Task-Technology Fit in Construction Scheduling

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Abstract: Construction managers use scheduling methods to improve the outcome of their project. Despite 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 tasks expected to be performed by schedulers has been an on-going concern in the construction industry. This study proposes a task-technology fit model to understand why CPM is not used as extensively as expected in construction scheduling. A task-technology fit model that aims to measure the extent to which a construction scheduling method functionally matches the tasks expected to be performed by the scheduling staff. 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

Proper construction scheduling and control at all phases of a project improve the outcome of the project. Therefore, many researchers have worked in the area of scheduling. These efforts have been made to help construction managers to use a suitable scheduling method such as the critical path method (CPM) and linear scheduling methods (LSM) in their projects. CPM is an activity dominated scheduling method and has been used in most projects.

The linkage between construction scheduling methods and the tasks performed by scheduling and project management staff has been an on-going concern in the construction industry. Galloway [1] wrote that even though the CPM scheduling has been used for over half a century, its application in the construction industry has still not reached 100% acceptance or consistency in how to use it.

The objective of this study is to evaluate the extent to which CPM is used in the industry by investigating their task-technology fit. The idea is to see how much the characteristics of a construction scheduling method (technology) fit the requirements of the construction activities (tasks). By scrutinizing the task-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 TASK-TECHNOLOGY FIT MODEL

A task-technology fit model in construction scheduling is proposed to measure the extent to which technology functionally matches task requirements in the construction industry. Figure I shows the task-technology fit model. The major features of this model are described in the following subsections.

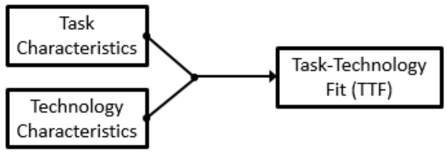

FIGURE I
TASK-TECHNOLOGY FIT MODEL

A. *Characteristics of the Tasks*

Tasks are viewed by individuals as an activity or piece of work [2]. Activities are identified to describe the project in sufficient detail so as to satisfy the schedule objectives [3].

According to Chua and Shen [4], construction can be viewed as a production flowing through the activities of a project, and being supported by resources. The precedence relationships between activities reflect the flow of production.

Many construction operations in building, industrial and civil works are repetitively performed. These repetitive projects consist of a large number of similar or identical units. Thus, maintaining work crew continuity in repetitive projects is essential in minimizing disruption that makes schedules difficult to develop as well as maintain [5]. The general consensus in the literature is that linear scheduling methods (LSMs) are better suited in situations that involve repetitive activities

Construction time and resources should be considered simultaneously for proper project scheduling. Time often takes precedence over resource utilization in construction projects. To be specific, when the interrelationships between project participants and activities are critical to the project or when the time constraints assume critical significance, time has a higher priority than resource utilization [3]. In contrast, optimal resource utilization is recognized as the key to meeting a repetitive construction project

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schedule [5]. To be specific, construction managers need to develop a schedule for directing and controlling resources of manpower, machinery, and materials, which play a significant role in making work plans reliable, in a coordinated and timely fashion in order to deliver a project within the limited time available [6]. Thus, construction project scheduling should be performed under resource constraints by considering flexibility for time through proper resource leveling.

B. Characteristics of the Technology

Technologies can be defined as tools that individuals use in carrying out their tasks [2]. In the context of construction research, schedulers utilize CPM to perform their tasks. CPM is a dominant scheduling method that is mostly based on precedence relationships and the identification of the longest path through a network.

C. Task-Technology Fit

Task-technology fit can be defined as the degree to which technology functionally matches task requirements. [2]. In the context of construction research, the task-technology fit can be interpreted as the extent to which a scheduling method is supportive of and instrumental in scheduling a project's tasks.

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

A scheduling system that does not have a good fit is considered failed or unacceptable. According to the study conducted by Moosavi and Moselhi [7], there are obligatory criteria such as contractual compliance and reasonableness of job logic. Thus, by examining to what degree a scheduling system satisfies its fit to these criteria, the scheduling system can be considered acceptable or not.

Eight questions for measuring task-technology fit were prepared for CPM inspired from the study of Goodhue and Thompson [2]. These questions were set up to measure how scheduling-related tasks are fulfilled by 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 task-technology fit model in construction scheduling to investigate the current situation. The questionnaire survey method was chosen for data collection in the research presented here 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.

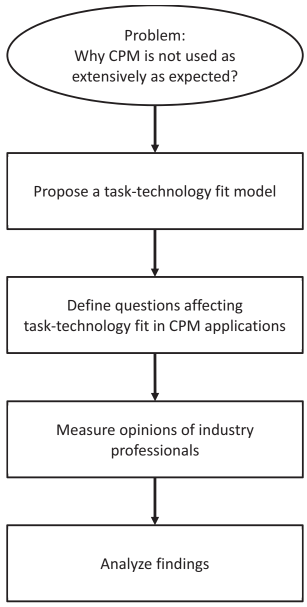

FIGURE II
RESEARCH METHODOLOGY

The eight questions described in the following section were identified as task-technology fit measures that affect the linkage between the requirements of the construction activities (tasks) and the capabilities of CPM (technology).

