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Challenges and suggestions of resource planning for standardized concurrent construction

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Abstract: Concurrent construction offers considerable improvement for shorten the project duration of its production process. Therefore, standardized concurrent construction is widely applied in building construction projects. However, resources planning for standardized concurrent construction project is manually developed by construction manager. This practice is not effective since it is time-consuming and error-prone for managers to identify all project-specific information, distinguish different activity-resource types, interpret these types and analyze how they affect resource allocated on an ad hoc basis. Therefore, this research investigates the opportunity for leveraging activity modeling to enable automated resource planning for standardized concurrent construction during project development, with identifying the characteristics of construction activities under standardized concurrent planning and determining the activity-resources types that affects resource planning. Both will function as a basis for modeling these construction activities in a computer-interpretable manner and for automation in resource planning.

Key words: Resource management; Standardized concurrent construction; Project planning; Characteristic of construction activities; Activity-resource types

1. INTRODUCTION

Optimum resource planning is one of the key impact factors that affect the smooth production progressing of a construction project, which is more important to standardized concurrent construction (SCC) project that achieve the maximum duration overlapped in scheduling the construction activities [1-3]. SCC is designed to reduce the production time in a maximum level, in which a major set of activities is resulted in highly interdependent activities, i.e., at least two activity groups that depend upon each other to start and progress [3].

1.1 Resource planning for standardized concurrent construction project

Manual allocation is mainly applied in resource planning for construction projects [4]. This practice is not effective since it is time-consuming and error-prone for managers to manually identify all this information and make the allocation for all project-specific activities of concurrent construction [5]. In addition, inconsistent identification and input may result in discrepancies among different types of resources' planning, which affects the concurrent construction activities' progressing as some of them are interdependent with each other [1]. Therefore, there is a need of automation for supporting the resource planning in a quick and consistent manner, rather than such a manual manner. To enable automated resource planning for SCC project, initial steps are 1) identifying the characteristics of construction activities of SCC projects; and 2) determining the activity-resource types of SCC activities. Both of them will function as a basis for research efforts related to capture reliable information in modeling these construction activities as a computer-interpretable manner and automation in resource planning.

1.2 Modeling construction resources in activity representation

The first step in automated resource planning is to formalize a generic activity modeling capturing resources information in a computer-interpretable way. The benefit of such an activity modeling, is that once the users represent the required resources within it, then the system can automatically generate the project-specific instances of those resources. The opportunity for leveraging activity modeling in resource management of SCC project development is that enabling automation in resource planning. Recent studies have clear showed that even industry had applied SCC in building projects, tools such as Critical Path Method and Program Evaluation and Review Technique are not available for modeling concurrent activity groups that are interdependent [3, 6].

Activity representation provides the basis for an explicit modeling of construction knowledge to enable construction managers to develop the project plan in a fast and constant manner. Compared to conventional method, activity representation can enable the related resources be allocated and updated quickly even once change order is issued by the client. Available activity modeling that enable capturing and transferring construction information are mainly based on the OARPLAN and AROW schemas [7-11]. Construction activity representation in this area are extending from the tuple, i.e., <Action>, <Resources>, <Object>, and <WorkArea>, which is available for project prediction such as planning and scheduling, etc. [7, 12-15].

Even current activity representation has specified its specific actions and resources for construction planning and scheduling, it is limited to model how SCC activities are going to be executed with its related resources, i.e., which activity groups are interdependent and when to progress them; which objects will be progressed by different activity groups; and which activities require critical, named or designated resources. Those representations extended from OARPLAN have formalized resources as who and how to proceed the work, including manpower, equipment and material. However, this representation of resources does not accommodate the production details of construction activities, such resource specific types, its available work hours and production rate. Generally, representation for SCC project is required to enable to retrieve the above activities, its groups' relationships and information, which is necessary for automated generation of resource planning.

In conclusion, current available knowledge is not available to fully capturing the necessary information of SCC projects for automated resource planning, in the following section of this paper, these will be discussed with a case example, and the opportunities with a specific emphasis on supporting SCC projects will be included.

