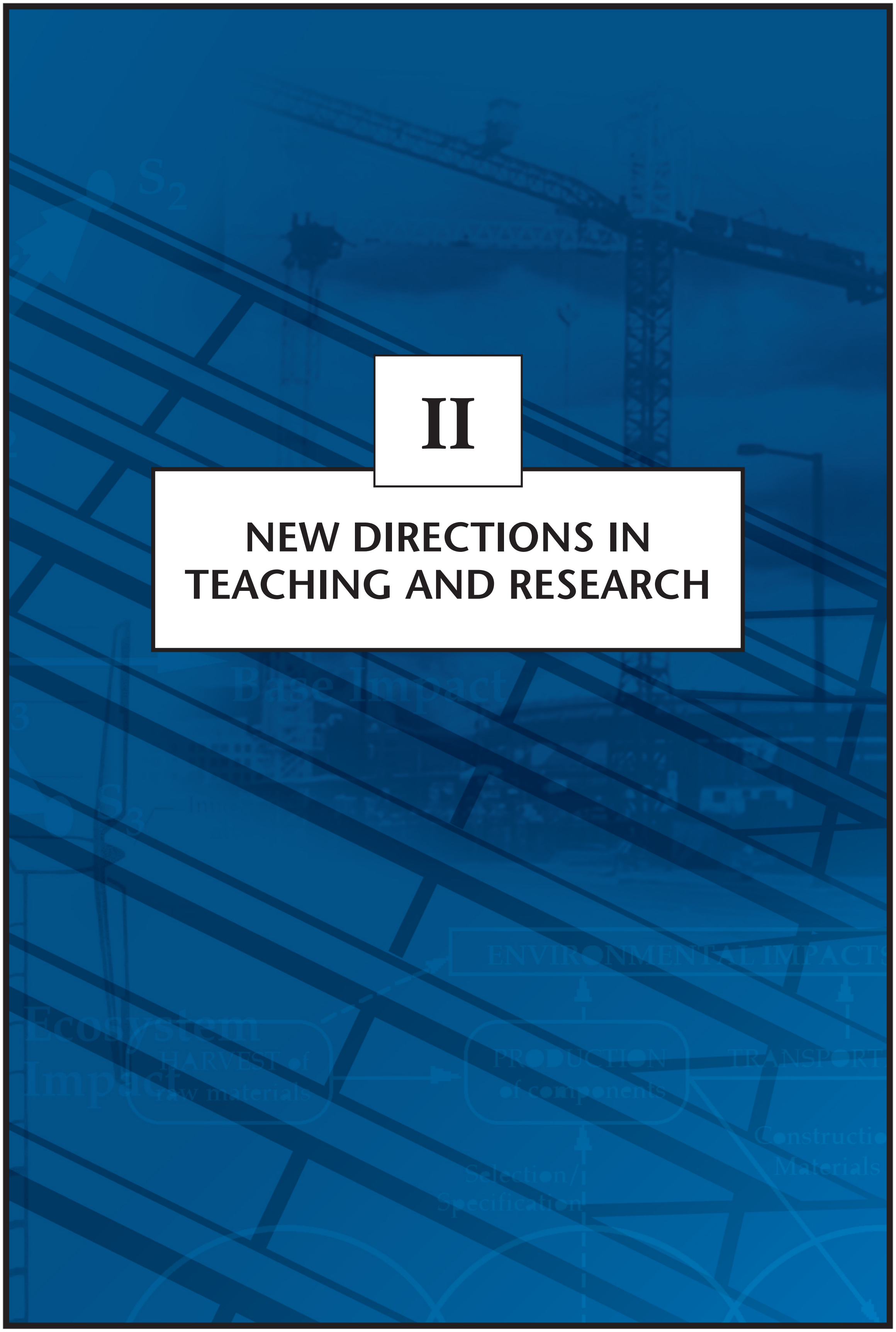

II

NEW DIRECTIONS IN TEACHING AND RESEARCH

TEACHING HOW TO USE A REPETITIVE SCHEDULING METHOD WHEN PLANNING A GREEN CONDOMINIUM BUILDING

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ABSTRACT

This paper aims to present a methodology for use in construction planning named the Repetitive Scheduling Method (RSM). Students on a graduate level construction management program can learn how to create a RSM schedule to be applied to a real project. Typically, the Critical Path Method (CPM) is used to plan general construction projects. This paper presents a case study wherein a CPM diagram is transformed into a RSM schedule for use in the construction of a green condominium. RSM is the most suitable tool for planning repetitive projects like condominium buildings, apartment complexes, or real estate development projects. It utilizes an uninterrupted flow of resource concept in order to eliminate manpower-related resource wastage. As a result, construction productivity can be improved by using the right construction planning tool on the right project. Interested graduate students researching construction engineering can apply RSM on their repetitive projects in the future.