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 task-technology fit in construction scheduling.

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 [8]. The statements that were part of the questionnaire are presented in the following section.

IV. TASK-TECHNOLOGY FIT IN CPM APPLICATIONS

In this section, eight questions, namely statements T1 to T8, were identified as task-technology fit measures that have an impact on the linkage between the requirements of the construction activities (tasks) and the capabilities of construction scheduling methods (technology).

T1. The schedule clearly shows activity sequences in my projects well.

A construction schedule typically represents the sequence of multiple activities that perform individual work while sharing common workspaces or resources. According to Moosavi and Moselhi [7], activity sequences should be realistic. To be realistic, the physical relationships that exist among the different construction components must be considered. The requirement of an interference-free path around the job site at construction time affects sequencing activities. Code regulations are also relative to determine the order of execution of certain activities [9]. The interrelationships of project activities should reflect these constraints between and among them. Coordinating activity sequences helps to maximize the workflow of follow-on work [10]. Also, proper identification of these logic ties frequently eliminates bottlenecks in the subsequent execution of the project [3]. For these reasons, a scheduling method showing activity sequences clearly is preferred.

T2. Software exists that does all the tedious calculations instantaneously.

The complexity of the project schedule indicates a high level of interconnection between many activities using a large variety of resources. The higher the network's degree of complexity, the more time needs to be spent for scheduling and control [11]. Therefore, commercial scheduling software packages have become very popular in the construction industry because of the industry's needs [12]. They are used to extract, read, and analyze the data with accuracy and high speed [13]. These packages also support management of labor, resource, material and machinery schedules. When properly scheduled and managed, projects can be completed on time by removing potential future bottlenecks, such as when the workforce waits on a prior phase to be completed.

T3. Activities` rates of production can be adjusted for efficient performance.

A production rate is the quantity produced or constructed over a specified time period. Realistic production rates are important for appropriate construction durations. Production rates may vary considerably depending on geographic location even for the same item of work. Although production rates are well established based on an accurate database, some constraints may result in misleading rates which tend to be low. Therefore, production rates should be updated and adjusted on a regular basis to assure they accurately reflect the site conditions in the construction area. Adjusting tasks' productivity rates allows a smooth flow of resources and working continuity by controlling items of work and constraints [3]. Adjusting tasks' productivity rates by balancing work flow and constraints of time and space allows to keep a smooth and efficient flow of tasks and resources, and work continuity. When these features are properly addressed and interrelated in a scheduling system, the scheduling system gives the expected benefits. [14].

T4. It is easy to schedule projects that are composed of repetitive activities.

Although most construction projects are dominated by non-repetitive activities, some construction projects such as highways, railways, pipelines, and tunnels are characterized by a series of successive and repetitive activities. These activities create a need for a construction schedule that facilitates the uninterrupted flow of resources (i.e., work crews, equipment, etc.) from an activity in one unit to the same (repeating) activity in the next unit, because it is often this requirement that establishes activity starting times and determines the total duration for tasks. Therefore, uninterrupted resource utilization becomes the most important issue in projects with repeating activities [15].

T5. A realistic schedule can be developed even if reliable resource data are not available.

Although Zheng, Ng and Kumaraswamy [16] asserted that the two major constraints of construction, i.e., time and resources should be considered simultaneously for proper project scheduling, time constraints sometimes have a higher priority than resource constraints. Indeed, according to Hartley [3], when the interrelationships between project participants and activities are critical to the project or when the time constraints assume critical significance, time has a higher priority than resource utilization. For example, reliable resource data are desirable but not required in network-based scheduling systems, because only technical precedence constraints are shown in the networks after all [15].

T6. The schedule provides a smooth and efficient flow of resources.

Resource management in construction industry is one of the most significant ingredients for competitiveness and profitability. In order to control the flow of resources smoothly, equipment and labor should be utilized in the most efficient way possible and the total cost of resources should be minimized [17]. A scheduling method should allow a smooth and efficient flow of resources.

T7. The schedule defines all contractual interfaces clearly.

All contractual interfaces should be in the schedule. According to Moosavi and Moselhi [7], schedules must be in line with related contracts and entirely cover the scope of the contract. A scheduling method defining all contractual interfaces clearly provides the legal basis for the administration of construction disputes and claims [3].

T8. The schedule can measure progress compared to a baseline schedule.

It is essential to ensure the fitness of schedules for their intended purposes. The project baseline schedule is required for project execution, tracking, and progress reporting [14]. A scheduling method that provides progress measurement compared to a baseline schedule ensures the fitness of the schedule. When things go wrong, baseline schedule helps all participants in the project to identify what factors caused a bottleneck and to assign responsibility accordingly.

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.

Two questions in the survey inquired about the task characteristics of construction scheduling related to the level of repetition in a project and the priority attached to time versus resource management. Each of these characteristics was also measured by using a five-point Likert scale. The results indicate that construction projects sometimes consist of repetitive activities, and that completion in a timely manner is more important than resource utilization.

