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Cost Optimization with Repetitive Scheduling Methods

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***Abstract*: Repetitive construction projects represent a large portion of the construction industry. Construction projects that contain several identical or similar units are usually referred to as repetitive projects which include multi-storey buildings, pipelines, highways, and housing developments projects. Although the conventional critical path method (CPM) has been widely used in scheduling construction projects, it possesses various deficiencies in scheduling repetitive projects. The Repetitive Scheduling Method (RSM) recognizes the additional resource continuity constraint that cannot be shown in a CPM network, and thus provides for continuous resource usage. It incorporates commonly accepted activity precedence concepts from CPM, and can be applied to both vertical and horizontal projects that may contain either discrete or continuous activities. An RSM schedule is presented graphically as an X-Y plot of a series of production lines, each of which represent a repetitive activity. RSM introduces the controlling sequence of activities as a new concept for the determination of the project duration. This sequence includes activities between control points on successive unit production lines and extends from projects start to project finish. RSM diagrams are easy to prepare and understand, and the unique concepts of control points and controlling sequence are quickly comprehended. Thus, RSM has all the necessary performance characteristics to serve as a convenient and practical tool for scheduling multi-unit projects.**

***Keywords*: Repetitive construction projects, Scheduling methods, Critical Path Method.**

1. Introduction

A. *Repetitive construction projects*

Repetitive construction projects represent a large portion of the construction industry. Construction projects that contain several identical or similar units are usually referred to as repetitive or linear projects. Linearity may be due to the uniform repetition of a set of activities throughout the project, or due to the physical layout of the project.

Activities that repeat from unit to unit create a very important need for a construction schedule that facilitates the uninterrupted flow of resources from one unit to the next, since it is often this requirement that establishes activity starting times and determines the overall project duration. Hence, uninterrupted resource utilization becomes an extremely important issue. To maintain work continuity, repetitive units must be scheduled in such a way as to enable timely movement of crews from one unit to the next, avoiding crew idle time. Ensuring work continuity, during scheduling, provides for an efficient resource utilization strategy.

Resources required to perform the work on an activity move from one stage to another. The quantity of resources for each activity is carefully selected to achieve the following goals.

1. To maintain a constant production rate for each crew on each activity throughout the project.
2. To maintain continuity of work for each crew from one stage to the other, thus to eliminate idle time for a crew waiting for preceding crews to finish their work.
3. To allow for time buffers between activities on the same stage—for example, a time buffer between a concreting crew and a formwork crew to allow for curing of concrete.
4. To allow for stage buffers between activities on different stages. For example, bricklaying should be two floors lower than the floor being poured to allow concrete to gain strength.
5. To finish the project at the minimum possible cost given a target project duration.

B. *Construction planning*

Construction planning is a fundamental and challenging activity in the management and execution of construction projects. A good construction plan is the basis for developing the budget and the schedule for work. Construction planning is not an activity which is restricted to the period after the award of a contract for construction. It should be an essential activity during the facility design.

Most repetitive construction projects for which formal plans are prepared tend to be defined with large number of activities. When a project plan consists of numerous activities, it is often advisable to organize the activities in some way to allow communication of plan information to others and to maintain an understanding of the various aspects of the project. While there are many ways that a plan can be organized, one common practice is the use of Work Breakdown Structure (WBS).

WBS is a convenient method for decomposing the project complexity in a rational manner into work packages and elementary activities. These work packages are then coded so that both costs and the schedule can be controlled. A common numerical accounting system is then applied to the activities, so that the coding indicates factors such as the type of material involved or the physical location within the project.

In essence, WBS divides and subdivides a project into different components by area, phase, function, or other considerations. The highest level in WBS consists of a single element, the project. At the next level, there may be only a few elements or items. Naturally, the further one goes down within the WBS, the greater the granularity of decomposition and the amount of detail.

Therefore, WBS is a deliverable-oriented decomposition of the project scope until a sufficient level of granularity enables easy definition of all information required to execute and manage detailed tasks.

C. Construction scheduling

A schedule is also a good communication tool, between the managers, owners, investors, and the general public. Once a plan is complete, it has to be communicated to the different levels of supervision and execution within the project. Scheduling is a means of communicating the project strategy and determining the amount of time required to carry it out. A schedule must be made to make optimal use of time and to ensure the activities are completed in time so that no sacrifices are made in the quality of the planning in order to meet deadlines. The construction schedule is usually based on the WBS and is very meticulous. It usually includes detailed plans, such as engineering schedules, construction sequencing, quality-assurance activities, as well as procurement plans.