KEYWORDS

Planning, Repetitive Scheduling Method, Scheduling, Teaching, Writing RSM

INTRODUCTION

The Repetitive Scheduling Method (RSM) is a topic within the construction planning and resource curricula of graduate level classes in Thailand. Study of this topic is a required course in most Master of Engineering programs in the construction management field. Students may exploit the principles and methodologies outlined in this paper to plan a repetitive construction project, such as a condominium. Most green condominium buildings are planned using the Critical Path Method (CPM) as a typical tool prior to construction starting. However, this tool is incapable of handling the repetitive activities regularly found in the construction processes of condominium buildings. Its usage leads to work interruptions and inefficiencies in handling the continuous supply of resources (Harris and Ioannou 1998; Ioannou and Yang 2016). Several applications can be used to schedule repetitive tasks within a project, such as time versus distance diagrams (Gorman 1972) and location based scheduling (Kenley and Seppanen 2009).

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A linear scheduling method, such as line of balance, is appropriate for projects with repetitive characteristics, but their use is limited (Arditi and Albulak 1986). RSM was first introduced by Harris and Ioannou in 1998 and can be used effectively within both horizontal and vertical construction projects. It can be used to model repetitive projects with probabilistic activity duration (Ioannou and Srisuwanrat 2006, 2007). Ioannou and Yang (2016) increased its versatility by emphasizing units versus locations and introducing the concept of elements when modeling repetitive projects. As a result, RSM is appropriate when planning construction projects with repetitive characteristics, such as a green condominium building which is the case study in this paper. The objective of this paper is to demonstrate the transformation of a typical construction plan from being represented by a CPM diagram to comprising a RSM approach. Students or interested architects and engineers can use the method presented as a guideline in planning a condominium or similar kind of repetitive project.

CASE STUDY BUILDING

Our example building is a low-rise green condominium project located near Rattanathibet Road in the northern outskirts of Bangkok, Thailand. It is approximately 600 m. from the Phra Nang Klao Bridge Station of the MRT Purple Line, part of Bangkok's mass transport railway system. The project is also conveniently connected to two other forms of public transportations, a Chao Phraya express boat pier and a local bus stop. Moreover, the project provides a shuttle bus service connecting residents to public transportation. The green condominium project is surrounded by three schools, one university, one health care center, two hospitals, and two department stores. The total land area is 16,208 square meters. The project comprises four low-rise buildings, with each residential condominium building eight storeys high. The residential units and parking spaces total 905 and 300, respectively. Figure 1 is an image of the green condominium

FIGURE 1. A perspective view of the green condominium project.

FIGURE 2. Installation of mesh sheets to prevent dust.

at the phase where it is ready for residents. During construction, mesh sheets are used to control the airborne dust generated daily, as shown in Figure 2. Construction workers are trained to continually clean the job site to help eliminate pollutants, such as dirt, dust and debris. As a result, this project site was able to pass the Construction Activity Pollution Prevention (CAPP) standardization, which is a prerequisite in terms of the Sustainable Site of LEED.

Figures 3–7 show the job site implementation constituents of this green construction project in accordance with the guidelines necessary to earn credits from both LEED and TREES (Thai Rating of Energy and Environmental Sustainability). Figure 3 shows the site entrance which conforms with the preparation standards concerning clearance of access roads to the site. Preparations of separate construction waste bins and the proper dry storage of prefabricated wall panels are shown in Figures 4 and 5. Figure 6 shows the storage area for toxic materials, such as paints and sealants, which is prepared to minimize indoor-air quality issues. Figure 7 illustrates the site watering process used to minimize construction dust, according to the environmentally friendly concepts within LEED and TREES. Interviews with the project executive team and green expert staff affirmed that at least a certified level of LEED would be able to be obtained. However, in this project information was not submitted to either the USGC or TGBI (Thai Green Building Institute). Table 1 contains the LEED-NC Version 3 equivalent scores based on the design and construction processes and management of this project.

CPM diagram as a typical master project schedule for construction of a green condominium building

Figure 8 shows a typical CPM diagram, in this case related to this green condominium project before changing it to the RSM format. The construction process starts with piling work for 27 days, followed by foundation work and site mobilization for 30 and 7 days, respectively. As a result, the total duration of these three activities amounts to 64 days. Structural work, architectural activities, and MEP, represent repetitive activities since the floor plan is the same. In managing a repetitive construction project using CPM, work interruptions and crew inactivity

FIGURE 3. Front entrance from access road to the site.

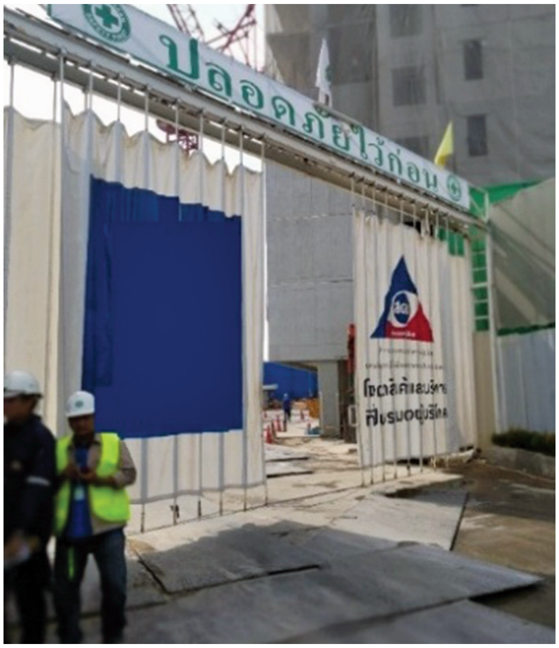


FIGURE 4. Separate construction waste bins.