2. MOTIVATING EXAMPLE

This section will illustrate the above knowledge gaps by using a case example. Figure 1 shows part of the plan of a SCC case. Taking rebar bending activity as an example, which belongs to main structure engineering, it has been represented using AROW schema as Figure 2 shows. However, such a representation cannot differentiate 1) whether the group the rebar bending activity belongs to are interdependent with other activity groups or not and when they have to start and progress; 2) whether the wall will be progressed by activities from other groups; whether it occupies the critical path with named or designated resources needed. In addition, this representation cannot accommodate the production details of resources such as the required available time and production rate, etc. All of these aspects is necessary to permit the automated resources planning for SCC projects.

As mentioned before, activity modeling is being proposed and applied for representing and storing construction information throughout the production process. This research will aim at automated resource planning for SCC in residential building projects. Therefore, the anticipated approach does not only make use of the activity modeling, but also leverages this medium for automated resource planning that predict and update the resource allocation effectively. In order to enable the automated resource planning, there is a need to capture concurrent construction information in a computer-interpretable format. Along with this research target, the next section will present the results of this study in which characteristics of SCC activities are investigated and activity-resource types are formalized, which is the basis for developing the activity representation and for use in automated resource planning.

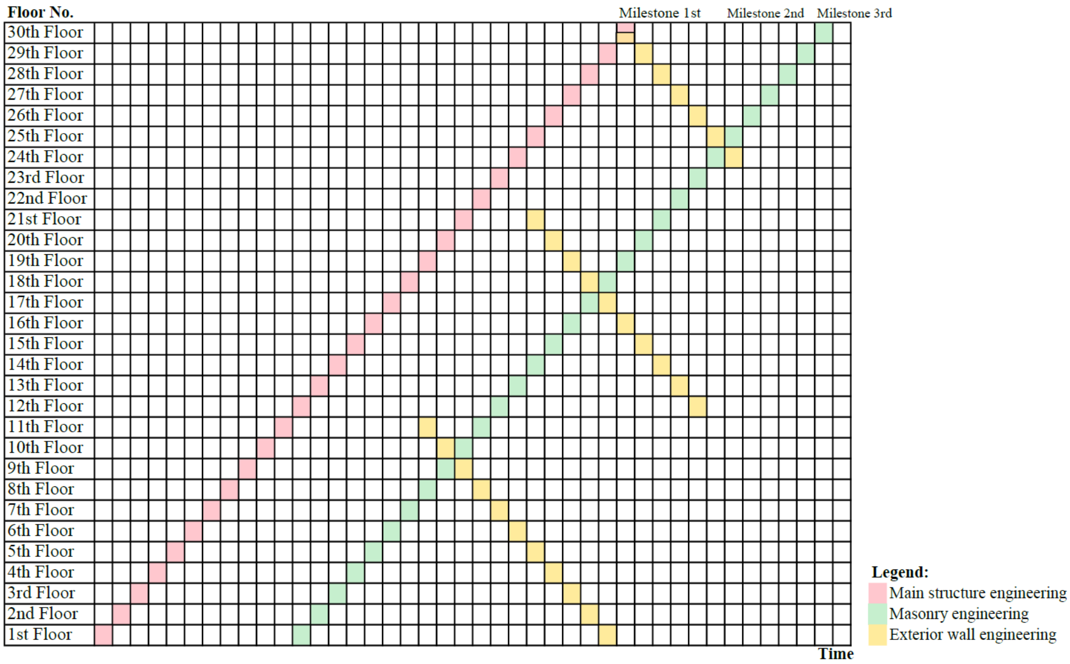


Figure 1. Part of a SCC project's plan

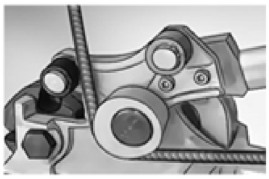
AROW Example			
	Activity		Rebar Bending
	Action		Bending
	Resource	Labour	Rebar Workers
		Equipment	Bar Bending Machine
		Material	Rebar
	Object		Wall
	Work area		Site Rebar Processing Area

Figure 2. Activity example represented using AROW schema

3. DIFFERENT TYPES OF ACTIVITY-RESOURCE REQUIRED OF SCC PROJECTS

Activity-resource type, which affects the resource planning, is the basis to automated resource planning. This section describes the 192 types concerning activity-resource of SCC activities. Without automated resource planning for SCC projects, construction manager should manually distinguish different activity-resource types and interpret these types for resource planning, which is not efficient as the number of possible activity-resource types of a construction activity reaches about two hundred.