The development of an effective and realistic schedule requires the following steps:

1. The construction activities and tasks must be sequenced in the most logical and efficient order.
2. A duration must be assigned to each and every single activity and task within the schedule, and
3. Adjustments must be made as deemed necessary to ensure the schedule matches the planned strategy and time frame required to complete the job.

D. Problem statement

The scheduling problem posed by multi-unit projects with repeating activities is akin to the minimization of the project duration subject to resource continuity constraints as well as technical precedence constraints. The critical path method (CPM) is the most widely used and accepted planning and scheduling method for traditional (non-repetitive) projects. However, CPM does not suit the planning and scheduling needs of repetitive projects.

2. Literature review

A. Introduction

This chapter reviews the available literature that is related to repetitive construction projects from several perspectives. Many scheduling techniques have been developed for planning and scheduling of repetitive projects. These techniques include:

1. Critical Path Method (CPM)
2. Program Evaluation and Review Technique (PERT)
3. Line-of-Balance (LOB)
4. Vertical Production Method (VPM)
5. Linear Scheduling Method (LSM)
6. Horizontal and Vertical Logic Scheduling method (HVLS)
7. Linear Programming (LP)
8. Repetitive Project Model (RPM)

B. Existing techniques

The following discussions concentrate on the advantages and disadvantages of the existing techniques and their underlying concepts. Various aspects of repetitive project scheduling and their ultimate objectives are assessed to verify their practical usages and their realistic representatives of construction projects.

1) Critical path method (CPM)

The Critical Path Method (CPM) was developed in the 1950s by James Kelly and Morgan Walker. The method offers an easy calculation to derive a project schedule and to assess the criticality of activities using its proposed concepts of floats and the critical path, focusing on time. Activities and their interrelationships are depicted in a network by nodes and arrows. Nodes represent the activities and activity information such as title, duration, etc. Arrows represent the interrelationships (precedence constraints) between activities and the lead time between them. After the network is constructed and the activity durations are given, the calculation of critical path, critical activities, and floats can be performed straightforwardly.

The derived information informs project managers of the criticality of activities, which allows them to plan in advance how to schedule the activities and manage the project effectively, based on the current schedule. On the other hand, the managers may decide to alter the original schedule to suit the project deadline, the company resources, and so forth.

Most scheduling software (Microsoft Project, Primavera, etc.) offers automation of CPM calculation and network drawing, within seconds after inputting data. These programs facilitate schedulers in altering and updating the schedule purposely for planning and controlling. Accordingly, CPM has been widely used in the construction industry.

However, CPM has been criticized for its incapability of taking resource consideration into account in its calculations. This usually leads to an unfeasible schedule due to the unawareness of resource constraints such as resource availability constraints. From the perspective of repetitive project scheduling, CPM is incapable of capturing the realistic and stochastic nature of repetitive projects (Reda 1990; Harris and Ioannou).

The reasons for such incapability are:

1. CPM does not take resources into account in calculating schedules. It is designed primarily for

scheduling and monitoring activity and project duration; CPM is a pure time-based schedule technique. CPM cannot ensure the continuous resource utilization of a crew from unit to unit. Therefore, it cannot maximize efficiency in resource utilization.

2. CPM calculation does not include nor is it concerned with the imbalanced production rate of resources resulting in inefficient resource utilization.
3. CPM is not applicable to non-deterministic activity duration. It is important to recognize that CPM, as a deterministic scheduling method, would schedule projects only to the level of reliability of the input values of the duration of activities. For reliable representation, the productivity data must be expressed in some probabilistic measure.
4. CPM cannot eliminate idle time, since it schedules activities based on their earliest start dates, (Reda 1990, Yang 2002). If a predecessor has a lower production rate than its successor, the successor must wait until the predecessor completes, which results in idle time.
5. CPM and its graphical presentation are considered ineffective when applied to repetitive projects having a large number of units. Its calculation becomes tedious and labor intensive (Yang 2002). For example, a repetitive project consisting of 7 activities for 1000 units will require 7000 nodes to represent the network. A network of this size is confusing and unmanageable (Reda 1990; Yang 2002).

To alleviate the mentioned deficiencies of CPM, the integrations of CPM and other techniques such as Line-Of-Balance (LOB) have been developed during the last couple of decades. Nevertheless, they still cannot handle the stochastic nature in the repetitive projects.