FIGURE 5. Storage of prefabricated wall panels.

FIGURE 6. Proper storage of paints and sealants.

FIGURE 7. Water spray for dust reduction.

FIGURE 8. Original CPM diagram of the entire project.

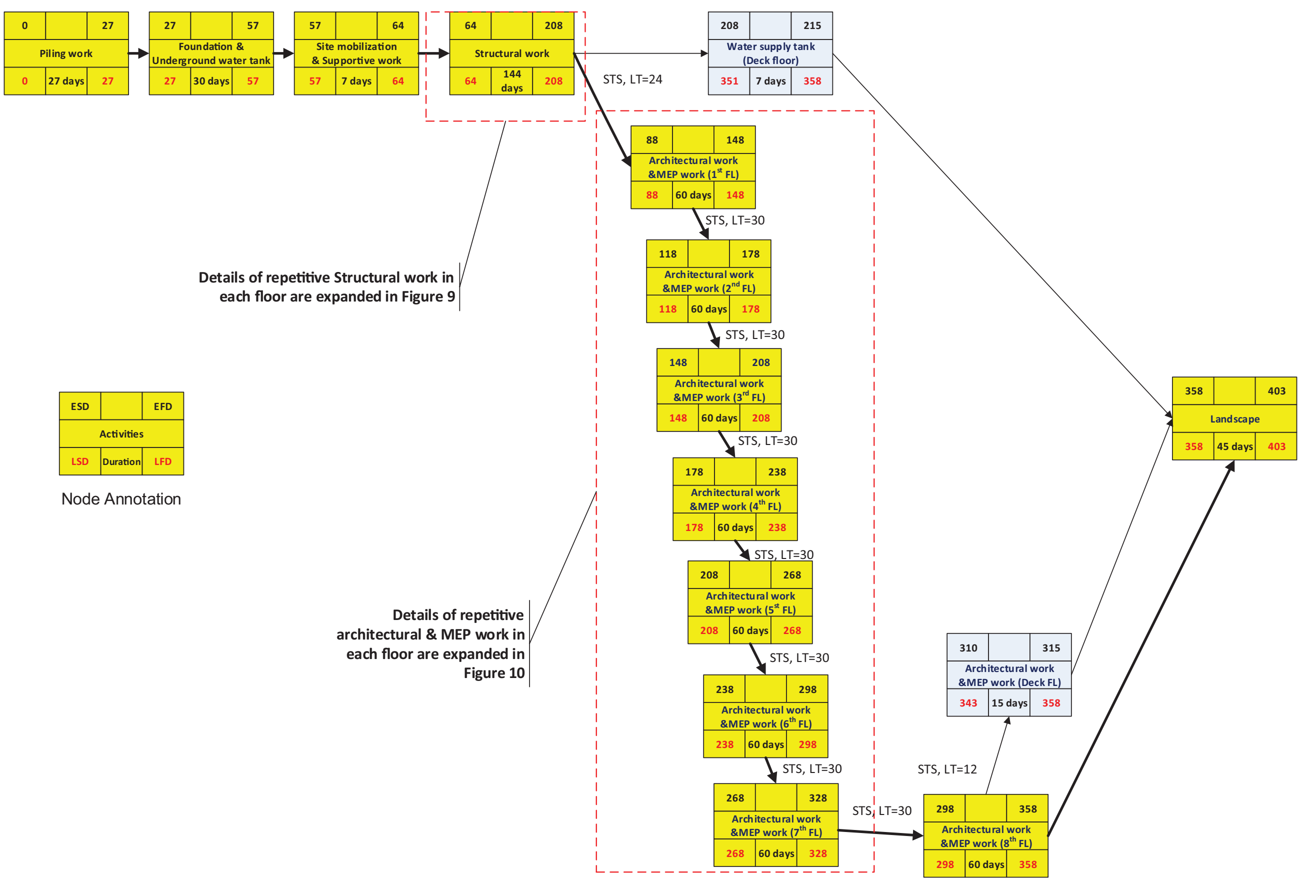
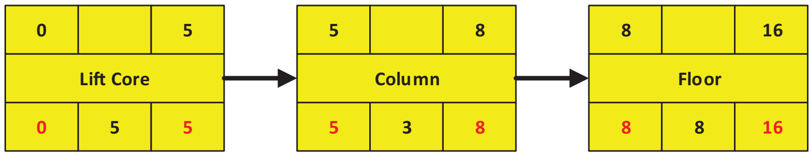


FIGURE 9. CPM diagram of repetitive structural concrete work on each floor.



can sometimes be expected as CPM does not factor in resource flow from working on one unit to another. Normally, delays in activities or crew interruptions arise in the middle of projects due to the discontinuous flow of resources, especially manpower.

