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Activity Creating Method for Multi-Unit Projects

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Abstract

The typical Critical Path Method (CPM) leaves it to the construction managers to overcome two problems in developing networks. First, the construction manager needs to prepare information on the type of activities and their precedence relations in order to develop a network schedule. Second, he or she can include space information into the network schedule such as the locations where the activities take place, only with difficulty. These two problems make it difficult for an inexperienced person to create a network. The purpose of this paper is to provide construction managers with set equations of creating a network schedule for multiunit projects. A space-resource combined network creation are presented in this paper, which includes equations for generating a list of required activities, their precedence relations, and information on their location. Information on the space (location) and the resource is the required data for this method. Based on this information, this method divides a project into a number of activities so that each activity contains the information on the location where the activity takes place and the principal resource required for that activity. Precedence relations are then obtained from the sequence of space and resource. This method has the potential to reduce human efforts in scheduling activities.

Keywords: scheduling, construction, resource, space, network, project

1. INTRODUCTION

A typical network scheduling process is performed in two phases: network creation and network computation. Activity definition and arrangement are associated with the network creation while determining a critical path and calculating project duration are included in the network computation. In the network creation phase, the construction manager normally divides the project into a number of activities and arranges them in an appropriate order. In the network computation phase, he or she assigns duration to each activity, and then computes the project duration along the critical path.

Typical scheduling techniques such as the critical path method (CPM), a convenient tool in network computation, leave the network creation to the construction manager. Most scheduling tools have concentrated on the computation of the project duration and the control, thus disregarded methodology for dividing the project into activities and arranging the activities in an appropriate order. One of the reasons is that network creation requires the construction manager to possess not only a sufficient knowledge, but also certain amount of insight and work experience, even though network computation is performed through a routine process. A construction project contains many processes that are not, in act, standardized or systematized for automatic network creation. Because of these, arriving at a definite rule and logic in generating and arranging the activities is not an easy task. Such a task requires intuition and experience to a certain degree.

However, in facilities that consist of several similar or identical components, it is possible to derive certain logic in the sequence of creating those components. Construction managers are often faced with projects that include several identical or similar space units, such as classrooms in schools; wards in general hospitals; or rooms, toilets, stairs, or floors in multistory buildings. Whoever controls a number of activities on a multiunit project, frequently encounters such activities, which are performed in regular sequence. These multiunit projects are characterized by activities which are repeated, and which, in most instances, arise from the subdivision of a generalized activity into specific activities associated with particular units (Harris, 1998). These units are not separate from and independent of project scheduling, but should be combined with resource and activity in order to provide a systematized network creation process.

A number of attempts have been made to interpret the construction process by the space-resource or the space-activity combination. These include “Line of Balance” (O'Brien 1969), “Planning Construction of Repetitive Building Units” (Carr 1974), “Construction Planning Technique” (Selinger 1980), “Vertical Production Method” (O'Brien 1975), etc. Stradal (1982) devised the Time Space Scheduling Method, which facilitates the scheduling of repetitive work in spaces of a project. A three-dimensional concept, including time, activity, and space, is incorporated in a simple two-dimensional chart which displays both the relation of the activities and the space where they take place in a given time. “Space-constrained Resource-constrained Scheduling” (Thabet 1992) represents another approach that considers not only the horizontal and vertical logic in scheduling, but the space demand and availability as well. Harris (1998) integrated these methods into one generalized model, insisting that each of the above methods was essentially the same, in that they schedule the work in the project by plotting the progress of repeating activities against time.

Although each of these models has its own merits in interpreting space-resource relationships, they have concentrated on applying line of balance techniques to the network creation. In addition, they fail to provide a systematized procedure for generating and arranging the activities. The purpose of this research is to provide a procedure for creating a network that divides a project into a number of activities for a project and then arranges their sequence according to the space-resource relationship. It generates and arranges the activities by the location where the activity should be performed and by the principal resource for that activity. Unlike the above-mentioned models, the method presented here does not attempt to remodel the network scheduling technique nor to improve Line of Balance technique. Rather, it provides equations that offer the construction managers the information on the required activities and their precedence relation, which constitutes the essential information for network scheduling.

2. SPACE-RESOURCE RELATIONSHIP IN MULTI-UNIT PROJECTS

Project scheduling techniques, such as bar charts and network diagramming, employ time and activity as the two principal coordinates of scheduling. These two scheduling coordinates, however, are not useful for describing the position where the construction activities should take place. Typical network scheduling techniques regard the technological constraints as the major factors that decide the sequence of activities. Therefore, it is difficult in network scheduling to describe space features such as the locations of the space units, the distances between the units, or the materials that comprise the space. In most building construction projects, however, such space features are the principal determinants of the types, quantities, or travel distances of resources, all of which affect the duration and sequence of activities. This space-resource relationship is also important for the uninterrupted utilization of such resources that travel from an activity in one unit to the same (repeating) activity in the next unit.

