Construction Project Planning and Control Integrated System Model

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Abstract
A conceptual model of an integrated system for construction project planning and control is presented in this paper. The model is the result from an exploratory study upon current construction project management practice in small and medium size companies in Southeast Mexico. The model provides a general solution to the problems detected in the study, based on two key sources: 1) the managers’ opinion gathered from the study, and 2) project management theory. This model proposes guidelines to improve project management current practice in the region, through a better organization of the flow of information in all processes seeking to obtain an adequate “timely” decision making. The model addresses four areas: 1) project planning, 2) resources management (materials, labor, equipment, subcontracts and field overhead), 3) cost control and 4) cost forecasting. The model is described through: conceptual charts, flowcharts, and recommendations concerning the way the integrated model is expected to work. This model is the theoretical base for further development of computational tools, which eventually will help small and medium size companies to improve their effectiveness through the integration and automation of several managerial processes.

Keywords
Project planning, cost control, cost forecast, resource management.

INTRODUCTION

One of the main aspects that ensure the successful achievement of a construction project is comprehensive planning and control. However, there is evidence that small and medium size construction companies in Mexico (PYMES) dedicate great deal of effort to cost estimating, relegating the planning aspects of their projects. Lacking a thorough planning those firms are less likely to achieve comprehensive project control, and take timely decisions to keep projects on track. Such practice leads to overruns in both time and cost.

Many research studies have addressed that problem, showing the convenience to have cost and time integrated during the generation of plans. This goal could be achieved following also an integrated approach for the planning and control phases of the project. For instance, Syal et al., [1992] proposed a “Construction Project Planning Process Model for Small – Medium Builders.” However, even though other models have been developed to help PYMES [Syal et al., 1992], the context and
the objectives considered are quite different to the conditions faced by PYMES in developing countries.

Similar studies conducted at the School of Engineering of the Autonomous University of Yucatan (UADY) in the same topic resulted in an “Automated Cost Control Comprehensive System for PYMES,” by González and Domínguez [1998], and a “Materials Management System Prototype for Large Low Cost Housing Developments,” by González and Tirado [1998]. These studies, and others conducted in the region, share two main aspects: a) surveys administered to construction companies, aimed to know current project management practice, and their needs and requirements in that regard and b) system models proposals upon how to cope the problems found.

Alcudia [2002] updates the information through a new survey, addressing more specifically key aspects of the planning and control management functions. His study frames a conceptual model of an integrated system for construction project planning and control, and it is presented in this paper.

Alcudia’s exploratory study revealed, among other issues, the following:
• Twenty two percent of the companies do not perform planning at all.
• Eighty six percent of the companies that do planning use Gantt charts as their solely planning tool. Those charts, however, are not obtained from network diagrams (CPM, PDM, or alike).
• Resource planning is done by only 64% of the companies and it is mainly used for bidding purposes. Once the companies get contracts, only 26% of them review their plans prior to the start of the execution phase, and only 10% during the construction phase.
• Sixty eight percent of the companies that do planning, namely 43.5% of the total population, use computing tools for it. However, most of them use a widely known computing program developed at UADY, which was designed mainly for the initial unit price cost analysis and cost estimate.

This leads to think that PYMES have to implement several modifications and adjustments to their current management practice in order to achieve a more comprehensive planning and control of their construction projects. Furthermore, the fact that less than half the companies use computers for their planning function leads to think that they lack a comprehensive system to handle the great amount of information usually generated during the project management processes.

To help PYMES to solve problems mentioned above, a conceptual model needs to be framed first. Then, the conceptual model should be the basis for future development of computational tools that will help PYMES to improve their effectiveness. As suggested by Liberatore et al. [2001], to maximize the impact on practice, development of new planning and control methods should include their integration into project management software. From the Software Engineering perspective, the model proposed here constitutes the stage of “requirements definition” in the incremental software development process [Mills, 1980 on Sommerville, 2002]. Currently, a computational system based on the model discussed here is under development at UADY [González et al., 2005].

The improvements proposed in this model are primarily referred to the organization of the information flow, in all processes involved. The model addresses four main areas for improvement: 1) Project planning, 2) Resources Management: materials, labor, equipment, subcontracts and field overhead, 3) Cost Control, and 4) Cost and Time Forecasting.
As a starting point for the model's development, a “Basic Scenario” that is common to most of the interviewed companies was outlined, and a theoretical “Scheme of Departure” was proposed to frame the model's workspace.