CPM diagram of repetitive structural concrete work

In the CPM diagram of structural concrete, work activities are separated into three types—lift, core, columns and floors, as shown in Figure 9. Each floor has a total area of 450 square meters. It takes 16 working days to complete the structural work for each floor. Every floor follows the same process.

CPM diagram of repetitive architectural and MEP Work

A CPM diagram depicting both the repetitive architectural and MEP work for each floor is shown in Figure 10. The process begins with marking out the interior wall partitions of each floor, before installing interior walls over a period of seven days. After that, exterior prefabricated concrete walls are installed over seven days and then ceilings over an additional seven days. Once this has been completed, plastering activities for both interior and exterior surfaces are simultaneously undertaken over three days.

This is followed by wall painting taking five days, installing floor tiles over seven days, installing all electrical and telecommunication systems over eight days, bathroom accessories and sanitary were five days, room closets seven days, and cleaning up over three days. Two non-critical activities involve installing bathroom floor tiles over five days and windows and doors over ten days. The total number of working days required for repetitive architectural work and MEP on each floor amounts to 60.

TRANSFORMING CPM TO RSM

RSM refers to an uninterrupted flow of resource concept which factors as a major constraint. On a discrete unit, as in this example, planners usually schedule a project using the vertical axis as the unit and its horizontal axis as time. In this case, the discrete unit is the number of floors. Therefore, the y-axis shows floors one to eight and the roof deck. The production rate of activities on each line can be calculated in terms of duration and completion for each floor. This is called the unit production rate (Harris and Ioannou 1998). The line activities assume the use of an uninterrupted flow of resources concept which means all resources must available to be exploited and supplied continuously. Each activity is performed by different crews or subcontractors. So, they can work independently of each other.

Block and line concepts (Ioannou and Yang 2016) are used in this paper. Piling work, foundations and underground water tanks, and site mobilization and supportive work represent block activities, as shown in Figure 11. From day zero, the total working days required to

FIGURE 10. CPM diagram of repetitive architectural and MEP work on each floor.