Multiunit projects contain several repetitive units such as floors in multistory buildings, and houses in housing developments. In the case of a building, the project consists of several hierarchical sets of space such as floors, zones, rooms, stairs, cores, corridors, pipe ducts, and other similar space divisions. These repetitive units, which are identical or similar to one another, are also constructed by several repetitive processes which install resources in those units. Tommelein (1999) referred to these repetitive processes as a “parade,” a process that consists of consecutive activities. In each parade, a set of definite resources (i.e. work crews), which “flows” from one unit to the next, also produce activities which are repeated from unit to unit. Building construction projects involve a large number of specialty trades that generally work in a continuing and repeating sequence as they move from one floor to another, and have been referred to as “parades of trades” by Tommelein (1999). The construction schedule for such projects should serve to facilitate the uninterrupted flow of resources.

One of the most challenging jobs for schedulers is to arrange the numerous activities involved in each project in

From a resource’s situation, a resource moves from unit to unit in multiunit projects. The products being built tend to be stationary, whereas resources move from location to location. On the other hand, from a space unit's point of view, a set of resources, one resource and the next, consecutively “drop in and leave” there. These movements can be compared to the train and station. For instance, a person sitting in a train can see a series of stations consecutively passing the train while another person standing in a station can see a series of trains consecutively passing the station. It is possible to describe the multiunit project as the combination of the two series below:

(1) Resource series: a series of resources passing a space unit - Each space unit consecutively accommodates several resources during the construction period. Such resources can be referred to as “resource series” for that particular space unit.
(2) Space series: a resource which passes a series of space units - One resource used to be consecutively installed or stationed at a number of space units during the construction period, and constitutes the “space series” for that resource.

3. NETWORK CREATION PROCEDURE

A. Scheduling Procedure

A Schedule is the plan for the completion of a project based on a logical arrangement of activities (Popescu 1995). Jobs related to the activities in scheduling are categorized as:

(1) Dividing a project into several activities;
(2) Arranging the activity sequences;
(3) Assigning their detailed resources and costs;
(4) Estimating their duration;
(5) Determining a critical path and estimating the entire project duration from the critical path.

The Critical Path Method (CPM), the typical scheduling procedure, effectively estimates the critical path and the project duration from the activities, yet it does not include the method of generating the very activities. CPM performs jobs (3), (4), and (5) well, while the method presented in this research emphasizes jobs (1), (2), and, partly, (3).

B. Designating Activities

An activity in scheduling is a unique unit that brings a particular resource in a particular range in space and at a particular interval of time. Thus, one can specify an activity by three coordinates: the resource of trades, the location (unit) in space, and its sequence among other activities. One could elaborate on the coordinates by choosing a new set of coordinates which specifies, for example, the priority level, cost, position in organization, and more, which requires careful consideration.

C. Arranging Activities

an appropriate order. Such a task requires sufficient amount of knowledge and insight to find the logical order among the activities. In this research the two flows of space and resource are scheduled independently and then merged to form an actual work process. This requires the following steps in order to generate and the arrange activities in three coordinates.

First, a project should be defined as a set of definite number of space units. Second, two basic flows, resource series and space series, should be investigated. The sequence of resource series is largely determined by the technological constraints, while the location factors affect the sequences of space series. Different trades move through a building in different directions, which requires different sequences of space series for each trade. Compared to the example of train relative to a station, trains can have different destinations and some express trains skip minor stations. Third, by tracing the two different flows, two groups of process are derived. Next, a matrix of space units and principal resources should be prepared as shown in Table 4. This matrix can be a quantity matrix or a unit cost matrix (Lee and Yi 1999). Finally, the activities are derived from the relevant cells of that matrix and their sequences are derived from the combination of the two sets of predecessors (in resource and in space).

4. NETWORK CREATION PROCEDURES

The objective of the equations presented in this research is to find a systematic procedure for (1) dividing the project into a number of activities; (2) arranging the activities in an appropriate sequence. This procedure also includes the identification of the type and sequence of the resources to be stationed to each unit, as well as the location and sequence of the units where each resource should be stationed.

It is possible to describe the entire construction process in terms of a collection of overlapping patches. In each patch, it is possible to use different sets of two coordinates, space and resource coordinates, to specify the position and the resource of an activity. Each set is then linked to one or more sets according to the logical dependencies in each coordinate.

A. Notations

This paper uses the following notations for modeling the procedure of creating networks.

(1) Space units and Principal resources
   a. Space unit, s : a section of space which is identifiable as a single unit such as rooms, toilets, stairs, or floors in multistory buildings.
   b. Principal resource, r : a resource that represents a work item or a resource whose installation can be the purpose of a work item, for example, bricks in masonry, tiles in tiling, etc.

(2) Space series and Resource series
   a. $S(r_u)$: A series of spaces to accommodate the resource r_u (Space series for resource r_u).
   b. $R(s_I)$: A series of resources to be stationed at the space s_I (Resource series in space s_I).

