EVALUATION OF LOCATION BASED MANAGEMENT SYSTEM IN THE CONSTRUCTION OF POWER TRANSMISSION AND DISTRIBUTION PROJECTS

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ABSTRACT

Construction projects are becoming more demanding both in terms of time and complexity. This necessitates intricate planning and sequencing of activities at the macro and micro level and continuous flow of resources across the project in order to achieve planned targets. Work and Resource planning need to be done in such a way that limited resources give optimal output. Currently dominant activity-based scheduling techniques like Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT) do not model work-flow or resource-flow through a project life cycle. An extension to the conventional activity based planning is Location Based Management System (LBMS). LBMS has been explored and utilised in the case of repetitive and cyclic projects such as high rise buildings. This study focusses on the application of LBMS to repetitive and non-repetitive components of Power Transmission and Distribution (PT&D) projects involving construction of substation and cable laying. This paper presents the findings on comparing the current planning practice for cable laying with an LBMS based approach. A key finding of the study was that the conventional practice resulted in a schedule with several coordination issues that could not be identified in the planning reports. Using the LBMS based approach these issues could be identified and decisions required for resolving these could be made.

KEYWORDS

Work-flow, Resource-flow, Location

INTRODUCTION

Activity based scheduling techniques (Viz. CPM and PERT) have dominated the construction industry. The term activity-based is used because projects are modeled solely based on individual packages of works/activities and their logical relationships with each other (R. Kenley & Seppanen, 2009). Activity based scheduling methods provide limited insight in to the spatial configuration of projects, especially the construction operations, thereby limiting effective communication among project stakeholders and thus, restricting the planning and control of work-flow (Jongeling, 2006). Different stakeholders of a project may develop varying interpretations of activity relationships in a schedule and project components, which in turn can be susceptible to errors in judgments and thus limiting decision making capabilities. The dominance of activity based methods can be mainly attributed to the existence of numerous software that work on this platform. This has created a barrier in the construction industry towards other methods of planning. One of the major drawbacks of the existing activity based techniques is that it emphasizes more on the activity and not on the location where these activities are executed. This makes it difficult to manage variance in the schedule and also manage resources. Even though activity based schedules focus on the activity, the duration estimation for the activity does not take in to account the quantity of work to be done and the productivity rate of the particular activity thus produces implicit calculations of durations with the variation in resources. CPM based schedules use extra lags and float to account for the lack of accuracy of the estimated data, which paints an inaccurate picture of the project (Nageeb & Johnson, 2009). The schedules are generally represented using Gantt charts. Even though this type of representation has dominated the industry, it fails to enable the user to see through the project. This creates an inherent but invisible waste in the schedules that usually go unseen in when there are too many activities to be monitored. This in turn leads to poor plan implementation and a requirement to coupe up lost time by unplanned compression of the planned schedule (Olli Seppänen, 2009). This makes project monitoring difficult as coupe-up plans in case of delays have to be made separately independent of the master schedule. A promising alternative that could counter the limitations for activity based schedules is Location Based Management System (LBMS).

LBMS supports the effective use of resources and the elimination of waste which parallels to some of the principals of Lean construction (Andersson & Christensen, 2007). The key connection between LBS and lean construction is the focus on efficient resource usage and thus eliminating non-value adding activities like waiting and idle time (Kankainen & Seppänen, 2003). The lean construction focus of waste elimination can be used in LBMS to emphasize on key activities performed over various locations and identify the corresponding waste and to allocate resources accordingly. Application of lean principles to location based projects necessitates constant monitoring of productivity rates and resource allocation since these two factors incorporate the maximum waste in a project.

Most of the available work on LBMS focuses on repetitive projects Viz. high rise buildings, roads etc. A prominent research gap that limits the use of LBMS is that the LBMS has not been evaluated for smaller projects and those that are not repetitive in terms of the structures. The existing research on LBMS also does not focus on how projects can be effectively broken down in to locations or LBS that in turn would lead to the effective use of locations in terms of work and utilization of resources. Smaller projects with an overall lesser number of activities have not been studied in depth. Two aspects that this paper will focus on would be –

1. Evaluation of effective use of LBMS for repetitive projects with a small number of activities repeated over multiple locations in the PT&D sector. A case study of an underground cabling project has been considered to study the nuances of applying LBMS to this type of project.