MODEL'S DEVELOPMENT

Basic Scenario

According to Alcudia [2002], there is a common scenario for most PYMES that are about to start the execution phase of a project. It is important to consider this scenario for the model's development:

- The unit price scheme is the most common way for contracting construction projects in Mexico.
- Construction projects proposals are primarily valued on the merits of economic terms, neglecting other important aspects such as the proper planning of the project.
- As a result of the previous practice, contractors concentrate their effort in the integration of a bid primarily based on economic terms. This effort, as well as the company’s experience can be summarized in a single document: the project’s budget.
- The selected proposal becomes a contract for the winning company. However, such document does not contain enough information to manage the project properly.
- In general, most companies perform an inadequate and incomplete planning process, jeopardizing the execution of the project.

As a result, at the onset of project execution, most contractors only have the following documents to manage their projects: a) a work contract obtained primarily through a competitive bidding process, b) a detailed cost estimate for that contract, based on unit prices, c) a set of drawings and specifications and d) a simple schedule in the form of a Gantt's bar chart.

Since this scenario occurs shortly prior to the start of the project’s execution, it is strongly recommended to PYMES that they carry out comprehensive programming and pre-control schemes. This is the only way to be able to implement an efficient cost control that subsequently leads to effective decisions making. It should be clear that the model has to be based on the unit price scheme. Furthermore, it should facilitate the use of information already used in the budgets such as labor and equipment productivity, and the resources resulting from the takeoffs.

Schemes of Departure

From Alcudia’s exploratory study [2002], it was found that most PYMES carry out planning and control of their construction projects following the steps shown in Figure 1.
Since the purpose of this work is to improve current project management processes, the following new general steps are proposed: A, B, C, and D, shown in Figure 2. Those are suggested to substitute steps 5 and 6 in Figure 1.

Figure 2. General proposal for improvement in the execution of construction projects.

The results of the research clearly showed the authors that four major areas of improvement had to be included in any proposal: a) Comprehensive programming of the execution phase, b) Effective management of resources, c) Integration of cost and time control, and d) Cost forecasting.

Therefore, the first scheme to approach the problem was based on the four aspects shown on Figure 3.
Comprehensive programming of the execution phase

A basic premise for the development of the system is that most PYMES do not prepare a comprehensive planning based on networks scheduling. Therefore, that needs to be the starting point. From there, two additional key aspects have to be addressed: 1) resources management, and 2) project’s performance control. Alcudia’s survey reveals that constructors actually control their projects. However, such control does not come from a thorough planning process. This raises the following question: How can they implement an effective control if during planning time and cost are dealt separately? That characteristic has also been identified by Syal et al. in similar studies [1992]. Therefore, another important goal of the model should be the integration of cost and time for a more comprehensive and effective project management.

This starting phase is integrated by five different stages. Every stage is composed of several steps and requires a somehow lengthy description. Only a brief explanation is included in the following paragraphs. The reader could address the authors of this paper if requires further information.
The first and must important task the PYMES have to carry out is to make a work plan (program of activities) based on network diagramming. One of the first steps is to define the proper activities. Since the PYMES usually have close to one week from “notification of contract award” to the execution's starting date, they need to have beforehand the tools to prepare the programs in a very expedite way. PYMES also must take advantage of all the information gathered during the cost estimate, therefore they need tools for making quick references to this document, assuming it is in a digital media, while preparing the program in parallel. The outputs of this stage are: the list of activities, and their durations.

In the second stage, having the list of activities, PYMES have to establish the relationships among them, draw the activity network diagram, and do all computations. Following, they have to do adjustments to meet the contract's completion deadline. Finally, they will come up with the general work plan.

Once they have the work plan, it is extremely important to allocate all the resources from the cost estimate to the program of activities. Cost concepts definitions obtained from cost estimates based in a unit price scheme are many times far from activities definitions, however the same amount and cost of resources in cost estimates have to be allocated. For this step, PYMES need to take advantage of current information technologies. This proposal recommends the use of an electronic worksheet to integrate planned resources with activities (planned time). The electronic worksheet was named HEIAP in this work. This third stage's output is the integration of cost and time in digital media (HEIAP) and the “resource consumption schedules”.

The next stage is to compute and analyze the project's cash flow and look for all the project's financing options. The HEIAP will also facilitate this task.

Making use of HEIAP, the final stage is to define a Cost Accounts Scheme (CAS). The organization of information in the HEIAP has, at least, three categories: group of activities, activities, activity resources. Thus, the CAS should have the same organization. The quantity and unit cost of every activity resource will be the basic information for every cost account.

This phase's general purpose is to have all documents ready before starting execution. These documents (in digital media, preferably) go from contract, drawings and specifications all the way to the CAS, construction's strategies and methods and “gathering info cards”, including all sort of plans, programs and schedules. Only with a comprehensive planning strategy PYMES will be in a position to effectively manage the resources during project execution, establish and perform an integrated control, and take the best possible decisions relevant to the project [Russel et al., 1997].