(3) Activities
   a. $r_u @ s_I$: An activity that performs a work item using resource r_u in the space s_I.
   b. $A(s_I)$: A set of activities to be performed in the space s_I.
   c. c. $A(r_u)$: A set of activities to be performed by or with the resource r_u.

For instance, assume that $S(r_a)=\{s_1, s_2, s_3\}$ and resource r_u should be stationed at each spaces in $S(r_a)$ in a sequence $s_1 \rightarrow s_2 \rightarrow s_3$, and $R(s_1)=\{r_a, r_b\}$ and that each resource in $R(s_1)$ should be stationed at s_1 in a sequence $r_a \rightarrow r_b$. In this case, it is possible to generate three activities for resource r_a and two for space s_1, such as $A(r_a)=\{r_a @ s_1, r_a @ s_2, r_a @ s_3\}$ and $A(s_1)=\{r_a @ s_1, r_a @ s_2\}$. Here, $r_a @ s_1$ is the intersection of the two sets, i.e. $A(r_a) \cap A(s_1)= r_a @ s_1$

(4) Predecessors
   a. $p_r(r_u | s_I)$: A set of resources that precede the resource r_u in the resource series for space s_I, $R(s_I)$.
   b. $p_s(s_I | r_u)$: A set of spaces that precede the space s_I in the space series for resource r_u, $S(r_u)$.
   c. $p_a(r_u @ s_I)$: A set of activities that precede the activity $r_u @ s_I$

B. Rules for Activities and Predecessors

As mentioned above, there are two types of series or flows in a construction process:

(1) Space series for a resource, $S(r_i)=\{s_I,\ldots,s_{I+N}\}$: A series of space units that a specific resource be stationed.
(2) Resource series for a space unit, $R(s_I)=\{r_i,\ldots,r_{i+n}\}$: A series of resources to be stationed at a specific unit (where *I*, *N*, *i*, and *n* are arbitrary integers).

By drawing a relevance matrix of space and resource, one can divide a project into a number of activities as shown in Figure 1. This relevance matrix shows which resources are required for or have relevance to which space units. Each cell remains empty where the resource on the row has no relevance to the space unit on the column. The non-null cells marked inside the matrix represents the "relevant" cells where the resource on the row is required for the space on the column. Each row of these relevant cells is the resource series for a corresponding space. In the same way, the space series lie in each column. For instance, s_2 and s_N are the space series for resource r_2, and r_2 and r_n are the resource series for s_N in Figure 1 ($S(r_2)=\{s_2, s_N\}$ and $R(s_N)=\{r_2, r_N\}$). An activity is derived from each relevant cell and can be located by row and column combination such as "*resource@space.*" For instance, "*paint@lobby*" stands for an activity that requires the resource "*paint*" and takes place in the space unit "*lobby*."

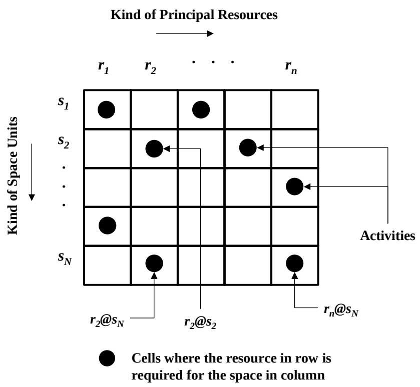

Figure 1 Matrix of Space and Resource

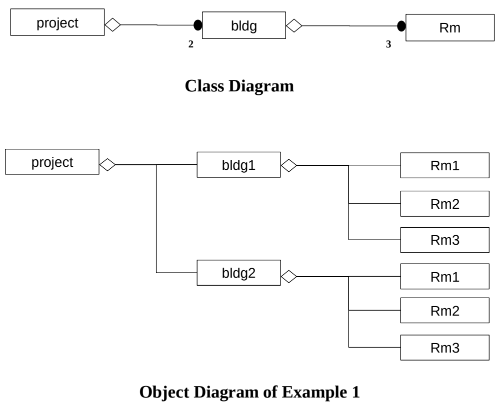

Figure 2 The Hierarchy of Space Units in Example 1

Rule 1: Dividing a Project into Activities

If a cell (s_I, r_i) in a relevance matrix of space and resource is not null, or s_I and r_i have relevance to each other, an activity is derived from the cell. Each activity is denoted as $r_i@s_I$, which indicates an activity that utilizes the resource r_i in the space s_I.

Determining a sequence of activities is the same as finding the predecessors for each activity. As mentioned above, an activity in scheduling represents an item that brings a particular resource in a particular range in space and at a particular interval of time. Typically, resources used to be sequentially utilized in space, such as from inside to outside, or from farthest to nearest. On the other hand, a number of resources are sequentially utilized in a space unit, such as lath→mortar→paint in building construction. Therefore, there must be two types of predecessors for an activity: predecessors relative to space and predecessors relative to resource.