2) Project Evaluation and Review Technique (PERT)

The Project Evaluation and Review Technique (PERT) was introduced to the construction industry in the 1950s. It is a probabilistic scheduling technique using three point estimates of activity durations to determine an estimated project duration. The difference between CPM and PERT is that PERT is capable of scheduling non-deterministic activity durations while CPM cannot.

However, PERT has not been widely used in the construction industry compared to CPM as it requires more data of activity durations, which is often difficult to obtain and justify. Moreover, PERT requires intensive computation compared to CPM. Since the technology of personal computers has been improved in the last couple of decades, the improved technology causes simulation method to supersede PERT. From a repetitive project perspective, PERT and CPM have the same limitations due to their underlying time-based scheduling calculation and their graphical presentation in precedence networks (Yang 2002).

3) Line-of-balance (LOB)

The Line-Of-Balance method (LOB) was developed at the Goodyear Company by George E. Fouch in the early 1940's for the purpose of managing and controlling production processes in industrial manufacturing where tasks are repetitive. Then, LOB was applied in the Navy (Miller 1963). LOB's main objective is to balance the size of labors and machines based on their production rates so that their resources are employed at full capacities. The major benefit of LOB to construction scheduling is that it conveys important production rate and duration information in a graphical format.

LOB shows progress of activities against time in graphical presentation. The accumulated work completed is plotted with work progress on the Y-axis and time on the X-axis. The line representing completed work is termed the "Production Line". It is evident that LOB offers a better visual presentation than the precedence network, especially for repetitive projects, because the comparisons between activities and between units can be easily perceived in the diagram.

The easily interpreted graphics format enhances the viewers understanding of the project and also individual activities. It allows the viewers to detect a potential bottlenecks by simply observing the production lines.

LOB allows schedulers to observe and adjust the production rate of activities in a production diagram to maximize resource utilization. This process of adjusting production rate is known as "balancing production rates." LOB provides a means of selecting crew size in order to minimize inefficiency and waste in resource utilization. To balance unit production rates, activities are assigned to work at the minimum unit production rate among activities. For example, Activities A, B, and C have unit production rates of 2, 1, and 3 units/day. Thus, to balance these activities, production rates of A, B, and C should be set at a rate of 1 unit/day. If the scheduler desires to expedite the project furthermore, more resources could be assigned to Activities A and B so that they progress as fast as Activity C. For this example, additional resources must be assigned to Activities A and B to speed up their unit production rates to 3 units/day.

3. Methodology

The methodology used in this thesis is the use of Repetitive Scheduling Method (RSM) for the planning and scheduling of repetitive construction projects to overcome the limitations of the traditional networking techniques.

The Repetitive Scheduling Method (RSM) recognizes the additional resource continuity constraint that cannot be shown in a CPM network, and thus provides for continuous resource usage. It incorporates commonly accepted activity precedence concepts from CPM, and can be applied to both vertical and horizontal projects that may contain either discrete or continuous activities.

The construction of RSM schedules involves the positioning of successive unit production lines by using the new concept of control points. There is a specific point along each production line that controls the schedule position of its successor production line. This point, called a control point, tends to be located toward the first unit in the sequence of units if the lines diverge, and toward the last unit in the sequence if the lines converge. These control points have significance in the determination of the project duration, and serve as points of rotation for unit production lines whose resource rates are increased or decreased.

A. RSM schedule representation

An RSM schedule is presented graphically as an X-Y plot where one axis represents units, and the other time. For vertical construction projects, the repetitive units are usually discrete entities, such as houses, stores, apartments, or floors in high-rise construction, and work progress is measured in units completed. Hence, the units are typically shown along the Y-axis and time is shown along the X-axis. For horizontal construction projects, such as highways, pipelines, canals, tunnels, and so forth, work progress is measured in units of length and these units are shown along the X-axis to correlate with horizontal and vertical alignment charts, while time is shown along the Y-axis.

The repetitive units of the project must be arranged in some logical sequence along the chosen axis to define their pattern of repetition. This sequence may be accepted as a natural occurrence or may be established to suit some production need. For example, building floors must naturally be constructed one upon another, stations along a highway may follow in the natural numerical order from project start to project finish, or may be planned to recognize particular site or traffic conditions.