3.1. Characteristics of SCC activities

Regarding activity-resource, the characteristic of SCC activities serves as precursors of the resource-use type differentiator (RUTD). Therefore, six characteristics were identified based on observations, literature reviews, and case studies. These six characteristics indicates how RUTDs should be proceed concerning activity-resource of SCC activities (Figure 3). These six characteristics are:

C1: SCC activities are classified into six groups based on the overlapped progress, i.e., Main Structure, Masonry, Plastering, Exterior Wall, Dismantle Scaffold, Interior Decoration. This characteristic derives RUTD 1.

C2: Some SCC activity groups are interdependent, in which at least two groups depend on each other to start and progress [3]. This characteristic derives RUTD 2.

C3: Some object needs to be progressed by activities from different groups. This characteristic derives RUTD 3.

C4: Some SCC activity groups are partly or wholly occupying the critical path, while others do not. This characteristic derives RUTD 4.

C5: Some SCC activities requires named resources, rather than resources that satisfied its requirements. This characteristic derives RUTD 5.

C6: Some SCC activities are required a designated resource, which is not allowed to use by other activities. This characteristic derives RUTD 6.

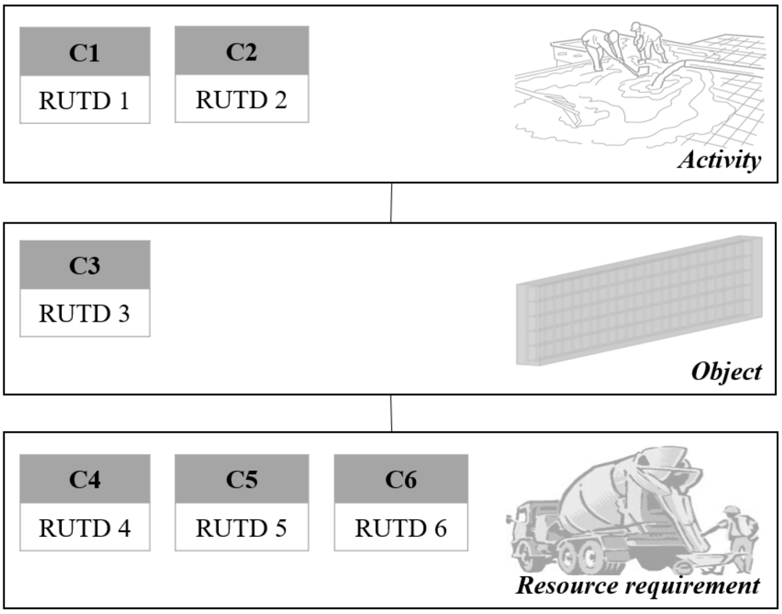


Figure 3. Derivation of RUTDs based on six characteristics

3.2. Activity-resource types

Resource-use type differentiators (RUTDs) are used to distinguish between different activity-resource types in automated resource planning of SCC projects. An activity-resource type of a SCC activity can be characterized as a combination of choices among these RUTDs, and automated resource planning checks the chosen group of RUTDs to proceed the resource allocation. Based on the six characteristics of construction activities, this research defined six RUTDs considering three perspectives (i.e., activity, object and resource). The differentiation of SCC activities was defined in terms of resource-use and its calculations as Figure 4 shows, which concerns all activity-resource types simultaneously. The six RUTDs are:

RUTD 1 differentiates between Main Structure, Masonry, Plastering, Exterior Wall, Dismantle Scaffold, and Interior Decoration activity groups.

