Track Work Construction Scheduling using Linear Scheduling Method

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Abstract

Railway projects have been increased recently in Thailand but the scheduling method used by contractors for this kind of project was not appropriate based on the nature of activity in a project. Linear scheduling method (LSM) was reviewed and applied to schedule a project case study. The case study was a conventional railway ballast track project. Data related to construction are collected such as method statement and production rate and a case study of 20-kilometer new line project for conventional ballast track was then scheduled using LSM. The case study project duration was 156 days. Feedbacks and comments from contractor were positive when compared with current schedule technique used by a contractor as a project plan can be displayed distance and production rate consequently macro view and micro view of a project are provided.

Keywords: *Scheduling, Railway, Linear scheduling, Track work*

1. Introduction

Numbers of railway projects have been increased recently in Thailand according to government policy to improve the infrastructure of the country. The related projects are composed of a high-speed train, mass transit train in Bangkok and its suburban, double-track railway project all over the country as well as replacement of the old tracks. Those projects related to high-speed train and double-track railway will ensure the development of a railway network of the country. The government is aiming that it will extend the cooperation in trade, investment, logistics, tourism, science and technology, culture, and other aspects among ASEAN countries. It will reduce the cost of logistics and promote economic growth due to huge demand for materials used in the projects. Thailand will also achieve the status of ASEAN's transportation hub eventually. The government is hoping that better rail infrastructure will help pull the country from its middle-income trap, in which a country reaches a certain level of economic success, while the mass transit trains are also being upgraded and expanded. A new line running north and south through Bangkok will join an existing line to connect outlying areas of the capital to Bang Sue Grand Station. This will improve the quality of life for the people who live in the city of Bangkok and its vicinity. Traveling time will be shortened and traffic demand will also reduce.

Planning and scheduling of large-scale projects play an important role in project success because they will be fundamental in estimating and monitoring of a project afterward. In general, the universal objective of all construction projects is to finish the project on time within a budget while the specification is also achieved. Various scheduling methods are available but Gantt chart technique and critical path method (CPM) are widely used in the construction industry, not only in Thailand but all around the world. However, those methods have some limitations for the repetitive type of project that activities are performed continuously over the entire project duration (Callahan et al., 1992). For example, a road project includes the following activities for clearing, grubbing, grading, sub-base, base coarse, and paving. Each of these activities must be repeated by the same crew for the entire project duration. These activities are commonly addressed as repetitious activities. To use CPM techniques for this type of project, it is necessary to break a continuous activity into multiple discrete activities, such as associated with sections of the road and studies have indicated that CPM has certain limitations of in scheduling linear projects (Lucko, 2008). In addition to road construction, typical linear projects include high-rise buildings, pipelines, tunnels, and absolutely railway. Traditional scheduling methods as mentioned earlier such as CPM or PERT have been found to be inappropriate for scheduling the linear construction projects (Liu et al., 2016). However currently, typical linear construction projects including railway, still mainly apply CPM to schedule the process. (Liu et al., 2016).

Researches that applied linear scheduling method (LSM) are including; Kannan and Sentil (2014) presented production based scheduling method for linear construction in road projects by adopting the Delphi process. For railway project, Liqiang Liu, Yisheng Lui and Tang (2015) analyzed characteristics of railway construction projects and then applied LSM to propose a method for determining the duration. The results of the study also confirm the effectiveness of the proposed calculation method of construction duration.

As mentioned that numerous railway construction projects are taking place. Those projects might include building, tunnel, and track work parts. The track is a long line from station to station and it can be either slab type or ballast type. Work activities of this part are not single location activity since activities will be started from location to another location because of its linear nature. Scheduling methods of ballast track used by contractors in Thailand were reviewed and found that most of the contractors used a Gantt chart technique to schedule a project because of its ease of use and it is easy to prepare. The construction method for the new ballast track is studied and will be used as a case study to schedule the project by using LSM and then discussing with the contractors for suggestion and comment.

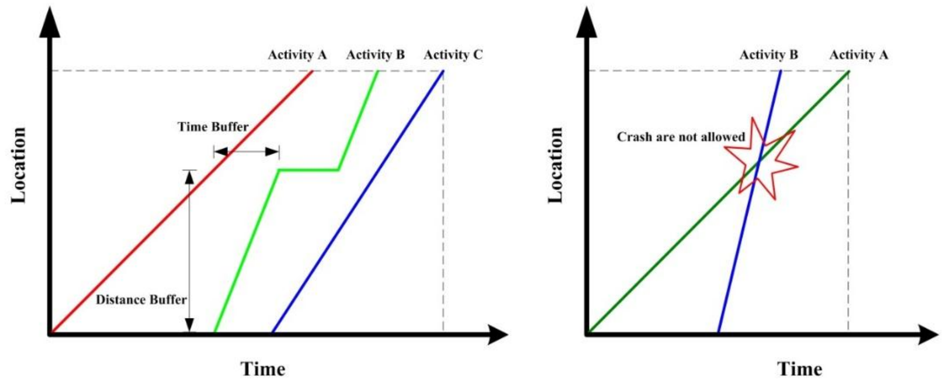
2. Objectives

The objective of this paper is to apply linear scheduling method for new line ballasted track work construction of railway project and then compare in term of its ease of use with the current method used by a contractor.