2. The paper will also compare CPM based planning systems with LBMS for the case study under consideration.

Location Based Management System (LBMS)

The Line of Balance (LoB) is a visual method of construction planning which has been in use since the 1950's. LoB has been used in the planning and scheduling of repetitive projects like high rise buildings etc. and has provided unique and useful information to the users about the project for monitoring purposes and also helps in taking advantage of the economy of repetition of activities. LoB helps the planner to account for the flow in the project (Olli Seppänen & Kankainen, 2004; Suhail & Neale, 1994). A lot of research has been carried out in the area of graphical scheduling methods and they differ very little from each other. Various names were used for these graphical scheduling tools like Repetitive scheduling method, Linear scheduling method, Flow-line scheduling, Vertical production method, Time space scheduling method, Time Location scheduling, Time versus distance diagrams etc. (R. Kenley & Seppanen, 2009). LBMS integrates CPM with repetitive scheduling methods. LBMS is a construction planning and production control system most often visualized as a flow line (Kala, Mouflard, & Seppänen, 2012). The overall emphasis of location based scheduling is planning for productivity. Unlike CPM, LBMS manages the continuity or flow of work and resources, thus optimizing production and in turn the schedule.

A location can be considered to be the database of all project data and is used as the primary work division in the form of a Location Breakdown Structure (LBS), analogous to the more commonly used Work Breakdown Structure (WBS) (R. Kenley & Seppanen, 2009). Similar to the WBS in CPM, LBS is prepared by breaking the locations into hierarchical levels. LBS are a collection of 3D zones that define the schedule and cost planning areas of a project. Based on the LBS, the quantities of work to be done are distributed in each location. The tasks are defined based on their location priority. The task duration is calculated based on the quantity of work to be done, task productivity and crew size. Location-wise quantity information is critical to get the benefits of flow-line management as it optimizes the production rates to achieve continuous resource flow (Olli Seppänen & Kenley, 2005). The logical relations between the tasks are specified to complete the location based schedule.

LBMS focuses on physical locations to plan, analyze and control work and resource flow. It also monitors the production efficiency as resources move through specified locations (Lowe, D'Onofrio, Fisk, & Seppänen, 2012). Some advantages of LBMS include the potential to include flow of resources through locations (Yaowu & Qingpeng, 2011) and the ability to monitor the flow of work and resources and also potential to identify time space conflicts. Work and resource flow can be visualized by the flow-line output that is generated by using LBMS.

The improved overview of the project schedule in the flow-line view of LBMS supports better interpretation of the schedule and also effective communication with subcontractors and other stakeholders involved to facilitate successful implementation of the schedule (Andersson & Christensen, 2007). The primary assumption in LBMS is that resources drive the work-flow, and that work-flow through multiple locations will be a part of a continuous process (Russell Kenley, 2004). LBMS schedules continuous work and resource flow through locations and hence avoids overlapping of work in the same location and thus effectively utilizing unused locations. LBMS supports improved project control by planning and monitoring each individual location for work and resources at a given time.

LBMS can be effectively integrated with Lean principles such as elimination of waste and "just in time". The difference in the application of Lean principles to a LBMS is that the impact will be felt more on the resource utilization and not much on the activity directly. Lean will enable effective and efficient allocation of resources across various locations within a project leading to much lesser idle times and thus preventing under and over-usage of valuable resources.

Introduction to Power Transmission & Distribution (PT&D) Projects

PT&D projects consist of myriad variety of projects out of which the focus is on three types of projects namely – Gas Insulated Switchgear (GIS) substations (non-repetitive type) and Underground cabling and Transmission Line projects (repetitive type). Repetitive projects viz. underground cabling and transmission line projects are so coined because it consists of a set of activities that are repeated throughout various locations across the project. In the case of non-repetitive projects like GIS substations, the project comprises of a combination of different types of construction activities that vary between locations. They are put under the non-repetitive category because they do not have activities that repeat across locations.

CASE STUDY

An underground cabling job was considered to explore the possibilities of LBMS. The job was to be executed in an industrial zone located in the Middle-East. The project involved repetitive activities occurring across various sections of the project. The project under consideration had 32km of cabling in terms of ground length. To derive the WBS, this length was further divided in to equal sections of 500m each i.e. a total of 64 sections. Each of these sections consisted of the same activities that repeated across all the sections as shown in Figure 1.

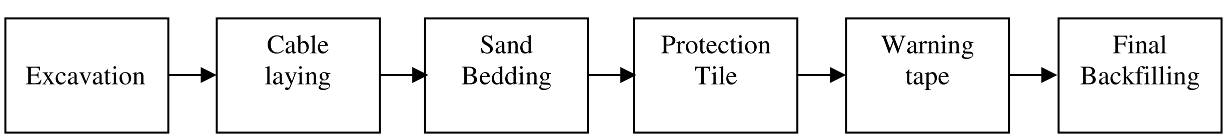


Figure 1 - Activity sequence of the underground cabling job

As the project was located in an industrial zone, the land was relatively level and hence the quantities of various activities were considered to be equal throughout all the sections of the project. The sections were further grouped in to circuits. One circuit had on an average about 16 sections under its umbrella. Each circuit had one crew of specialized manpower and equipment executing the work. Therefore there was a critical requirement for the crew to have a continuous flow between the sections in order to achieve effective utilization of the resources and thus eliminating wasteful idle time.