Rule 2: Space and Resource Predecessors

a. Predecessors relative to space: The predecessors for an activity that utilize the same resource yet take place in different locations, or If $s_I = p_s(s_J \mid r_i)$ where $s_I \in S(r_i)$ and $s_J \in S(r_i)$, $r_i @ s_I = p_a(r_i @ s_J)$ (which means if a space unit s_I precedes another unit s_J where s_I and s_J belong to the space series for the resource r_i respectively, then the activity $r_i @ s_I$ precedes the activity $r_i @ s_J$).

b. Predecessors relative to resource: The predecessors for an activity that utilize different resources yet take place in the same location, or If $r_i = p_r(r_j \mid s_J)$ where $r_i \in R(s_J)$ and $r_j \in R(s_J)$, $r_i @ s_J = p_a(r_j @ s_J)$ (which means if a resource r_i precedes another resource r_j where r_i and r_j belong to the resource series for the space s_J respectively, $r_i @ s_J$ precedes the activity $r_j @ s_J$

Rule 3: Activity Predecessors

The set of activities that precedes an activity $r_u @ s_I$ is the union of the preceding activities along the flow of r_u in the space s_I and the preceding activities along the flow of s_I for the resource r_u, i.e. $p_a(r_u @ s_I) = [p_r(r_u \mid s_I) @ s_I] \cup [r_u @ p_s(s_I \mid r_u)]$.

For instance, if $p_r(r_c \mid s_7)=\{r_a @ s_7, r_b @ s_7\}$ and $p_s(s_7 \mid r_c)=\{r_c @ s_1, r_c @ s_5, r_c @ s_6\}$ (r_a and r_b precede r_c in the s_7 and if s_1, s_5, and s_6 precedes s_7 for the resource r_c), then $p_a(r_c @ s_7)= p_r(r_c \mid s_7) \cup p_s(s_7 \mid r_c)=\{r_a @ s_7, r_b @ s_7, r_c @ s_1, r_c @ s_5, r_c @ s_6\}$

It is possible to generate and determine the sequence of activities from the combination of the two rules. Applying these equations to the scheduling procedure, the procedure must be as follows:

(1) The identification of resource and space: Prepare the relevance matrix of resource and space, spaces on the column and resources on the row, as shown in Table 4.
(2) Determining the relevant cells: Match the resources and the space units, in terms of their relevance to each other.
(3) Activity definition: Generate the activities from the relevant cells in the matrix.
(4) Activity arrangement: Determining the predecessors using the above equations.
(5) Network computation: Next, simply follow the general procedure of scheduling techniques for estimating the duration of the project, such as assigning the duration of each activity, drawing the network diagram, calculating the slacks, finding a critical path, and estimating the project duration.

5. IMPLEMENTATION

Generally, in a building construction project, there are two types of activities: outdoor activities and indoor activities. Indoor activities perform works inside the spaces, while outdoor activities are for outside. The work sequence of most indoor activities are related to the space features of the facilities to be constructed, such as the location, size, materials, and other factors that define the features of the spaces. These two examples limit their modeling scope to several major indoor activities for convenience.

Table 1. Space Notation and Address in Example 1

Notation	Address	Description
s_1	*Rm1.bldg1*	Room 1, 1st building
s_2	*Rm2.bldg1*	Room 2, 1st building
s_3	*Rm3.bldg1*	Room 3, 1st building
s_4	*Rm1.bldg2*	Room 1, 2nd building
s_5	*Rm2.bldg2*	Room 2, 2nd building
s_6	*Rm3.bldg2*	Room 3, 2nd building