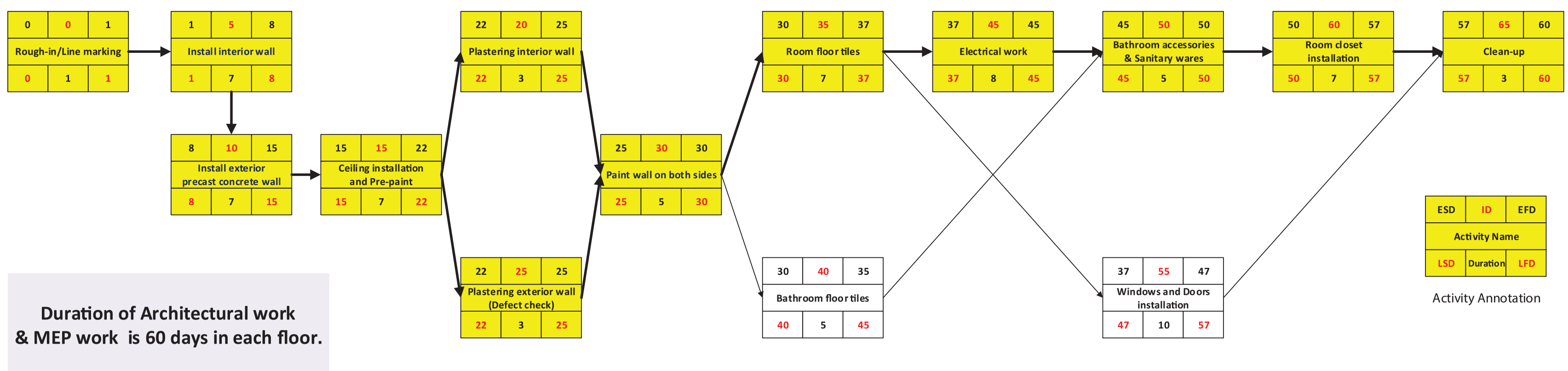


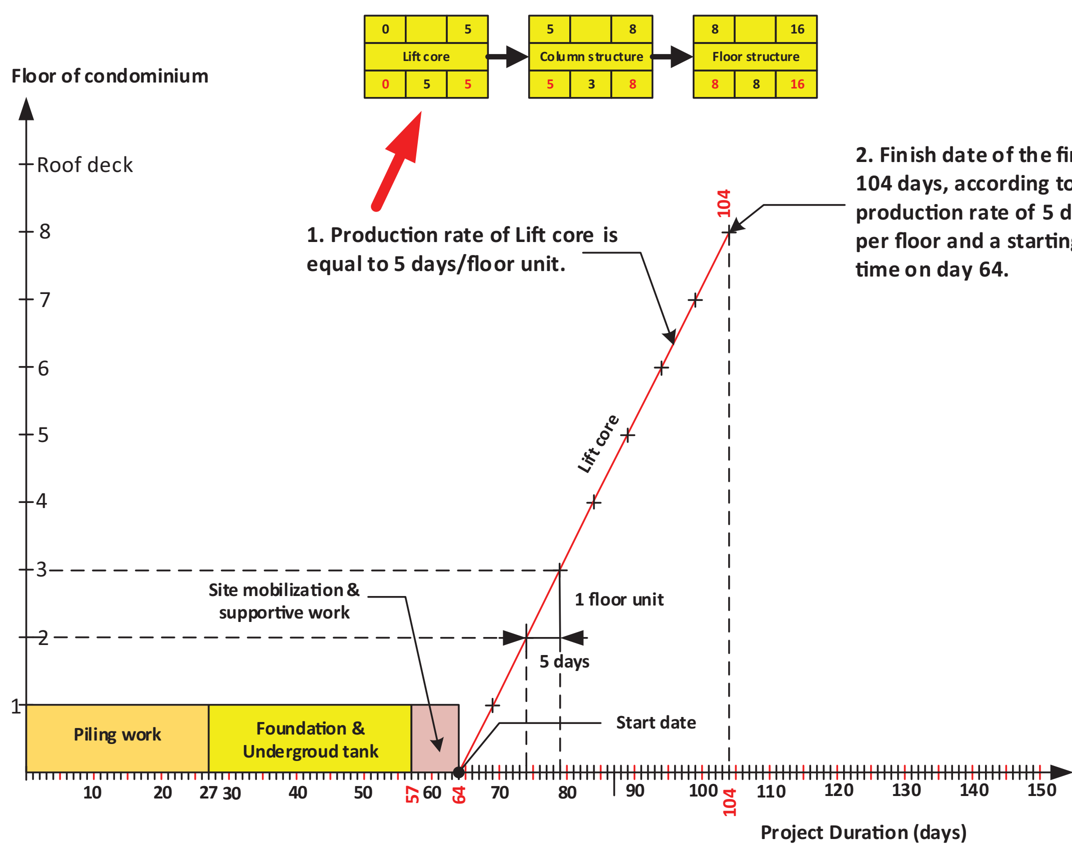
TABLE 1. LEED-NC V.3 scores of constituents of the project in terms of earning a certified level.

		Scores
Sustainable Sites	**Possible Points**	**16/26**
Prerequisite 1	Construction Activity Pollution Prevention	Required
Credit 1	Site Selection	1
Credit 2	Development Density and Community Connectivity	5
Credit 4.1	Alternative Transportation—Public Transportation Access	6
Credit 4.2	Alternative Transportation—Bicycle Storage and Changing Rooms	1
Credit 4.4	Alternative Transportation—Parking Capacity	2
Credit 6.1	Storm water Design—Quantity Control	1
Water Efficiency	**Possible Points**	**3/10**
Prerequisite 1	Water Use Reduction	Required
Credit 3	Water Use Reduction	3
Energy & Atmosphere	**Possible Points**	**10/35**
Prerequisite 1	Fundamental Commissioning of Building Energy Systems	Required
Prerequisite 2	Minimum Energy Performance	Required
Prerequisite 3	Fundamental Refrigerant Management	Required
Credit 1	Optimize Energy Performance	5
Credit 4	Enhanced Refrigerant Management	2
Credit 5	Measurement and Verification	3
Materials & Resources	**Possible Points**	**5/14**
Prerequisite 1	Storage and Collection of Recyclables	Required
Credit 2	Construction Waste Management	2
Credit 5	Regional Materials	2
Credit 7	Certified Wood	1
Indoor Environmental Quality	**Possible Points**	**7/15**
Prerequisite 1	Minimum Indoor Air Quality Performance	Required
Prerequisite 2	Environmental Tobacco Smoke (ETS) Control	Required
Credit 3.1	Construction Indoor Air Quality Management Plan—During Construction	1
Credit 4.1	Low-Emitting Materials—Adhesives and Sealants	1
Credit 4.2	Low-Emitting Materials—Paints and Coatings	1

TABLE 1. *(Cont.)*

		Scores
Sustainable Sites	Possible Points	16/26
Credit 4.3	Low-Emitting Materials—Flooring Systems	1
Credit 4.4	Low-Emitting Materials—Composite Wood and Agrifiber Products	1
Credit 5	Indoor Chemical and Pollutant Source Control	1
Credit 7.1	Thermal Comfort—Design	1
Innovation In Design	Possible Points	3/6
Credit 1	Innovation in Design	2
Credit 2	LEED Accredited Professional	1
Regional Priority	Possible Points	1/4
Credit 1	Water Use Reduction	1
	Total score equivalent in terms of LEED	**45**

FIGURE 11. Three block activities and a line activity on a RSM diagram.

