was conducted to collect information about CPM applications. The staffing-technology fit model was used to find out respondents` perceptions of how their capabilities fit the requirements of CPM.

Professionals` opinion regarding staffing-technology fit show that respondents mostly agree that CPM satisfies the requirements of all project participants who need information that is useful to them depending on their position and function in the project organization. On the negative side, respondents mostly agree that CPM requires much time and effort to produce, and that training opportunities to learn how to use CPM are not enough for project managers and their staff. Thus, it is recommended that project managers and their staff receive training and learning opportunities at work or school. All parties in the project should be able to understand the graphics and information that CPM provides in order to improve their job performance by easily and effectively communicating scheduling-related issues. The practice of converting network diagrams into bar charts is a step in the right direction.

The performance of a scheduling method is likely to be enhanced if all project participants are cognizant of scheduling-related matters.

- For owners, the scheduling method should monitor work progress.
- For contractors, the scheduling method should create opportunities for users to meet deadlines because contractors have to pay liquidated damages for contractor-caused delays. Thus, a scheduling method that can predict bottlenecks that may result in delays will allow contractors to complete the project in the shortest possible time.
- For construction managers, the scheduling method should allow managers to coordinate the activities over the entire project, communicate with other participants, and respond to schedule-related matters.

This empirical study has two minor limitations. Firstly, it was assumed that the respondents understand fully the implications of using CPM. Secondly, the study is limited only to the theory of staffing-technology fit. However, utilization based on theories of attitudes and behavior, or on principles of task-technology fit may also help to predict performance impact.

Although the study has limitations, the findings and implications are significant in that the fit between the technical capabilities of the staff involved in scheduling and control and the characteristics of CPM technology does affect the extent to which CPM is used in the construction industry.

Future work may involve the examination of other factors than staffing-technology fit, such as task-technology fit, expected consequences of utilization, social norms, habit, and facilitating conditions. Also factor analysis can be used to group the variables for further quantitative studies.

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