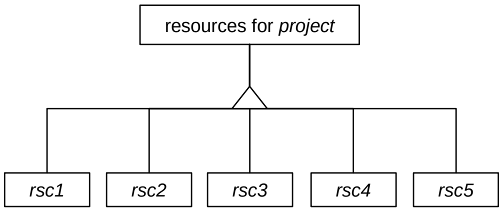

Figure 3 Resources for Example 1

A. Example 1: Multiple Buildings

In this example, a network schedule will be constructed for the interior finish work of a hypothetical building project, by applying the space-resource combination method presented in this research. In Figures. 2 and 3, each space unit and resource is represented according to the Rumbaugh notation (Rumbaugh et al. 1991). Figure 2 shows the hierarchy of the units in the project, two buildings and three rooms in each building. Notation and Address are given for each unit according to its hierarchy as shown in Table 1. For instance, *s1* indicates the first room in the first building, whose address is given as *rm1.bldg1*. It is assumed that five resources are required for the interior work for this project and are referred to as *rsc1*, *rsc2*, …, and *rsc5*, for convenience, as shown in Figure 3. The sequence of each space and resource series is assumed as shown in Figure 4. Figure 4(a) means that three independent crews of resources *rsc1* and *rsc5* are performing their activities starting from space units *s1*, *s2*, *s3* to *s4*, *s5*, *s6*, respectively. Figure 4(c) indicates that resource *rsc3* travels from space unit *s2* toward *s6*. Figure 4(e) shows the space units *s2*, *s3*, *s5*, and *s6* consecutively accommodate *rsc1*, *rsc3*, and *rsc5*. Combining the three space series and the two resource series, 20 activities are generated and the predecessors are derived as the network diagram shown in Figure 5. The network in Figure 5 is arranged in the form of a matrix, resources on the column and space units on the row. Activities are generated only in the relevant cells where the resources are required for the spaces. For instance, as shown in Figure 4(a), *rsc1* is required for all space units, and six activities are generated for *rsc1*. On the other hand, only three activities are derived for the space *s2*, since Figure 4(e) shows three resources, *rsc1*, *rsc3*, and *rsc5* are required for the space unit *s2*.

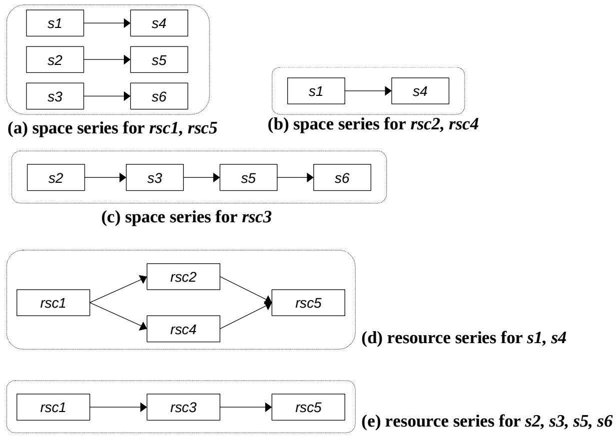

Figure 4 The Sequence of Resource and Space in Example 1

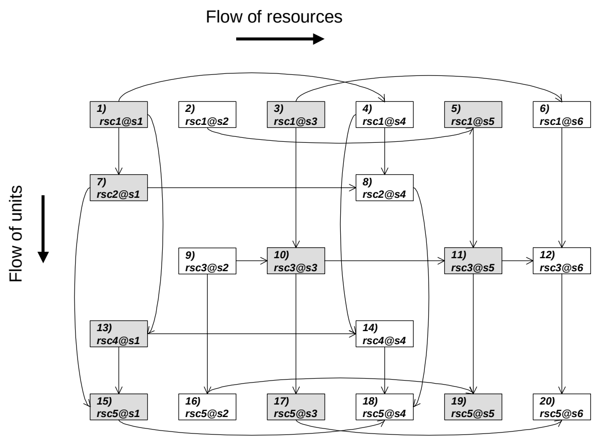

Figure 5 Network Diagram in Example 1

B. Example 2: A Multistory Building

In this case, the network creation procedure is applied to a realistic project, a three-story school building, the typical floor plan of which is shown in Figure 6. The school building in Figure 6 contains 24 space units, which are listed in Table 2, three classrooms, an office, a lounge, a corridor, a toilet, and a set of stair on each floor. The authors abstracted eight principal resources for the indoor activities of this building as listed in Table 3. The input sequence of the resources is shown in Figure 7. The relevance matrix of space and resource is prepared as shown in Table 4, and the relevant cells are marked “X” where the resources are required for the corresponding space units during construction. Figure 7 shows the sequence of resource series for each type of space and Figures. 8 to 10 shows the sequence of space series for each resource type. In Figure 7, solid boxes represent the required resource for the space, while the dotted ones are “dummies,” which are not required and should be skipped. Likewise, in Figures. 8 to 10, the dotted boxes represent the space units where the resources are not required during construction. Based on this information, the activities and their predecessors can be generated as shown in Table 5. This table is a basic data set for network creation and can be transferred to scheduling tools and utilized for network computation by assigning duration to each activity.