3. Materials and Methods

3.1 Linear Scheduling Method

Linear Scheduling Method (LSM) is a graphical scheduling method focusing on continuous resource utilization in repetitive activities. LSM diagram is used to plan and record progress on multiple activities performed continually over the duration of the entire project. The origin of linear scheduling is not clear but it has some relationship to line-of-balance scheduled used in manufacturing industry (Callahan et al., 1992). The horizon axis plots time while the vertical axis plots location or distance along the length of the project, however, the distance and time buffers between activities have to be considered as shown in Figure 1(a). A slope of each activity on the LSM schedule represents a production rate. The main advantages of LSM over CPM are its underlying idea of keeping resources continuously at work. The uniqueness of the LSM is that the production rate of each crew is critical and evaluated to ensure adequate spacing between activities. If crews cross over because the work rate of the successor crew is greater than the predecessor, then a crash occurs. The Linear Scheduling method makes it possible to identify crashes so that work rates, the lag time between crews or distances between crews can be adjusted to eliminate clashes as shown in Figure 1(b). The overall progress or sequence of activities is of lesser concern than optimizing the productivity rates to minimize the total time. In other words, it schedules activities in such a way that resource utilization is maximized, interruption in the on-going process is minimized, and the effect of the learning curve phenomenon is also maximized. Additionally, the graphical element of the linear scheduling method is beneficial as it provides a visual resource which communicates both the macro perspective of the whole of the project and the micro view to specific activity and location.



(a) (b)

Figure 1 Linear Scheduling Method Diagram

3.2 Types of construction activities

The construction activities of the linear project can be divided into three types which are linear activities, bar activities, and block activities. The three types of activities can be further divided according to whether they are continuous constructions or whether they are throughout the whole project (Rowings and Harmelink, 1998). In order to make schedule look familiar and easy to understand, scheduler sometimes adds milestone activities into the schedule as used in the CPM or Gantt chart. Construction activities, therefore, are primarily depicted as shown in Figure 2.