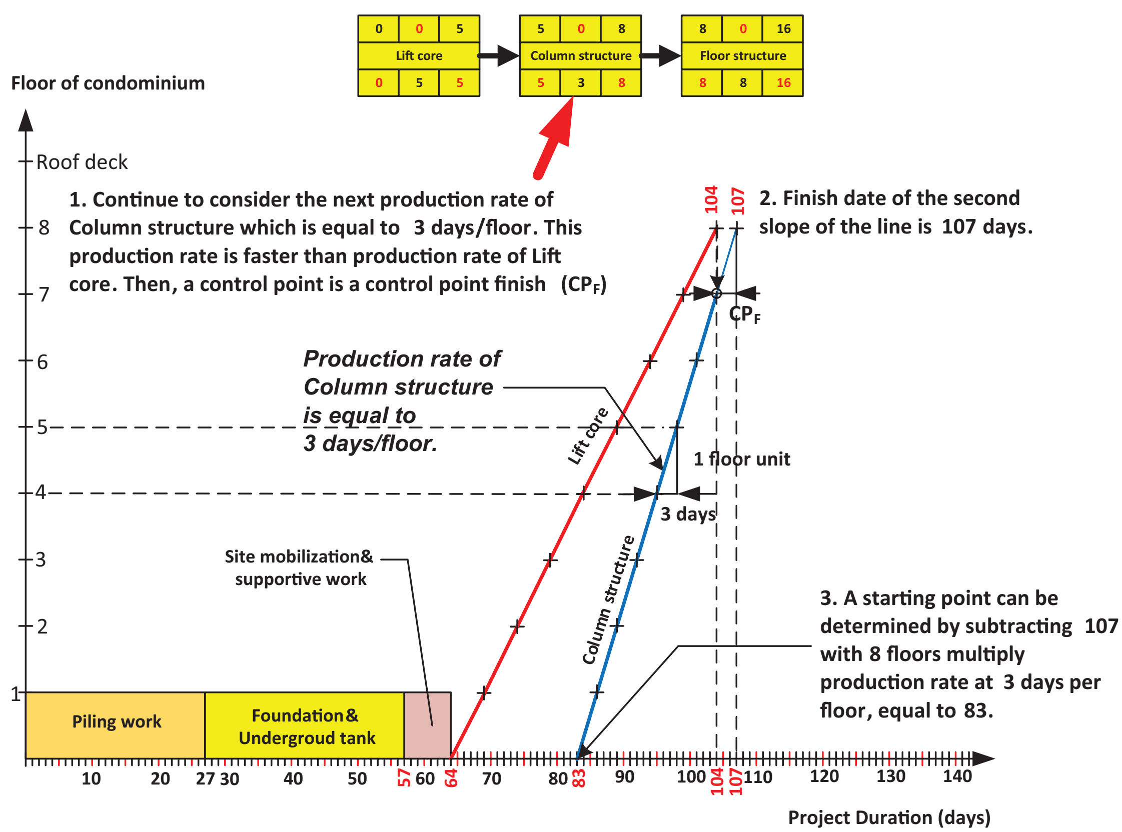


complete the three activities comprises 64 days. The lift core activity, the first sub activity of the repetitive structural concrete work, represents the first line on the figure and its production rate amounts to five days per floor. The total duration for construction of the concrete lift core is 40 days. Therefore, the completion of the lift core is scheduled to be at day 104.

The second line activity represents column structure, as shown Figure 12. This has a faster production rate than the first line activity at only three days per floor. Therefore, the control point between these two activities is a "control point finish (CP_F)" (Harris and Ioannou 1998), which denoting the completion of the last unit of lift core construction triggering the start of the last unit of column structure tasks. The completion of the column structure will be achieved in 107 days. As a result, the starting point of activity in connection with column structure activities can be calculated as 107 minus three days per floor, multiplied by eight floors, which is equal to 83.

The third line activity concerns floor structure, as shown in Figure 13. This has a production rate of eight days per floor, which is slower than that of column structure. Therefore, the control point between these two activities is a "control point start (CP_S)" (Harris and Ioannou 1998). This indicates that the ending of the first unit of the preceding process triggers the start of the succeeding activity. In this case, the end of construction of the concrete column on floor one is realized at day 86. This activates the start of the first unit of the floor structure. This creates a zero slack concept. As a result, the completion of floor structure is scheduled to be on day 150 of the project. An RSM planner should follow the concepts explained and apply them to the rest

FIGURE 12. A control point finish (CP_F) between a lift core activity and a column structure.



of the activities in their particular project. Finally, the RSM of the eight storey project in each building will be as shown in Figure 14. Using RSM procedures in construction management allows main contractors to use different subcontractors on different activities independently. The major duties of main contractors now shift to preparing optimally detailed designs and ensuring construction quality control. A flow chart of the processes involved in developing an RSM schedule from a CPM diagram can be summarized in Figure 15.

Overall, one condominium can be completed within 346 days using 23 different subcontractors. The duration each subcontractor is assigned to work is a major concern as the number of workers needed can vary according to different subcontractor performance standards and productivity levels.