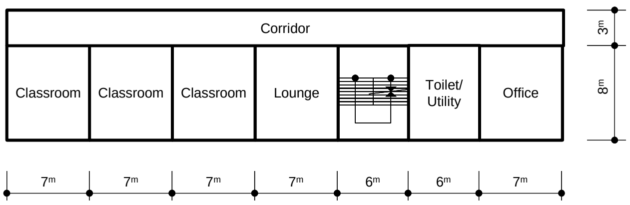

Figure 6 Typical Floor Plan for Example 2

Table 2. List of Space Units In Example 2

Notation	Address	Description
s01	*ClassRm1.1stFL*	The 1st classroom on the 1st floor
s02	*ClassRm2.1stFL*	The 2nd classroom on the 1st floor
s03	*ClassRm3.1stFL*	The 3rd classroom on the 1st floor
s04	*Office.1stFL*	Office room on the 1st floor
s05	*Lobby.1stFL*	Lobby on the 1st floor
s06	*Corridor.1stFL*	Corridor on the 1st floor
s07	*Stair.1stFL*	Stair on the 1st floor
s08	*Toilet.1stFL*	Toilet on the 1st floor
s09	*ClassRm1.2ndFL*	1st classroom on the 2nd floor
s10	*ClassRm2.2ndFL*	2nd classroom on the 2nd floor
s11	*ClassRm3.2ndFL*	3rd classroom on the 2nd floor
s12	*Office.2ndFL*	Office on the 2nd floor
s13	*Lounge.2ndFL*	Lounge on the 2nd floor
s14	*Corridor.2ndFL*	Corridor on the 2nd floor
s15	*Stair.2ndFL*	Stair on the 2nd floor
s16	*Toilet.2ndFL*	Toilet on the 2nd floor
s17	*ClassRm1.3rdFL*	1st classroom on the 3rd floor
s18	*ClassRm2.3rdFL*	2nd classroom on the 3rd floor
s19	*ClassRm3.3rdFL*	3rd classroom on the 3rd floor
s20	*Office.3rdFL*	Office on the 3rd floor
s21	*Lounge.3rdFL*	Lounge on the 3rd floor
s22	*Corridor.3rdFL*	Corridor on the 3rd floor
s23	*Stair.3rdFL*	Stair on the 3rd floor
s24	*Toilet.3rdFL*	Toilet on the 3rd floor

Table 3. Resource List in Example 2

ID	Notation	Description
i	Wpfng	Waterproofing
ii	Plstr	Plastering
iii	Tile	Tiles
iv	Trz	In Situ Terrazzo
v	Ceiling	Ceiling board
vi	Wallpr	Wallpaper
vii	Flrng	Flooring
viii	Paint	Painting

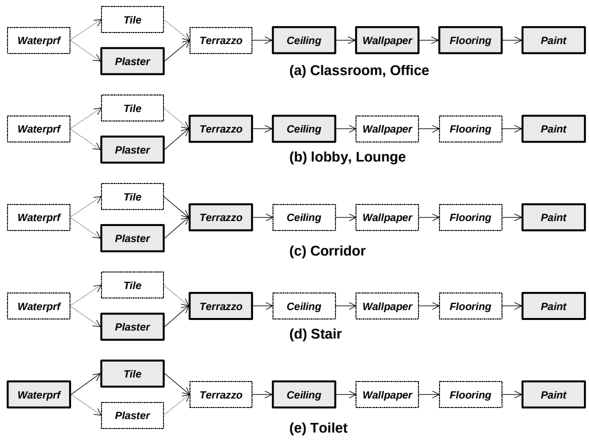

Figure 7 Sequence of Resource in Example 2

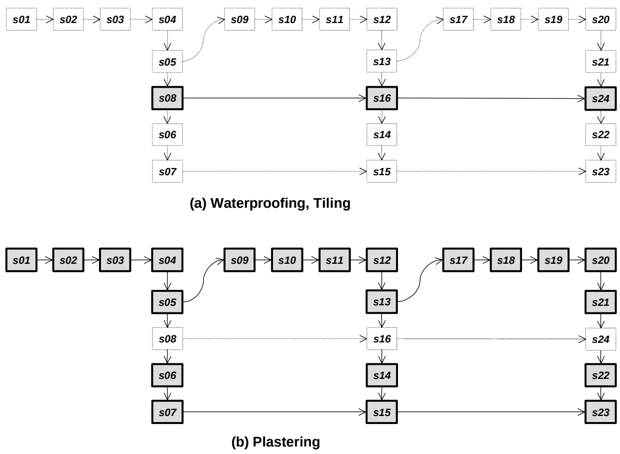

Figure 8 Sequence of Space in Example 2 (1)

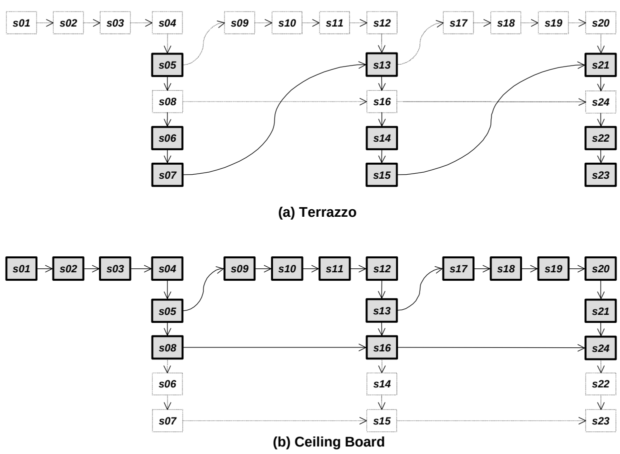

Figure 9 Sequence of Space in Example 2 (2)