B. RSM activity logic

In addition to establishing the pattern by which repetitive units follow each other, it is necessary to identify the precedence constraints among the activities in each unit. To do so, a CPM precedence network is prepared for each typical repetitive unit, or if necessary, for each non-typical unit.

The process to establish unit activity logic begins with the creation of a list of all the time consuming activities necessary for the completion of the project. Each activity in the list is given a name and the list is analyzed to determine the proper dependency relationships and to remove redundancies.

An examination of the activity list will most likely show groups of similar activities occurring again and again. For example, it may be observed that activities describing the construction of the first typical floor of a multistory building are repeated for several other succeeding floors. The collection of activities needed for each floor represents the details of a repetitive unit that is identified with that floor. The number of activities in the repetitive unit is not an important matter, because it is determined by the nature of the project. In some instances, the unit may contain only one activity.

Once all activities belonging to each repetitive unit have been identified, a logic diagram is prepared. This diagram can be either in the form of an arrow or a precedence network, but the precedence form is preferred. Each unit network should contain all production and want logic relationships among the activities. Because the main purpose of this diagram is to establish logical relationships among the activities, resource considerations within this unit can be temporarily ignored.

C. Activity logic constraints

While the activities within a repetitive unit must be logically related, they also must be logically related from unit to unit according to the logical sequence pattern of the units as previously described. There are two types of constraints that control unit-to-unit logic in RSM diagrams; one is a technical precedence constraint and the other is a resource availability constraint. In the first instance, a particular work activity in the network of one unit must be followed by a similar work activity in the network of a succeeding unit to ensure that the flow of the technical work between the units is maintained. In the second case, the resource assigned to an activity in one unit also must be assigned to the similar activity in the succeeding unit to ensure that the resource required in the first unit is available when needed by the second unit. Note that this does not ensure that the resource between the two units will be used continuously.

D. Resource considerations

RSM assumes that the same resource will be used for like activities in successive repeating units, so each activity's resource must be consistent from unit to unit. For example, if an activity in the first unit requires a crew of carpenters, that activity in each succeeding unit will require the same crew of carpenters.

The resource production rate for an activity, rpr_A, is the amount of work that can be accomplished by the resource in the given time period. In equation form:

$$rpr_A = Q_{Ai} / T_{Ai}$$

where rpr_A is the resource production rate; Q_{Ai}, is the quantity of work done in activity A, in any repeating unit, i; and T_{Ai} is the time needed to complete the 'A' activity in unit i.

The unit production rate is the number of repetitive units that can be accomplished by a resource during a unit of time. For an activity, A, in any repeating unit, i, the unit production rate, upr_{Ai}, can be expressed as:

$$upr_{Ai} = 1 / T_{Ai}$$

where T_{Ai} is the time needed to complete the unit. The unit production rate is the slope of a production line in an RSM diagram.

4. Basic RSM concepts

RSM employs a pull-system approach, where the finish time of the predecessor activity is pulled forward to meet the start date of the successor in order to achieve work continuity and uninterrupted resource utilization, in contrast with the CPM push system, where the start of every activity is pushed in time to maintain the precedence relationships with its predecessors.

The objective in RSM is not minimization of the project completion time but achieving work continuity which leads to minimizing the overall project cost. In construction projects, the minimization of the cost may be more desirable than the reduction of the project duration.

A. Converging Production Lines in RSM

Let us consider a pair of activities, A1 and B1 taken as an example where the link relationship between the activities is finish to start (FTS). The time duration, T, the resource designation, R, the Early Start Day, ESD, and the Early Finish Day, EFD, are as shown in the legend. The values of Rare expressed as alphabetic symbols to identify the particular resource being used by the activity.

There is only one repetitive unit, and the zero point on the Y-axis is designated by S to indicate the start of the unit. The finish of the unit is designated by F.

The inclined line drawn from the start of Activity A1 in Unit 1 to the finish of Activity A1 in Unit 1 represents the production line for Activity A1. In a similar manner, the production line for Activity B1 is drawn from its start at the end of Day 13 and the start of the unit to its finish at the end of Day 15 and the finish of the unit. The FTS precedence relationship between the activities is indicated by the dotted arrow at Day 13 drawn downward from the finish of Activity A1 to the start of Activity B1. Note that the unit production rate for Activity A1 is 1/3 unit per day (1/3 u/d), and for Activity B1 is 1/2 u/d. These rates will be recognized as the mathematical slopes of the respective production lines.

