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Object-oriented resource-based planning method (ORPM) for construction

Jonathan Jingshen Shi, Zhongming Deng

Department of Building and Construction, City University of Hong Kong, Tat Chee Avenue, Kowloon, Hong Kong

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Abstract

This research intends to develop a construction scheduling and planning method, named Object-oriented Resource-based Planning Method (ORPM), for meeting the different requirements at various planning stages. Object-oriented representation is adopted for modelling construction activities. Each object has attribute values to detail the required conditions to construct the activity, such as logical dependency, and resource demands. The planner can define a set of constraints as the active planning constraints based on the planning stage and availability of project information. The planning process checks the active constraints against actual availability of resources for each activity. An activity cannot be scheduled for construction until all of the active constraints are satisfied. At pre-construction stage, less constraints such as technological dependency and resource capacity can be selected into the active planning constraint set; and more constraints can be selected at the construction planning stage when more detailed project information is available. The planning mechanism is demonstrated for various planning purposes through an example project.

Keywords: Planning; Scheduling; Critical path method (CPM); Program evaluation and review technique (PERT); Construction resource planning

1. Background

Construction is one of the largest industries in many countries. However, the industry has been experiencing such problems as cost overrun, delayed completion, disputes and even litigation. Scheduling and planning are identified among the top potential areas needing improvements.[1]

For its simplicity, the bar chart is still the predominant scheduling method in the industry, especially for short-term planning.[2] The main drawback of a bar chart is that it cannot detail the logical interrelationships among activities. If an activity is behind schedule, it may not be possible to ascertain the effect of such delay on the completion of the project.

Network models can overcome the drawbacks of a bar chart by detailing activity interrelationships. CPM (Critical Path Method), to a less extent PERT (Program Evaluation and Review Technique), provide the most widely used network models. Many successful applications have been reported.[3–5] In the mean time, many drawbacks have also been identified.[6–12] Some of these criticisms are:

- CPM considers only logical constraints during planning, which is not the real world of a construction process. In practice, the logical constraint is only one of many conditions to determine whether an activity can be scheduled for construction or not.
- CPM treats the construction of an activity as a non-stop process, i.e., FT (finish time) = ST (start time) + D (activity's duration). In practice, an activity's construction may be interrupted if its required resources or other conditions cannot be met.
- CPM lacks the ability to model the projects as a stepwise, dynamic decision process.

Research has been conducted by addressing these drawbacks in order to enhance CPM-based techniques.

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Enhanced CPM based scheduling methods were presented, incorporating resource capacity into the scheduling process.[11,13] Project resource constraint issues have been studied extensively.[11,14–16,17–19] Re-definition and re-calculation of floats were discussed at the time of incorporating resources into scheduling.[20–23]

On the other hand, new planning and scheduling methods have also been studied. Russell and Wong[24] presented a planning method by integrating CPM and linear scheduling methods. Pultar[25] developed a progress-based scheduling technique based on progress charts and bar charts to overcome the problem of fragmentation of activities during the application of the conventional CPM to construction projects. Espedal et al.[8] discussed TOPP project planning concepts, which intends to find a schedule that gives the highest expected life cycle profitability given a set of restrictions. Jaafari[26,27] proposed the Time And Priority Allocation Scheduling (TAPAS) method. TAPAS treats each activity as 'critical' and of equal priority unless there are reasons to the contrary, such as resource or economic constraints. It can generate the project plan without a network and be integrated with risk management and earned value techniques.

Construction process simulation has been progressing very fast in the past two decades with the advancement of computer technology since CYCLONE was introduced by Halpin[34,35] in 1977. It is an effective planning tool which allows the user to investigate the detailed operations of a construction process with a dynamic and stochastic nature. Because of the difficulties and required knowledge in using simulation, research efforts are still needed to make simulation an applicable planning tool, especially at project level.[29]

Knowledge-based systems have been studied since 1980's with the intention of enhancing construction planning[30,28,31] in some or all of the following aspects:[32] representation of the project, generation of activities, determination of dependencies between activities, resource allocation and scheduling of activities. However, no applicable system has been reported yet.

In summary, the current planning methods in the construction industry are bar charts and CPM-based techniques despite their criticisms and drawbacks. This research presents a new method—Object-oriented Resource-based Planning Method (ORPM). ORPM provides an object-oriented representation for modelling construction activities. A set of constraints (e.g., technological dependencies and resource demands) can be selected by the user as the criteria for determining whether an activity can be scheduled for construction or not. The planning process checks the satisfaction of the selected constraints. An activity cannot be scheduled for construction until all of its constraints are satisfied. With the flexible customer-tailored set of constraints, ORPM is flexible for different requirements at various stages of a construction project. It should be mentioned that ORPM is in the process of being implemented into a computer system. The paper addresses the planning method.

2. Construction plans and resource constraint patterns

Both preconstruction and construction plans are widely used in the industry. The preconstruction plan of a project considers timing of works, work schedules and resource requirements before the project starts. The construction plan, similar to the short-term plan, incorporates the progress information in construction process to update the original plan in order to guide the works on site.

At pre-construction planning stage, the detailed project information, such as equipment, materials and labour, is usually unknown except for certain brief figures like maximum available units of resources. The pre-construction plan includes target schedule, milestones, and resource profile. The common resource constraints are: 1) The total demand should not exceed the maximum available units, and 2) the demand should be levelled.

At the construction stage, more detailed project information becomes available. The construction planning incorporates the available information and construction progress information to update the original schedule. Resource constraints can be detailed with real time, for instance, one crane in week 2, and three cranes in week 5.

A unified resource constraint pattern can be defined for both planning stages, mathematically,

$$R_i(t) \le r_i(t) \quad 1 \le t \le T \tag{1}$$

where i is the ith resource; t is current period; T is the total duration; $r_i(t)$ is the maximum available unit of resource i at time t; and $R_i(t)$ is the demand for resource i at time t.

$r_i(t)$ is a constant value at pre-construction stage and is represented by the maximum available unit. It is the function of time at construction planning stage and can be given by the actual availability profile along project duration.

3. Object-oriented representation of activities

A construction project can be represented as an interrelated collection of activities through work breakdown structure.[33] An activity may represent different level of information at different planning stages. For instance, it may indicate a work package at pre-con-