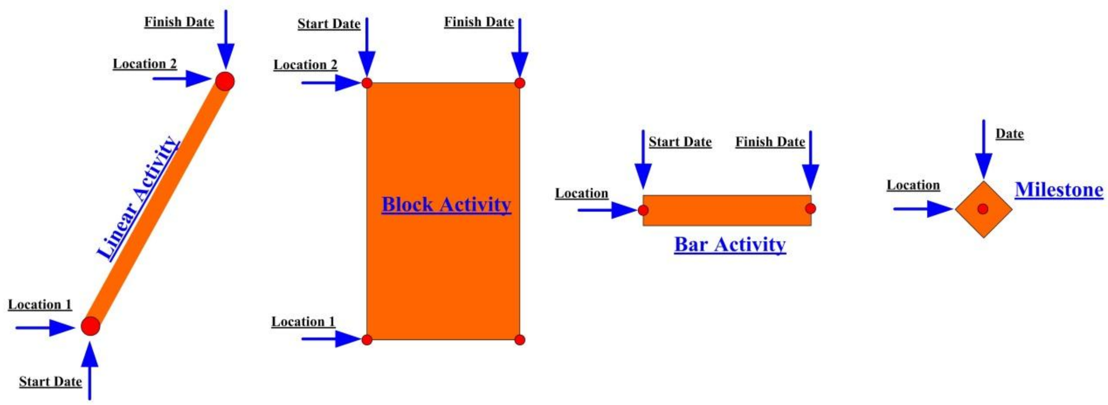


Figure 2 Construction activities

3.3 Railway Track

Tracks are long and large structures that are stretching hundreds of kilometers. It is a fundamental part of the railway infrastructure and track type used in this paper is conventional ballast track as shown in Figure 3. Railway track consists of rails and sleepers, laid in and fixed by ballast on the roadbed or formation. The roadbed is the ground upon which the track will be laid. The track itself is supported on the ballast that made up of stones. The ballast is provided to give support, load transfer and drainage to the track and thereby keep water away from the rails and sleepers. The ballast must support the weight of the track and the considerable cyclic loading of passing trains. The ballast is made up of stones of granite or similar material and should be rough in shape to improve the locking of stones. In this way, they will better resist movement. Ballast stones with smooth edges do not work so well. The usual track form consists of the two steel rails, secured on sleepers (or crossties, shortened to ties, in the US) so as to keep the rails at the correct distance apart (the gauge) and capable of supporting the weight of trains. There are various types of sleepers and methods of securing the rails to them. Sleepers are normally spaced at 650 mm (25 inches) to 760 mm (30 inches) intervals, depending on the particular railway's standard requirements. Traditionally, sleepers (known as ties in the US) are wooden. They can be softwood or hardwood. Most in the UK are softwood, although London Underground uses a hardwood called Jarrah wood. Sleepers are normally impregnated with preservative and, under good conditions, will last up to 25 years. They are easy to cut and drill and used to be cheap and plentiful. Nowadays, they are becoming more expensive and other types of materials have appeared notably concrete and steel. Concrete is the most popular of the new types. Concrete sleepers are much heavier than wooden ones, so they resist movement better. They work well under most conditions but there are some railways which have found that they do not perform well under loads of heavy haul freight trains. For rail, the standard form of rail used around the world is the "flat bottom" rail. It has a wide base or "foot" and narrower top or "head". Rail tends to creep in the main direction of travel so "rail anchors" ("anti-creepers" in the US) are installed at intervals along the track. They are fitted under the rail against a base plate to act as a stop against movement. Rail Welding Modern track work uses long welded rail lengths to provide a better ride, reduce wear, reduce damage to trains and eliminate the noise associated with rail joints. There are two main types of welding used for rails: Thermit welding and Flash Butt welding (Connor, 2017 and Miura, et al., 1998).

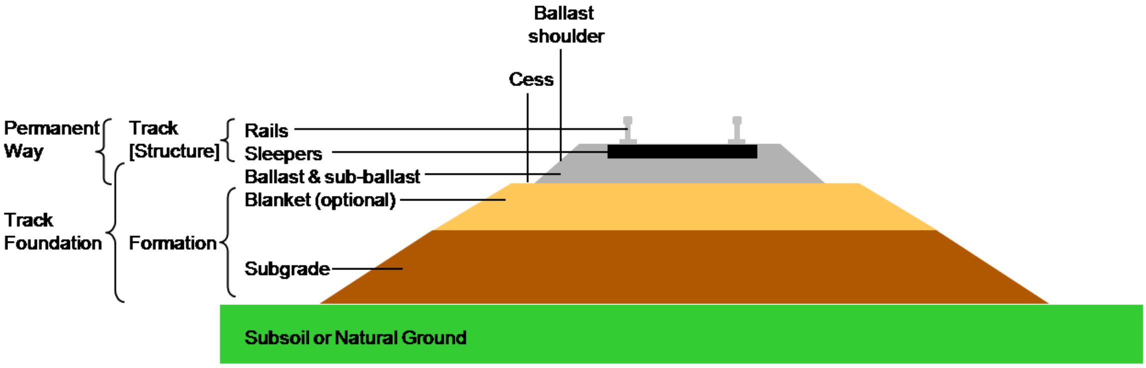


Figure 3 Conventional ballast track cross section

3.4 Case Study

In this paper, a new line for conventional ballast track as stated in section 3.3 will be used as a case to demonstrate railway track work construction scheduling by using LSM for a distance of 20 km. List of activity can be identified after studying the sequence of work and method statement whereas the production rate (km/day) of each activity is collected from the contractor based on their experience and resource used. From production rate data, the duration of each activity can be calculated from the distance of work divided by production rate.

4. Results and Discussion

Related data were collected from contractors and were concluded in Table 1.

Table 1 Activity data

No.	Activity	Description	Production Rate (km/day)	Duration (day)
1	Bottom Ballast Placing	10 wheel Dump Track/ Ballast Paver	4	5
2	Sleeper Placing	Back Hoe/Frame Beam	1	20
3	LWR Placing	Tractor/ Rollers/ Train of Trolleys/ Offloading Ramp/ Locomotive/ Rail Lifting Machine	2	10
4	Assembling Track	Hand Tools for Fastening Installation/ Clipper Machine/ Temporary Fishplate	2	10
5	1st Ballast Placing	Ballast Train (Loco + Ballast Hopper Wagon)	1.5	13.33
6	Ballast Profiling	Ballast Regulator	3	6.67
7	1st Tamping	Tamping Machine	2	10
8	Thermit Welding	Welding at every 200 m not more than 800 m.	2	10
9	2nd Ballast Placing	Ballast Train (Loco + Ballast Hopper Wagon)	3	6.67
10	Ballast Profiling	Ballast Regulator	3	6.67
11	2nd Tamping	Tamping Machine	1.5	13.33
12	Track Stabilizing	Track Stabilizing Machine	5	4
13	De-stressing	Thermit Welding Apparatus/ Rail Tensor	2	10
14	Ballast Placing	Ballast Train (Loco + Ballast Hopper Wagon)	3	6.67
15	Ballast Profiling	Ballast Regulator	3	6.67
16	Final Tamping	Tamping Machine	3	6.67
17	Final Ballast Profiling	Ballast Regulator	3	6.67