RUTD 2 differentiates between interdependent and independent activity groups.

RUTD 3 differentiates between objects that need to be progressed by activities from different groups and those that only be progressed by activities from same groups.

RUTD 4 differentiates between resources that are critical and non-critical ones.

RUTD 5 differentiates between activities that required named resources and those required resources with certain features.

RUTD 6 differentiates between activities that required designated resources and those do not require designated resources.

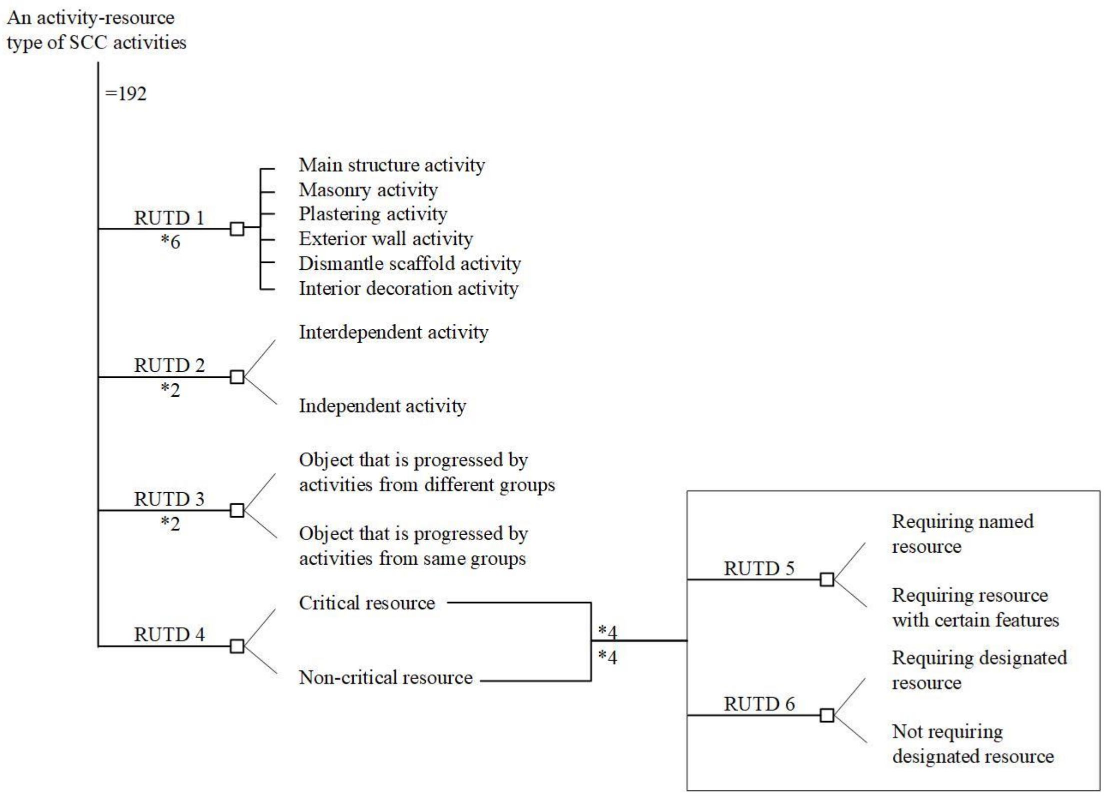


Figure 4. Differentiation of construction activities in terms of resource-use and its calculation.

4. CASE STUDY

In order to introduce possible benefits that can be gained by automated resource planning, this research conducted a case study. This case is a SCC residential project with 32 story high. Its typical floor was selected as a test-bed (Figure 5). This research investigated main structure activity group as listed under Table 1, presenting the information about 13 activity instances as an example. Afterwards, these activities were manually analyzed and mapped with specific resource instances in this study, which aimed to introduce the opportunities and benefits of automated resource planning for SCC projects.