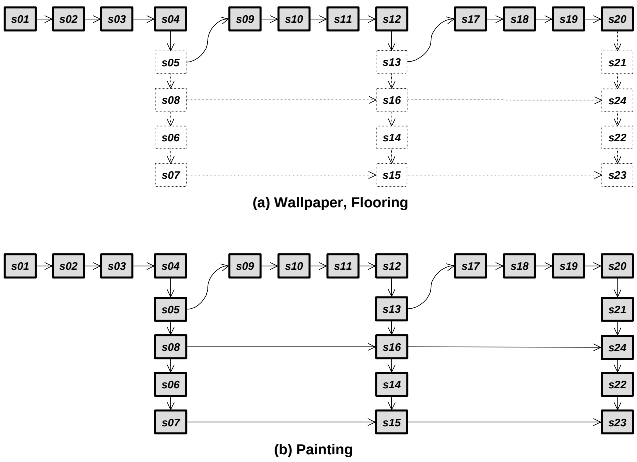

Figure 10 Sequence of Space in Example 2 (3)

6. CONCLUSION

In drawing a network diagram for construction projects, a certain amount of insight and experience for construction managers is required in deriving activities from the project and estimating their preceding and succeeding relationships. In the case of multiunit projects wherein activities are repeated from unit to unit, the activities need to be generated and arranged so that one can easily apprehend the locations as well as the resources for that activity. In addition, the schedule must not only show the sequence of activities but also readily convey the concept of the preceding and succeeding space for that activity.

The CPM scheduling techniques cannot clearly represent the spatial content of construction processes such as the work location for an activity, and it does not include the process of generating and arranging those very activities. Recognizing that the space, the resource, and the sequence (or time) represent the three coordinates that specify the status of an activity, the authors developed a space-resource combination method that systematically generates and organizes the activities in multiunit projects. Set equations are presented here as an aid to the organization of network schedules. These set equations can be most effectively applied to the interior finish work in multiunit projects. The outcomes of these set equations can be utilized for the network computation and can be transferred to other scheduling tools which include the typical CPM techniques.

These set equations require a matrix of space units and principal resources in order to generate activities. The relevant cells in the matrix are then combined to produce the activities of the project. The space units indicate the location where the activities will be executed, and the principal resources indicate the work items of the activities. Next, estimating the sequence of the resource series and space series, the predecessors for each activity are then estimated by combining the predecessors relative to resource and the predecessors relative to space. Since trades do not always move in the same direction, different sequences can be assigned for each series.

One of the goals of this research is to provide the construction manger a decision supporting procedure in terms of organizing a construction schedule. Since the proposed method definitely specifies an activity by resource and space, one can systematically determine the predecessors for the activity from the sequence of space series and the sequence of resource series. In addition, the method is capable of reducing the human effort in scheduling so that a network schedule can be created, even if the person in charge is not sufficiently experienced.

ACKNOWLEDGEMENT

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Table 4. Matrix of Space and Resource in Example 2

RoomName	Area (m2)	Space ID	i	ii	iii	iv	v	vi	vii	viii
			Wpfng	Plstr	Tile	Trz	Ceiling	Wallpr	Flrng	Paint
Classroom,Office	56	*S01,s02,s03, s04,s09,s10, s11,s,12,s17, s18,s19,s20*		X			X	X	X	X
Lobby,Lounge	56	*s05,s13,s21*		X		X	X			X
Corridor	141	*s06,s14,s22*		X		X				X
Stair	48	*s07,s15,s23*		X		X				X
Toilet	48	*s08,s16,s24*	X		X		X			X