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

Figure III shows the mean scores of 656 respondents for CPM applications. The results show that professionals` view concerning task-technology fit tended to “Agree” in three of the eight statements, namely statements T1, T2, and T5, whereas in two statements, namely statements T4 and T6, they tended to “Disagree.” In other words, respondents mostly agree that CPM shows precedence relationships well, generates reliable schedules ever if resource information is not available, set up and run using existing software packages.

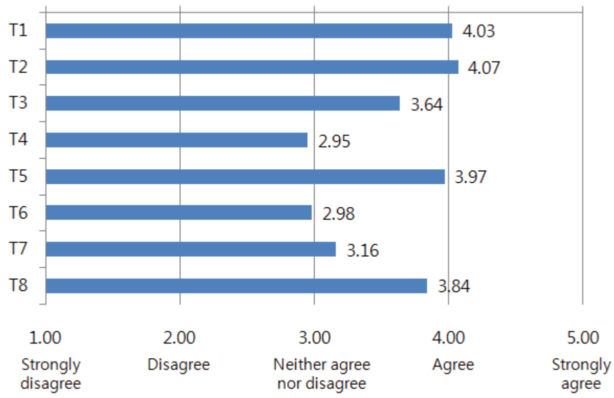

FIGURE III
MEAN SCORES OF TASK-TECHNOLOGY FIT IN CPM APPLICATIONS

Literature supports these results. Firstly, respondents mostly agree that CPM shows precedence relationships well (T1), just as all writers about CPM state that the CPM model is based on activities and precedence relationships (e.g., Hinze [18]). CPM shows logical relationships between activities, or between an activity and a milestone. Most of the relationships between activities are finish-to-start (FS) in nature, whereby the preceding activity must be completed before the succeeding activity can start. Other types of relationships are also encountered, namely, finish-to-finish (FF), start-to-start (SS), and start-to-finish (SF). The use of these four types of relationships between activities makes it possible for CPM schedules to be prepared that accurately depict the true relationships between activities.

Secondly, literature shows the results that respondents mostly agree that CPM generates reliable schedules even if resource information is not available (T5). Indeed, the basic CPM calculations of forward and backward runs do not need any resource information to identify the critical path(s). Granted, the scheduler needs to make assumptions about resource availability in estimating activity durations, but once activity durations are in place the CPM algorithm can identify the critical activities and floats throughout the network.

Thirdly, currently available commercial packages support the findings that respondents mostly agree that CPM can be set up and run instantaneously (T2). Many existing software packages such as Primavera Project Planner and Microsoft Project use CPM techniques for project scheduling. The availability of software packages allows CPM to represent complicated dependencies between activities more easily, and to make CPM calculations fast.

On the negative side, respondents mostly agree that CPM is not effective in repetitive projects (T4), and does not provide uninterrupted and smooth resource flows (T6). Literature shows that CPM is ineffective and cumbersome for scheduling linear continuous projects [19]. Also, Spencer and Lewis [20] state that planning and scheduling projects with repetitive characteristics is difficult using the critical path method, because CPM does not provide an uninterrupted and smooth resource flows. Resource management with CPM is commonly done by plotting resource usage per day in a bar chart diagram that shows a bar chart representing the man-hours spent in each activity of this project. This graph must be viewed together with the CPM network to understand how moving resources from one activity could affect other activities. CPM networks do not model work continuity for activities that are part of a wider workflow.

VI. CONCLUSION

Many researchers have investigated proper construction scheduling at all phases of a project because scheduling is directly related to the outcome of the project. These research efforts have been made to help construction managers to use a suitable scheduling method.

In spite of the many obvious strengths of CPM, its use in construction has been limited. This study proposed a task-technology fit model to understand why CPM is not used as extensively as expected in construction scheduling.

A questionnaire survey was conducted to collect information about CPM applications. The task-technology fit model was used to find out respondents` perceptions of how CPM fit with their scheduling tasks.

Concerning task-technology fit in CPM applications, the results show that respondents mostly agree that CPM shows precedence relationships well, generates reliable schedules even if resource information is not available, and can be set up and run using several existing software packages. On the negative side, respondents mostly agree that CPM is not effective in repetitive projects, and does not provide an uninterrupted and smooth resource flow. The findings also indicate that CPM applications should not be used in repetitive projects.

This empirical study has two limitations. Firstly, there is an assumption that respondents are familiar with CPM methods. However, usage of the method does not guarantee understanding of the discipline. The survey was sent to construction managers and it was hoped that the respondents understand fully the implications of different scheduling systems.

Secondly, the scope of this study is limited only to the theories of task-technology fit. However, Goodhue and Thompson [2] argue that utilization based on theories of attitudes and behavior (e.g., expected consequences of utilization, social norms, habit, and facilitating conditions) and on the fit between the capabilities of the staff and the technology used may also help to predict performance impact.

Although the study has limitations, the findings and implications are significant in that the fit between task and technology does affect positively the use of scheduling technology.

Future work may involve the examination of other factors than task-technology fit, such as the staff's attitude and behavior toward technology that eventually affect the acceptance of the technology.

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