4.1. Method

During this case study, this research investigated 13 activities within this typical floor example. Based on the project data, this research differentiated these activities based on their activity-resource types and analyzed how they types affect the resource allocated. The case study took two scenarios as a basis to further investigate how leveraging activity modeling to enable automated resource planning can help the construction manager during project development, where the current practice is not effective. In addition, this case study only focused on manpower resource variable to record and compare the changes between these two scenarios.

4.2. Results

As showed Table 1, these 13 activities are categorized into five types according to different combinations of choices among the formalized RUTDs. As all of these activities belongs to main structre activity group, their RUTD 1 are the same choices. In SCC planning, main structure, masonry and plastering activity groups are overlapped and interdependent by occupying part of the project critical path, therefore, the RUTD 2 of these activites are all chossing the interdependent one. In addition, as activities belonging to main structre activity group are scheduled in critical path, their RUTD 4 results are also same with each other. Consequently, what makes the activity-resource type different between these 13 activities shoule be their choices about RUTD 3, 5, 6. Usually the construction manager needs to distinguish these activity-resource types and interpret them before resource planning as the amount allocated will be affected. For example, the resource amount allocated to these 13 activities will be affected by the scheduled length of the overall critical path of this SCC project, which are detaily discussed as follows.

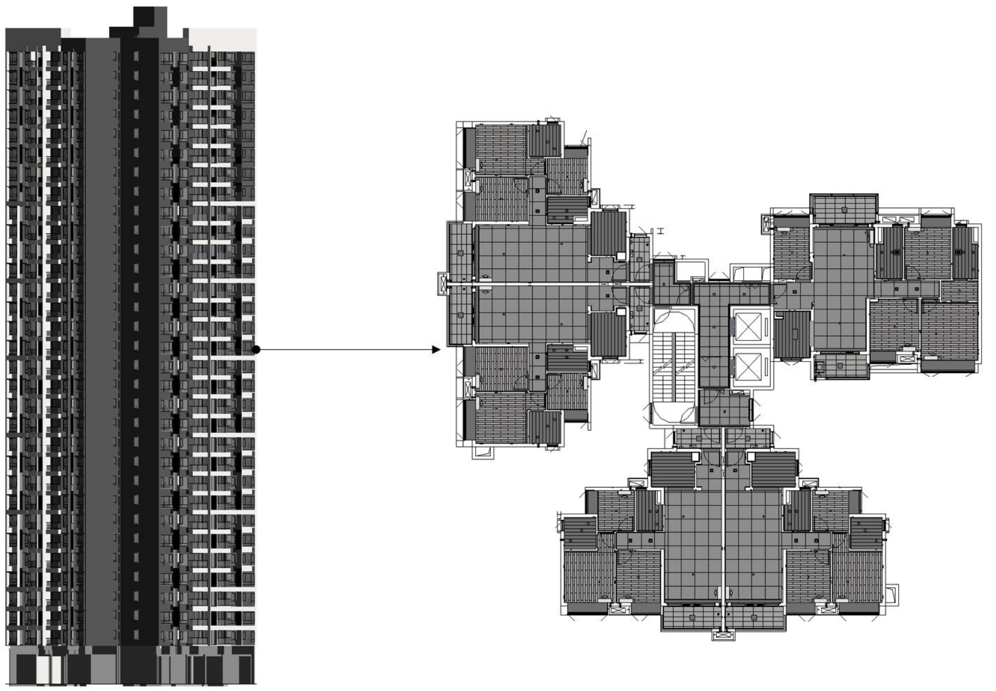


Figure 5. A SCC residential project with its typical floor plan

Table 1. Activity instances with their types

No.	Construction activities	Activity-resource type				
		1	2	3	4	5
1	Setting out the building	✓				
2	Placeing reinforcement	✓				
3	Removing suspended formwork		✓			
4	Chiseling	✓				
5	Welding positioning rebar	✓				
6	Binding rebar for column			✓		
7	Installing aluminum formwork for wall and column				✓	
8	Carcassing for wall					✓
9	Installing aluminum formwork for beam and slab				✓	
10	Binding rebar for beam and slab			✓		
11	Carcassing for slab					✓
12	Adjusting the formwork				✓	
13	Pouring concrete			✓		
	In total	4	1	3	3	2