Activities of railway construction track in this paper will start after the roadbed and all topographic surveying have finished. Works will start from the first activity, which is placing the bottom ballast, until the last activity, which is the final ballast profiling as ordered in Table 1. By using LSM, schedule of project case study composed of 17 activities, can be depicted as shown in Figure 4. The project duration was 156 days. Since the production rate of most of the activities in the project is very similar, the project schedule then looks very simple in term of progress rate. Per discussion with the contractor, during the construction, some activities can be performed partially concurrently in order that project duration can be shortened. Whereas the planned schedule is based on a work sequence that the activity is performed consecutively. By doing that, the time allowance has been added into the schedule. If this project is scheduled with the Gantt chart, a project duration is approximately similar.

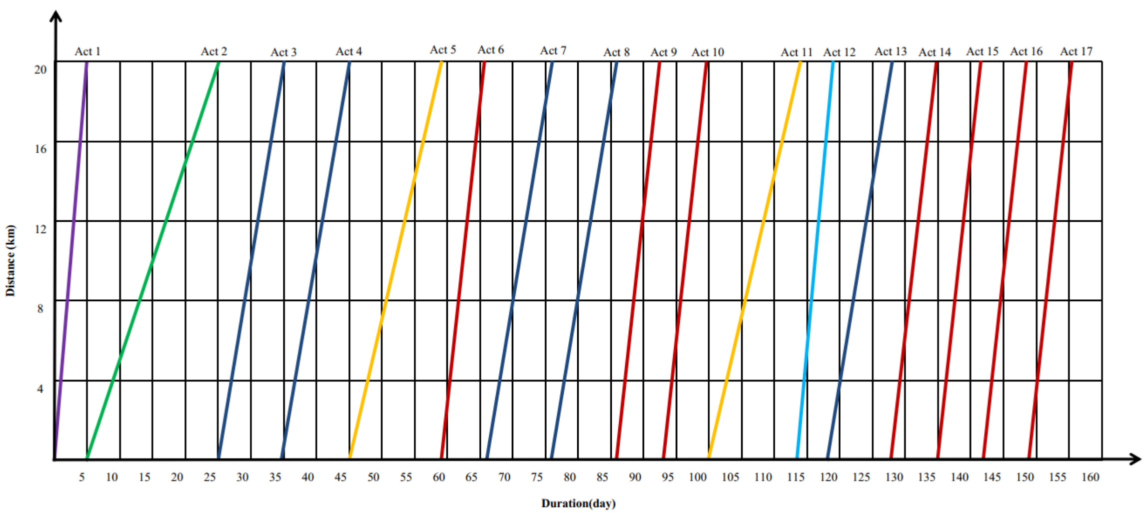


Figure 4 Schedule of project case study using LSM

After discussion with the contractor, the feedbacks and comments are positive. If compared with the Gantt chart that they were familiar with, the schedule based on LSM was very useful. They could get an outline picture of the project progress because distance and time dimension was displayed in the schedule as well as production rate and progress of each activity. However, in order to achieve the project target duration, all resources needed for construction have to be provided in timely manners such as ballast, sleeper, rail, construction crew and other equipment. In addition to resource management, during construction, there will be interfered from the traffic of a train from time to time. Continuousness of activity can be also interrupted from bridge construction or box culvert. In this case, sometimes track work construction has to wait for unstill working is ready to continue. Target duration of a project, therefore, may be required to adjust accordingly based on its surrounding.

The reason a contractor uses the Gantt chart to schedule a project because S-curve is required based on the term of reference to control and measure project progress. However, LSM can be applied for internal use of a contractor because it can provide a dimension of distance and time nonetheless when updated schedule production rate of activities can be easily noticed for the performance of an activity.

5. Conclusion

Railway project is repetitive by nature, therefore, LSM can be applied to schedule a project. Contractor in Thailand has widely used Gantt chart to schedule a project because of its ease of use and easy to prepare. This paper used a case study of 20-kilometer new line project for conventional ballast track was used to schedule with LSM. The case study project duration was 156 days. However, other data are needed to adjust final project duration as appropriate and realistic as possible. Feedbacks from contractors were positive since project information not only time is displayed on the plan but also distance and production rate. Therefore LSM is exceptionally appropriate with railway project especially the part of track work because the macro view and micro view of a project are provided.

6. Acknowledgements

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