X: relevant cells

Table 5. List of Activities and Predecessors in Example 2

ID	Activities	Predecessors		ID	Activities	Predecessors	
		In space	In rsc.			In space	In rsc.
1	*Wpfng@Toilet.1stFL*			52	*Ceiling@Office.3rdFL*	21	51
2	*Wpfng@Toilet.2ndFL*		1	53	*Ceiling@Lounge.3rdFL*	34	52
3	*Wpfng@Toilet.3rdFL*		2	54	*Ceiling@Toilet.3rdFL*	27	53, 48
4	*Plstr@ClassRm1.1stFL*			55	*Wallpr@ClassRm1.1stFL*	37	
5	*Plstr@ClassRm2.1stFL*		4	56	*Wallpr@ClassRm2.1stFL*	38	55
6	*Plstr@ClassRm3.1stFL*		5	57	*Wallpr@ClassRm3.1stFL*	39	56
7	*Plstr@Office.1stFL*		6	58	*Wallpr@Office.1stFL*	40	57
8	*Plstr@Lobby.1stFL*		7	59	*Wallpr@ClassRm1.2ndFL*	43	58
9	*Plstr@Corridor.1stFL*		8	60	*Wallpr@ClassRm2.2ndFL*	44	59
10	*Plstr@Stair.1stFL*		9	61	*Wallpr@ClassRm3.2ndFL*	45	60
11	*Plstr@ClassRm1.2ndFL*		8	62	*Wallpr@Office.2ndFL*	46	61
12	*Plstr@ClassRm2.2ndFL*		11	63	*Wallpr@ClassRm1.3rdFL*	49	62
13	*Plstr@ClassRm3.2ndFL*		12	64	*Wallpr@ClassRm2.3rdFL*	50	63
14	*Plstr@Office.2ndFL*		13	65	*Wallpr@ClassRm3.3rdFL*	51	64
15	*Plstr@Lounge.2ndFL*		14	66	*Wallpr@Office.3rdFL*	52	65
16	*Plstr@Corrider.2ndFL*		15	67	*FL rng@ClassRm1.1stFL*	55	
17	*Plstr@Stair.2ndFL*		16, 10	68	*FL rng@ClassRm2.1stFL*	56	67
18	*Plstr@ClassRm1.3rdFL*		15	69	*FL rng@ClassRm3.1stFL*	57	68
19	*Plstr@ClassRm2.3rdFL*		18	70	*FL rng@Office.1stFL*	58	69
20	*Plstr@ClassRm3.3rdFL*		19	71	*FL rng@ClassRm1.2ndFL*	59	70
21	*Plstr@Office.3rdFL*		20	72	*FL rng@ClassRm2.2ndFL*	60	71
22	*Plstr@Lounge.3rdFL*		21	73	*FL rng@ClassRm3.2ndFL*	61	72
23	*Plstr@Corridor.3rdFL*		22	74	*FL rng@Office.2ndFL*	62	73
24	*Plstr@Stair.3rdFL*		23, 17	75	*FL rng@ClassRm1.3rdFL*	63	74
25	*Tile@Toilet.1stFL*	1		76	*FL rng@ClassRm2.3rdFL*	64	75
26	*Tile@Toilet.2ndFL*	2	25	77	*FL rng@ClassRm3.3rdFL*	65	76
27	*Tile@Toilet.3rdFL*	3	26	78	*FL rng@Office.3rdFL*	66	77
28	*Trz@Lobby.1stFL*	8		79	*Paint@ClassRm1.1stFL*	67	
29	*Trz@Corridor.1stFL*	9	28	80	*Paint@ClassRm2.1stFL*	68	79
30	*Trz@Stair.1stFL*	10	29	81	*Paint@ClassRm3.1stFL*	69	80
31	*Trz@Lounge.2ndFL*	15	30	82	*Paint@Office.1stFL*	70	81
32	*Trz@Corrider.2ndFL*	16	31	83	*Paint@Lobby.1stFL*	41	82
33	*Trz@Stair.2ndFL*	17	32	84	*Paint@Corridor.1stFL*	29	86
34	*Trz@Lounge.3rdFL*	22	33	85	*Paint@Stair.1stFL*	30	84
35	*Trz@Corridor.3rdFL*	23	34	86	*Paint@Toilet.1stFL*	42	83
36	*Trz@Stair.3rdFL*	24	35	87	*Paint@ClassRm1.2ndFL*	71	83
37	*Ceiling@ClassRm1.1stFL*	4		88	*Paint@ClassRm2.2ndFL*	72	87
38	*Ceiling@ClassRm2.1stFL*	5	37	89	*Paint@ClassRm3.2ndFL*	73	88
39	*Ceiling@ClassRm3.1stFL*	6	38	90	*Paint@Office.2ndFL*	74	89
40	*Ceiling@Office.1stFL*	7	39	91	*Paint@Lounge.2ndFL*	47	90
41	*Ceiling@Lobby.1stFL*	28	40	92	*Paint@Corrider.2ndFL*	32	94
42	*Ceiling@Toilet.1stFL*	25	41	93	*Paint@Stair.2ndFL*	33	92, 85
43	*Ceiling@ClassRm1.2ndFL*	11	41	94	*Paint@Toilet.2ndFL*	48	91, 86
44	*Ceiling@ClassRm2.2ndFL*	12	43	95	*Paint@ClassRm1.3rdFL*	75	91
45	*Ceiling@ClassRm3.2ndFL*	13	44	96	*Paint@ClassRm2.3rdFL*	76	95
46	*Ceiling@Office.2ndFL*	14	45	97	*Paint@ClassRm3.3rdFL*	77	96
47	*Ceiling@Lounge.2ndFL*	31	46	98	*Paint@Office.3rdFL*	78	97
48	*Ceiling@Toilet.2ndFL*	26	47, 42	99	*Paint@Lounge.3rdFL*	53	98
49	*Ceiling@ClassRm1.3rdFL*	18	47	100	*Paint@Corridor.3rdFL*	35	102
50	*Ceiling@ClassRm2.3rdFL*	19	49	101	*Paint@Stair.3rdFL*	36	100, 93
51	*Ceiling@ClassRm3.3rdFL*	20	50	102	*Paint@Toilet.3rdFL*	54	99, 94

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