CONCLUSION

Construction planning and scheduling using CPM methodologies is sometimes unable to assure project completion on time due to resource allocation problems. Certain work crews experience task interruptions as a result of conflicts with other crews. The use of RSM practices has the potential to eliminate such problems. RSM promotes an assembly line type of process within a construction project based on the uninterrupted flow of resources. Workforce, supplies, and money are supplied and exploited on a continuous basis. Individual crews work on different activities. Wastage arising from resource conflicts and excessive waiting times can potentially be eliminated. Graduate students, architects and engineers can learn how to create an RSM schedule exploiting the methodology used in the case study outlined in this paper. Planning repetitive

FIGURE 13. A control point start (CP_S) between a column structure and floor structure.

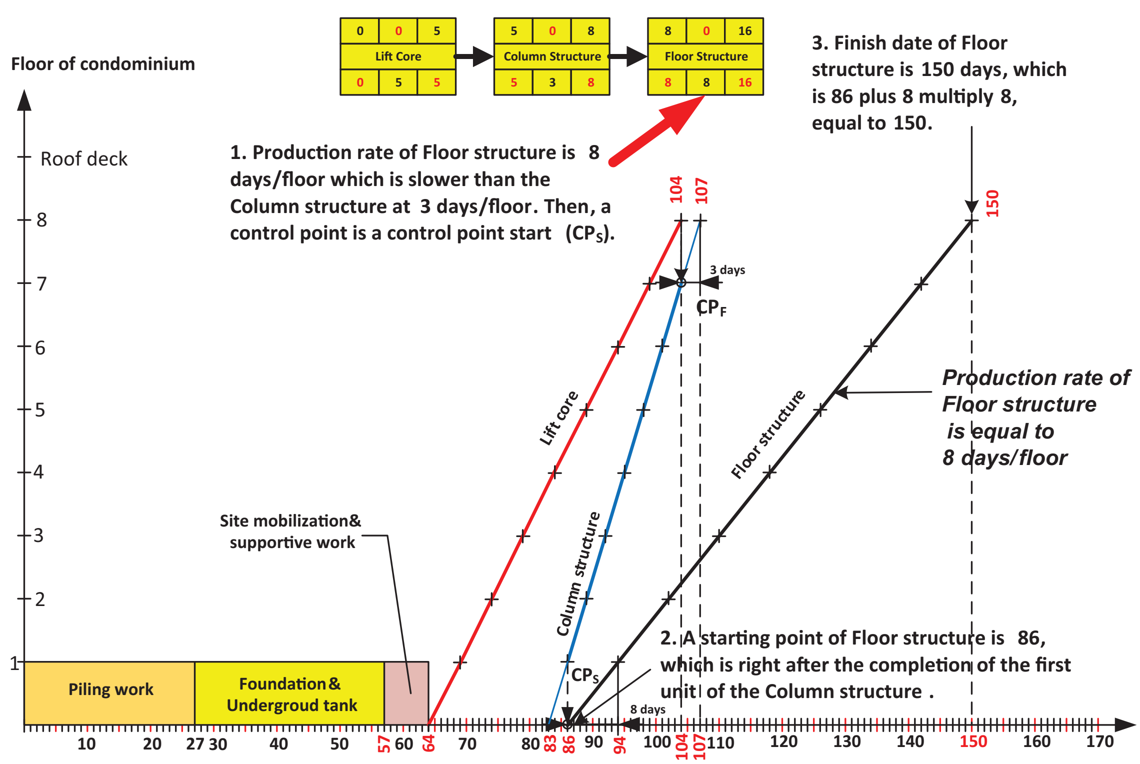


FIGURE 14. A complete RSM diagram of an eight-floor green condominium building.