5. Schedule development for high rise building

While high-rise buildings have a large degree of repetition, their scheduling needs are different from either linear projects such as highways and pipelines, or nonlinear projects such as multiple similar houses. This is because high-rise buildings involve repetitive activities that advance within the building not in one direction but in two directions: A horizontal direction through the floor, and a vertical direction from one floor to the next. The sequencing of activities is, therefore, controlled by horizontal and vertical constraints.

A. Step-wise procedure for schedule development for high-rise buildings using RSM

The step-by-step procedure for schedule development for high-rise buildings is explained as follows:

Step 1 - The first stage of RSM includes the following five steps:

1. In the first stage, activities would be sorted in sequence step order.
2. For each predecessor, determine the activity's 'pushed' position based on each relationship (link) in every possible unit.
3. For each 'pushed' position, determine the necessary 'shift' to that activity. The shift represents the difference between the shape starting at time zero and the pushed position.
4. Select the maximum shift over all units, all incoming relationships, and all predecessors.
5. Move the activity being scheduled to the position that results from the maximum shift.

Among all the activities that have to be executed in a high-rise building, the erection of the structure sets the rhythm for the remaining trades. In general, structural-core activities are the columns, beams, and slabs. They have a specific relationship and have to proceed in a specific manner to avoid scheduling errors.

For example, shows an example repetitive schedule for structural core activities along a five-story building. While it looks typical, it has a fatal problem with respect to a high-rise building. In the figure, the columns of the 2nd floor are scheduled to start at time Sc2 before the slab of the first floor is completed at time Fs1. This violates the basic logical relationship that columns at the upper floors require the slabs underneath to be completed.

The structural-core group is dealt with as one activity that uses one crew. The structural-core activity in an upper floor starts only after the completion of the whole group at the lower floor. Dealing with the structural core activities in this manner prevents scheduling errors that are specific to high-rise buildings.

6. Conclusion

Repetitive projects are those characterized by repetitive construction activities. Examples are highway, pipeline, high-rise building construction, etc. Repetitive projects require schedules that ensure the uninterrupted usage of resources from a unit to similar units in a repetitive activity while maintaining logical dependency constraints. The critical path method (CPM) is the most widely used and accepted planning and scheduling method for traditional (non-repetitive) projects. However, CPM does not suit the planning and scheduling needs of repetitive projects.

The Repetitive Scheduling Method (RSM) recognizes the additional resource continuity constraint that cannot be shown in a CPM network, and thus provides for continuous resource usage. It incorporates commonly accepted activity precedence concepts from CPM, and can be applied to both vertical and horizontal projects that may contain either discrete or continuous activities.

An RSM schedule is presented graphically as an X-Y plot of unit production lines that continue across designated units of the project. One axis of the plot represents units and the other time, and the repetitive units may be assigned to either axis depending on the type of construction project undertaken.

The construction of RSM schedules involves the positioning of successive unit production lines by using the new concept of control points. There is a specific point along each production line that controls the schedule position of its successor production line. This point, called a control point, tends to be located toward the first unit in the sequence of units if the lines diverge, and toward the last unit in the sequence if the lines converge. These control points have significance in the determination of the project duration, and serve as points of rotation for unit production lines whose resource rates are increased or decreased.

RSM also introduces a new concept for the determination of the project duration. As with all projects, the duration must be determined by some sequence of activities that extends from project start to project finish. This sequence in RSM is called the controlling sequence and includes the activities of the first production line from project start until the first control point is reached. It then switches to the next production line and includes all activities on that line until the next control point is found. The sequence continues to include activities switching from one production line to another production line at control points, until reaching the end of the project. An RSM controlling sequence may include both critical and non-critical activities. Conversely, activities can be critical because of resource continuity (resource critical), and thus not be part of the controlling sequence.

The unit production rate of any activity can be increased or decreased by altering the composition of the crews or equipment needed to carry out the activity. This causes the associated unit production line to rotate about a control point and to increase or decrease the project duration. However, care must be taken in choosing the activity and resource to change; a poor choice may shift the location of the controlling point for the production line and result in an unexpected project length.

RSM is a practical scheduling methodology. It uses customary work methods and crews to define repetitive activities that can be arranged in any desired pattern. RSM diagrams are easy to prepare and understand, and the unique concepts of control points and controlling sequence are quickly comprehended. Thus, RSM has all the necessary performance characteristics to serve as a convenient and practical tool for scheduling multi-unit projects.

