A decision support tool for subcontractor multi-project resource allocation

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Abstract

A main challenge that subcontractors face is to allocate finite resources across multiple projects under frequent, changing conditions. Most existing tools provide limited support for resource reallocation across projects, especially for rapid what-if analysis scenarios for decision making. This leads to reliance on manual resource allocation methods.

This paper presents a practical tool for multi-project resource allocation, including support for what-if scenario analysis. A test case with a variety of projects and task durations is presented to demonstrate the tool. Results show the tool is superior to current manual practices with respect to time to accomplish resource allocation as well as identification of resource conflicts.

*Keywords*: subcontractor, decision support tool, resource allocation

1 Introduction

It is common for a typical construction project to utilize dozens of subcontractors, with 80-90% of the work of most building projects in the U.S. being performed by subcontractors (Hinze and Tracey 1994). The performance of the subcontractor is critical to project success (Gray and Flanagan 1989; Arditi and Chotibhongs 2005). Commonly, subcontractors have to perform work on multiple projects simultaneously (Sacks 2004), but with limited resources, each subcontractor strives to maximize its workload at any given time for optimum resource utilization (O'Brien and Fischer 2000; Matthews, Howell et al. 2003). Thus, subcontractors work activities are subject to individual resource constraints (Kim and Paulson 2003).

During construction, changes frequently occur and conflict with subcontractor’s capacity constraints, causing immediate reallocation of resources (O'Brien 1998). As a result, resource allocation due to frequent changes is a critical challenge for subcontractors. Because of frequent changes, subcontractors normally switch resources among projects, and they strive to understand the potential impacts after reallocating resources. Unfortunately, most existing tools provide limited support for resource reallocation across projects, especially for rapid what-if analysis scenarios for decision making. This leads to reliance on manual resource allocation methods. In response, this paper presents a practical tool for multi-project resource allocation. A test case with a variety of projects and task durations is presented to demonstrate the tool.
2 Development of the tool

The tool aims to facilitate subcontractor’s resource management, particularly focusing on providing what-if analysis while switching a single resource among projects. This section covers the development environment, system input and output and the processes of reallocating resources.

2.1 Development environment

The tool was developed using Visual Studio.Net (2005) environment and the Visual Basic.Net programming language. The tool allows users to input information through a Graphical User Interface (GUI) and uses XML as the internal data exchange format.

2.2 System input and output

System input includes: 1) list of projects, with the attributes of name, expected project start, finish dates, address, project type, customer name, contract type. The manager must categorize each project priority as high, medium or low. The manager specifies overhead cost per day, 2) list of activities for each project, each activity should have basic information: name, temporal dependencies of activities, start date, finish date, required resource skill, and penalty delay cost per day, and 3) list of human resources, each employee should have information including name, skills, normal work hours per day, overtime rate per hour. Employees start work and finish work dates also need to be specified because some employees may only be temporarily employed.

System output includes: 1) list of projects: each project includes project priority, customer name, and contract type, 2) list of tasks: each task records start, finish dates, predecessors, successors, required resource skills, work days, overtime days, 3) list of resources: each resource tracks normal rate, overtime rate, and skills, 4) list of assignments: each assignment has information including assigned resource, assigned project, assigned activity, assigned dates, work days, overtime days, and expected expense, 5) status of projects, information about each project including status, priority and expected expense, planned finish date, and actual finish date, 6) status of tasks, information for each task including status, expected expense, start delay, resource delay, total delay, planned finish date and actual finish date, 7) impact of projects, shows original project expenses and new project expenses before and after resource reallocation, and 8) impact of tasks, shows original task expenses, new expenses, original and new delays, original finish date, and new finish date for tasks.

2.3 Processes of reallocating resources

The key capability of the tool is to provide the what-if analysis scenario of resource reallocation. The process of reallocating a resource is shown in Figure 1. When a manager wants to reallocate a resource, the first step is to check current project status, task status and capacity utilization of resources. If a specific project and task requires an additional resource, the manager can select an appropriate resource based on the resource capacity utilization. Once the resource is selected to be reallocated to the specific project and task, the potential impacts on projects and tasks will be displayed. By reviewing the potential impacts, the manager can either accept this exercise or select another resource to go over the process. This rapid what-if analysis facilitates decision-making process.
Figure 1. Process of reallocating a resource

Figure 2 presents the screen shots of reallocating a resource. It shows the current status of project and task, as well as the current resource utilization of the selected resource. The upper left project status table shows the priority, current expense and status of each project. The lower left task status table shows the status of each task, including the original start and finish dates and actual start and finish dates. While selecting a resource, the lower right capacity utilization chart shows the current capacity utilization of that resource overtime. Based on the information provided, a manager can reallocate a resource to a desired project and task.