Table 2 shows the manpower resource planned which the schedule control criteria of each typical floor is finished 5 days. The client of this SCC project want to shorten the critical path by requiring each typical floor should be finished within 4 days, with the emphasis on faster capital turnover. The results of the manpower resource planned due to the change of the schedule control criteria are showed in Table 3, as the work quantity and project quota remain the same. Comparing these two manpower resource plans, the resource change happened within the three activities: installing aluminum formwork for wall and column, installing aluminum formwork for beam and slab and adjusting the formwork. It can also be found that all resource changes are only available within type 4, in which the formwok workers are required to be designated and cannot be occupied with other activities. Otherwise, the duration to finish each floor's related work will be affected and the starting time of overlapped activities belongs to masonry and plastering group would be postponed because of their interdenpendency. As the results, the overall length of the critical path would be longer than the scheduled ones.

As presented in this case study, even only analyzing the manpower resource of main structure activity group for only one typical floor, it require the construction managers to identify all the project information related to activity's object and action (e.g., quantity and standardized start sequence), distinguish different activity-resource types, interprete them and analyze how they affect resource allocated manually. As the example discussed in the above case, critical resources will be affected by the scheduled length of the overall critical path. This practice is not effective since it is time-consuming and for construction manager to repeat this process for each activity. It can also be error-prone and cause discrepancies among different types of resource planning due to inconsistent identification of information and input. To overcome this challenge, this research suggests leveraging activity modeling by representing the required activity information, then the automated resource planning system can be developed to generate the project-specific instances of those resources within it. Such an method will also simultaneously involves information such as the SCC schedule data. Therefore, if this innovative method is available, once the construction manager simply represent the activity, the resource planned can also be updated quickly according to changes in schedule or others.

Table 2. Main structure group activities of a typical floor (5 days per floor)

No.	**Activity**	**Schedule**										**Manpower resource quantity**
		1		2		3		4		5		
		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	
1	Setting out the building	X										2
2	Placeing reinforcement	X										2
3	Removing suspended formwork	X										6
4	Chiseling	X										2
5	Welding positioning rebar	X										2
6	Binding rebar for column	X	X									13
7	Installing aluminum formwork for wall and column		X	X	X							20
8	Carcassing for wall				X							8
9	Installing aluminum formwork for beam and slab				X	X	X					20
10	Binding rebar for beam and slab							X	X			13

11	Carcassing for slab						X			8
12	Adjusting the formwork				X	X	X			23
13	Pouring concrete							X	X	15

Table 3. Main structure group activities of a typical floor (4 days per floor)

No.	Activity	Schedule								Manpower resource quantity
		1		2		3		4		
		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	
1	Setting out the building	X								2
2	Placeing reinforcement	X								2
3	Removing suspended formwork	X								6
4	Chiseling	X								2
5	Welding positioning rebar	X								2
6	Binding rebar for column	X	X							13
7	Installing aluminum formwork for wall and column		X	X						25
8	Carcassing for wall			X						8
9	Installing aluminum formwork for beam and slab				X	X				25
10	Binding rebar for beam and slab						X	X		13
11	Carcassing for slab							X		8
12	Adjusting the formwork					X	X			30
13	Pouring concrete							X	X	15

5. CONCLUSIONS

Current practice of SCC resources planning is mainly based on construction manager’s manual estimation. Generally, there are no methods available to enable automated resources planning to help construction managers in SCC project. Automated resource planning can provide a fast and consistent allocation of resources including manpower, machine, and material, which are directly related to construction cost. Hence, when inconsistent resource allocation across different planners, it can also provide a new control baseline for client to make better decisions.

This study, in which review current literature and practice, have identified six characteristics of SCC activities and defined 192 activity-resource types based on those characteristics. These activity-resource types, which affect the resource planning, are required to differentiate for SCC project. This finding provides a basis and motivation for further research in modeling SCC activities and automation in resource planning. With the development of automated resource planning for SCC projects, it is possible to achieve optimum planning by quickly and consistently analyzing those resource allocated.

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