In this thesis, a plan of 5-storeyed building is considered in order to represent how RSM can help in achieving work continuity. It has been observed that by using RSM, it is possible to eliminate the total resource idle time of 184 days. The total cost of the project also gets reduced as the total idle time of the resources is eliminated.

The total project duration can also be reduced by changing the unit-production rates of various activities. The increase in the unit production rate depends on the availability of the resources i.e. availability of labour, equipment and funds. The resource availability needs to be checked before the unit production rate of activities is increased.

Proper planning is required in order to balance the cost of adding resources with that of the reduction in project duration. The cost saved due to decrease in project duration should be compared with that of the cost of adding resources in order to increase the unit production rate. If the cost of adding resources turns out to be more than the indirect cost savings due to decrease in project duration, then it is not feasible to increase the unit production rate.

In the case study taken, it has been observed that by changing the unit production rate of activities ‘C’ and ‘D’, we were able to reduce the total project duration by 9 days and eliminate the total resource idle-time of 220 days by the application of RSM.

It has been observed that by increasing the unit production rates of certain activities, the total project duration may be increased after the application of RSM. In such cases, there is a need to apply necessary work breaks in order to decrease the total project duration. Tradeoffs between maintaining and relaxing resource continuity constraints must be carefully studied in terms of project cost and duration. The best work break position should result in the greatest decrease in project duration and a small increase in project idle time.

In the case study taken, it has been observed that by increasing the unit production rate of activity ‘D’, the total project duration is increased by 20 days from the original CPM schedule after the application of RSM. Therefore, work break is applied in order to relax the resource continuity constraint. From the above analysis, it can be concluded that work break at D3-D4 provides a better solution as this schedule is only five days longer than the project duration of 188 days in the CPM schedule, while at the same time it eliminates 198 days of resource idle time. Thus, the schedule with a work break results in a better solution.

References

[1] Tarek Hegazy, M and Ehab Kamarah, “Efficient Repetitive Scheduling for High-Rise Construction” - Journal of Construction Engineering and Management, 2008.
[2] Robert B. Harris and Photios G. Ioannou, “Scheduling projects with repeating activities” - Journal of Construction Engineering and Management, 1998.
[3] Rehab M. Reda (1990), “RPM: Repetitive Project Modeling” - Journal of Construction Engineering and Management.
[4] Arash Ranjbaran (2007), “Planning and control of high-rise building construction" – Project Report, Concordia University, Canada.
[5] Bin Cheng (2005), “Limitations of existing scheduling tools in planning utility line construction projects” Project Report, University of Florida, U.S.A.
[6] Mohammad A. Ammar, “LOB and CPM Integrated Method for Scheduling Repetitive Projects,” Journal of Construction Engineering and Management, 2013.
[7] I-Tung yang and Photios G. Ioannou, “Resource-driven scheduling for repetitive projects: a pull-system approach,” Journal of Construction Management and Economics, 1998.
[8] Pandelis G. Ipsilandis, “Multi-objective optimization in linear repetitive project scheduling” – Operational Research, Vol. 6, No. 3, pp. 255-269, 2006.
[9] Tarek Hegazy and Nagib Wassef, “Cost optimization in projects with repetitive non-serial activities,” Journal of Construction Engineering and Management, 2001.
[10] Osama Moselhi and Khaled El-Rayes, “Scheduling of repetitive projects with cost optimization,” Journal of Construction Engineering and Management, 1993.
[11] Rong-yau Huang and Kuo-Shun Sun, “Non-Unit-Based Planning and Scheduling of Repetitive Construction Projects,” Journal of Construction Engineering and Management, 2006.

[12] Pasit Lorterapong, "Constraint-Directed Scheduling for Multi-Storey Building Projects," 13th ISARC (International Symposium on Automation and Robotics in Construction and Mining).
[13] I-Tung Yang and Photios G. Ioannou, "Scheduling system with focus on practical concerns in repetitive projects" – Construction Management and Economics, (22), pp. 619-630,2004.
[14] Charchrist Srisuwanrat, "The Sequence Step Algorithm- A simulation-based scheduling algorithm for repetitive projects with probabilistic activity durations," Project Report, University of Michigan, U.S.A, 2009.
[15] Marco A. Bragadin, "Heuristic solution for resource scheduling for repetitive construction projects," Management and Innovation for a Sustainable Built Environment - 20 – 23 June 2011, Amsterdam, The Netherlands, 2011.