Figure 2. Select a resource, a project and a task based on current status

Figure 3 presents the potential impacts on overall schedule projects and tasks. The upper left project impact table shows the impacts of all projects on schedule and cost after reallocating the resource. The table below is the task impact table, which displays the impacts of all tasks on schedule and cost. The project cost impact chart, and the task duration impact chart locate beside the two tables and graphically present the differences before and after reallocating the resource. The lower part of Figure 3 displays two capacity utilization charts. The left chart with blue bars shows the capacity utilization overtime of a selected resource before reallocating the resource, while the right chart with pink bars shows the capacity utilization overtime after reallocating the resource.
3 Validation

Validation of the tool is conducted by a test case with a subcontractor in Louisville, Kentucky. A trial using a complete dataset of projects, tasks and employee assignments for two weeks, from July 6, 2009 to July 17, 2009 was performed. During the two weeks period, eight employees performed field work for eight different types of projects (Table 1).

Table 1. Projects for testing the tool

<table>
<thead>
<tr>
<th>Project ID</th>
<th>Project Name</th>
<th>Number of Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Church 1</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>High School</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>Church 2</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>Hospital 1</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>Church 3</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>Hospital 2</td>
<td>5</td>
</tr>
<tr>
<td>7</td>
<td>Hospital 3</td>
<td>9</td>
</tr>
<tr>
<td>8</td>
<td>Hospital 4</td>
<td>5</td>
</tr>
</tbody>
</table>

The validation is conducted in two ways to assess the usefulness of the tool. First, we compared the time used for generating plans by the tool with real practice. In the test case, the resource allocation plans were established through coordination and compromise among two project managers and one project coordinator throughout the week with interaction periods multiple times per day. In general, the time for manual practice was sporadically throughout the week. Table 2 shows the comparison for time used to generate plans by software and real practice.
Table 2. Comparison for time used to generate plans by software and real practice

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Time to generate a plan with manual exercise</th>
<th>Time to generate a plan with the tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switch resources between tasks in one project</td>
<td>Sporadically throughout the week</td>
<td>&lt;1 min</td>
</tr>
<tr>
<td>Switch resources between projects</td>
<td>Sporadically throughout the week</td>
<td>&lt;1 min</td>
</tr>
</tbody>
</table>

The other way to assess the usefulness of the tool is to test the capability of identifying potential conflicts during the two weeks duration. From the dataset, the tool displayed that a resource was over allocated on certain days (Figure 4).

![Figure 4. Example of a resource is over allocated on certain days](image)

Table 3 summarizes the overall results of identifying conflicts by the tool. Please note that those conflicts were identified between July 6 to July 17 2009.

Table 3. Results of identifying conflicts by the implementation software

<table>
<thead>
<tr>
<th>Employee</th>
<th>Projects with conflicts</th>
<th>Task with conflicts</th>
<th>Number of total assignments</th>
<th>Percentage of conflicts</th>
<th>Number of days with conflicts</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Church 1, Church 2, Hospital 2</td>
<td>Pull cable, build rack, install pager speaker</td>
<td>10</td>
<td>30%</td>
<td>4</td>
</tr>
<tr>
<td>B</td>
<td>Church 1, High School</td>
<td>Programming, speakers</td>
<td>10</td>
<td>20%</td>
<td>3</td>
</tr>
<tr>
<td>C</td>
<td>Hospital 1, Hospital 4</td>
<td>Test pagers, solder microphone</td>
<td>4</td>
<td>50%</td>
<td>1</td>
</tr>
</tbody>
</table>

This test case was considered a robust test case because the dataset involved a variety of project types and task durations. In addition to above quantitative validation, qualitative validation was also performed by live demonstration to the employees from different positions in the company. The tool was considered acceptable and useful from their perspective.
4 Conclusion

Subcontractors suffer frequent and rapid changes while performing tasks. Those changes commonly cause reallocating resources due to resource constraints. However, most existing tools are limited to facilitate decision-making processes under multi-project and rapid changing environment. This research presents a tool with the capability of providing what-if analysis to deal with resource reallocation. The tool was tested to be superior to existing manual exercise through a robust test case.

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References