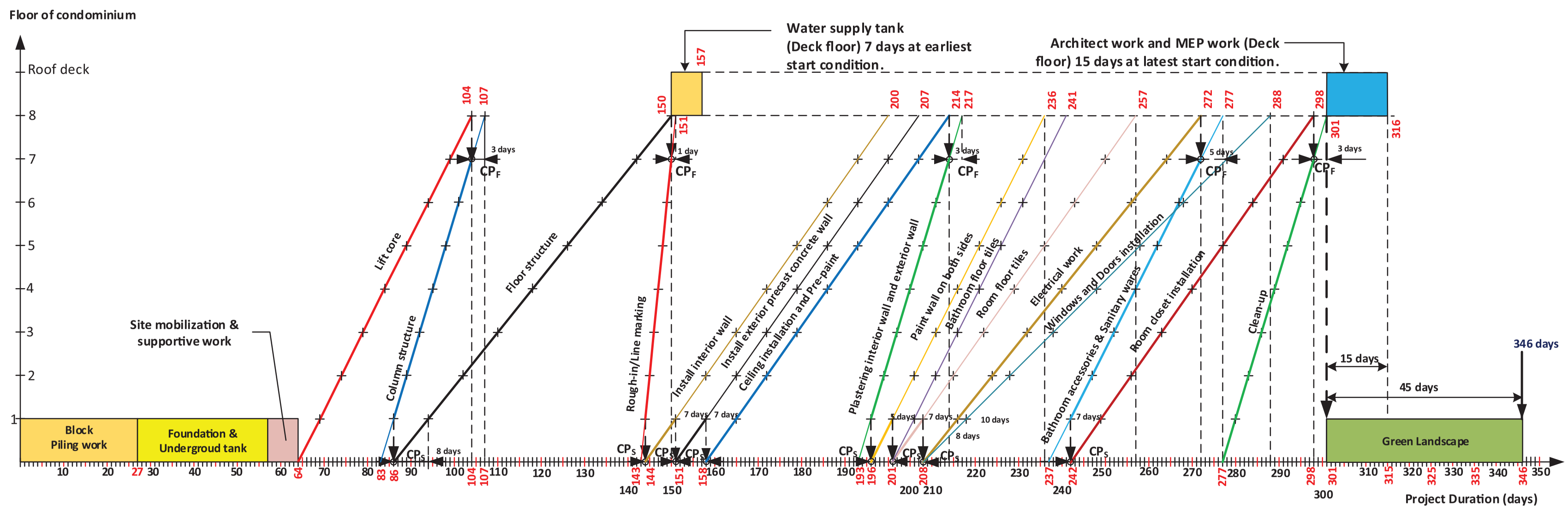
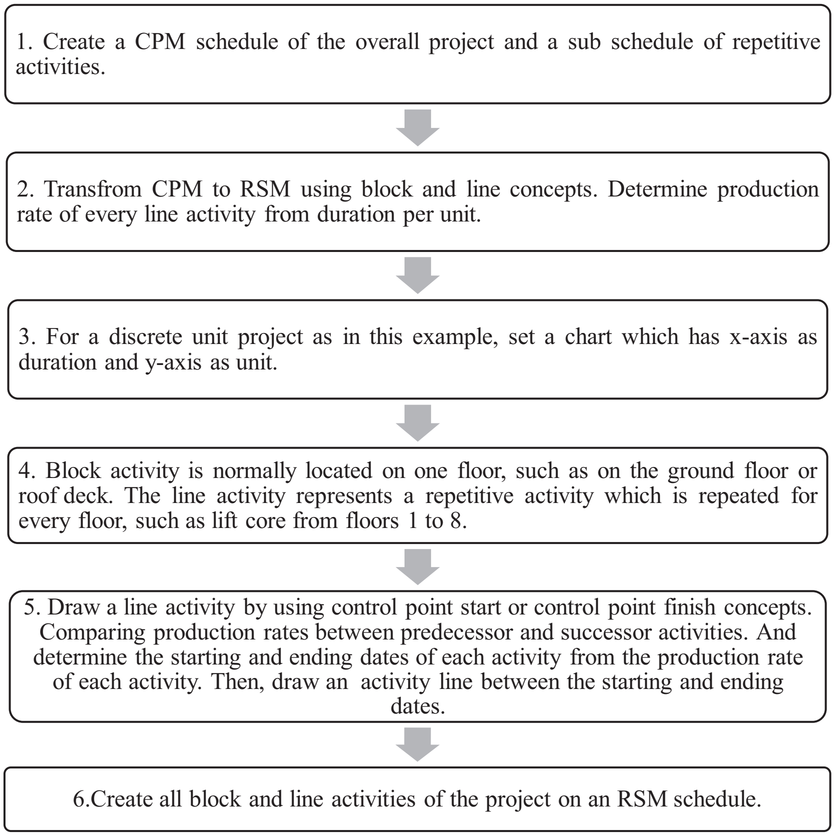


FIGURE 15. Flow chart for developing an RSM schedule.



construction projects utilizing RSM will potentially yield considerable benefits arising from more efficient construction practices. Improved productivity and job satisfaction are expected from using RSM when planning repetitive projects like green condominiums.

REFERENCES

1. Arditi, D., & Albulak, M. Z. (1986). Line-of-balance scheduling in pavement construction. Journal of Construction Engineering and Management, 112(3), 411–424.
2. Gorman, J. E. (1972). How to get visual impact on planning diagrams. Roads and streets, 115(8), 74–75.
3. Harris, R. B., & Ioannou, P. G. (1998). Scheduling projects with repeating activities. Journal of construction engineering and management, 124(4), 269–278.
4. Ioannou, P. G., & Srisuwanrat, C. (2006). Sequence step algorithm for continuous resource utilization in probabilistic repetitive projects. Proceedings of the 2006 Winter Simulation Conference, pp. 1731–1740, IEEE.
5. Ioannou, P. G., & Yang, I. T. (2016). Repetitive scheduling method: Requirements, modeling, and implementation. Journal of Construction Engineering and Management, 142(5), 04016002.
6. Kenley, R., & Seppanen, O. (2009). Location-based management of construction projects: part of a new typology for project scheduling methodologies. Proceedings of the 2009 Winter Simulation Conference (WSC), pp. 2563–2570, IEEE.
7. Srisuwanrat, C., & Ioannou, P. G. (2007). Optimal scheduling of probabilistic repetitive projects using completed unit and genetic algorithms. Proceedings of the 2007 Winter Simulation Conference, pp. 2151–2158, IEEE.