Effective resources management

Regarding the needs identified by Alcudia [2002], the following was deemed proper: a) the model should allow site data collection for analysis and decision making, and b) the model should be able to control schedules of needs, procurement, purchasing, and payment. In other words, it is necessary to establish an effective management of the “direct resources”; and it should be based on a planning process departing from network scheduling.

The “direct resources” this proposal recommends for effective management are: materials, labor, machinery and equipment, subcontracts and field overhead. On this regard, the authors consider
that both the administrative and technical aspects have to be improved. The first aspect (actual management of resources) is the way to achieve the availability of resources on site with the following characteristics: “punctuality”, “right amount” and “according to project’s specifications”. The technical aspect is also called “performance control” or “cost engineering”; this is the way to achieve that “actual costs” and “actual progress” be as close to “plans” as possible (programs, schedules, budgets, cash flow, etc.).

The proposed model includes a scheme for each resource mentioned. However, only the one for the materials is shown and explained in this paper as an example.

**Materials Management**

From the survey, interviewees mentioned they prefer quality materials, at competitive prices, and procured on time. This raises a contradiction, since to achieve the above it is mandatory to take care of several aspects that are currently neglected, or at least not considered enough, such as the preparation of a schedule for materials’ procurement, considering both the capacity and reliability of suppliers and the financial resources available at the company. Moreover, such schedule should be flexible enough to accommodate potential contingencies.

A general scheme for materials management is shown on Figure 4. The starting point is the information coming from programs: “weekly requirements”, “procurement” and “purchase and payments”. The field engineer has a very important role in this phase; he has the additional function of checking and reporting actual materials consumption. The warehouse clerk may help with this task recording every material delivered to workers (issued material notes- IMN). It is important to understand that in every IMN has to be specified the activity or group of activities where the material will be used. This information is very valuable for the model, because it constitutes the “real costs” corresponding to the “actual progress”, that have to be compared with “planned costs” and “planned progress” for evaluation of performance.

The field engineer can generate and manage this information easily with the help of the HEIAP. This should be done on a weekly basis (biweekly, at the most), in order to be able to detect deviations and to take timely decisions.
Figure 4. Materials Management Scheme

Cost control and forecasting

According to Alcudia [2002], PYMES generally have a clear idea of the final objectives for a good control system. Therefore, the implementation of such system is an answer not only to a requisite imposed by clients but to their own interest. However, regarding resources, there is not a common agreement upon what needs to be controlled. For instance some focus on “resources management” (namely, everything has to be managed) while others on “resources control” (Pareto’s Law).

The cost control is a process that allows knowing actual performance of a project regarding cost and time. A great amount of data has to be gathered during the management of resources and then, it has to be organized and analyzed for comparison to plans. Then, it will possible to identify sources of variability, assess risk, and take pertinent decisions affecting the project performance [Isidore and Bock, 2002]. Cost forecasting is a fundamental tool in order to know “performance trends” (future costs). Since cost forecasting utilizes a large amount of information generated during the resources’ control phase, the model addresses both phases simultaneously.

In this proposal, five different stages are recommended to carry out cost control and forecasting, as shown in Figure 5:

a) Determination of actual progress. From this point, it is straightforward to derive work completed up to date (or current work completed). It is advisable to carry out this task on a weekly basis.

b) Determination of planned costs according to actual progress (current value of project). It is easy to obtain by inputting actual progress on the HEIAP. This task must be done either weekly or every two weeks at the most.

c) Gathering of real costs corresponding to work completed. The inputting of real costs on the system must be done on daily or weekly basis, depending on the type of resource.

d) Reporting and evaluation of cost control. The reports must be prepared no more than every two weeks in order to take timely decisions.

e) Cost forecasting. The idea is to determine future cost trends and to infer final cost, profit, selling price, and actual contingencies, from project's forecasted completion date.

CONCLUSIONS

- Planning is addressed very lightly by PYMES. It is primarily based on past (undocumented) experiences and only occasionally is done through a rigorous analysis of information.
- After winning a contract, PYMES do not dedicate enough time to prepare a comprehensive plan. Such planning is the basis for their control.
- A comprehensive model system to integrate time and cost, for planning and control purposes, was proposed to respond to the needs of the common problem scenario. The model incorporates valuable managers’ opinions. It is aimed to be a guide for PYMES to prepare a comprehensive planning and pre-control process expeditiously; it should also be the basis for resource management, and cost and time control.
• It is very important to develop a computer program to help PYMES to carry out the tasks included in the model. This will make the model more attractive to PYMES. For an industry to survive in a very competitive market it must adopt emerging technologies to increase its efficiency.
• The model and the computer program will comprise an integrated system for planning and controlling construction projects.
• The system will require testing and validation, primarily by PYMES that expressed their willingness to participate in the research.
• The system should be flexible enough to be adapted to each company’s needs.

Figure 5. Cost Control and Forecasting Scheme

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