The site was using a combination of CPM based tools (Figure 3) and a spreadsheet based system for project monitoring. The progress was also monitored using a visual method by using an activity color coding system over the entire layout (Figure 2). The entire system was updated on a weekly basis. The update includes only the start and finish time of all activities along with quantity of work done. This report did not contain information on the productivity rates of various activities, which in turn was calculated separately on a monthly basis for management information only. The current project management system effectively serves only as a project monitoring system since the productivity data is not linked with the schedule, therefore, no information on aspects like idle time, slow work etc. is passed on to the management. Productivity rates of the resources are major components in an effective project planning system and therefore needs to be linked directly to the schedule in order to utilize the full potential of the schedule. The existing system did not convey important information about the work and resource usage parameters like productivity, idle time etc. back to the management.

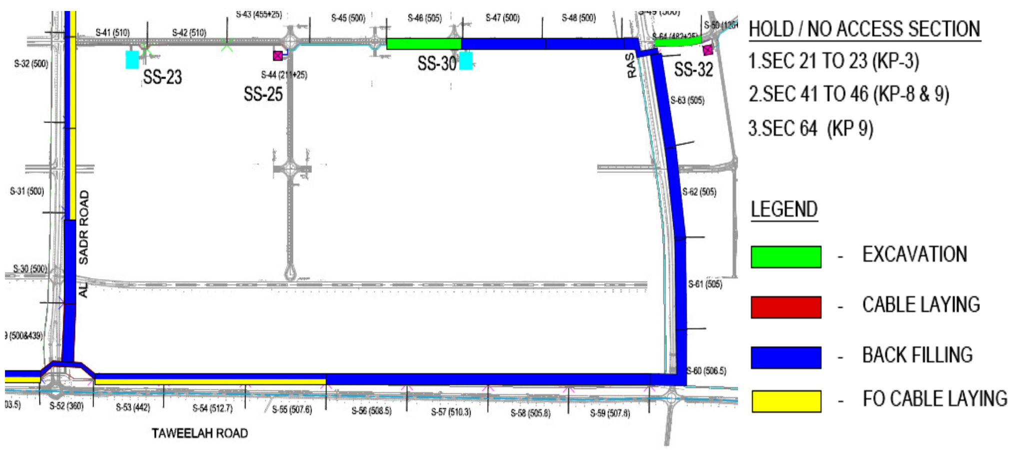
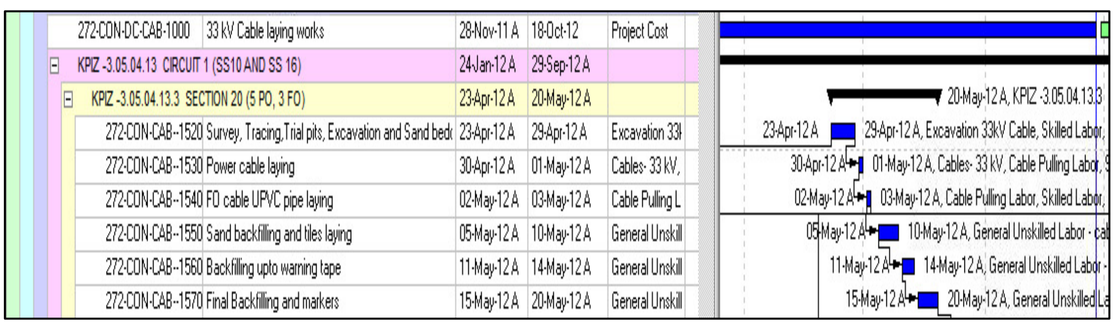


Figure 2 - Visual System used to track underground cabling project



272-CON-DC-CAB-1000	33 kV Cable laying works	28-Nov-11 A	18-Oct-12	Project Cost
KPIZ -3.05.04.13 CIRCUIT 1 (SS10 AND SS 16)		24-Jan-12 A	29-Sep-12 A	
KPIZ -3.05.04.13.3 SECTION 20 (5 PO, 3 FO)		23-Apr-12 A	20-May-12 A	
272-CON-CAB--1520	Survey, Tracing,Trial pits, Excavation and Sand bedd	23-Apr-12 A	29-Apr-12 A	Excavation 33k
272-CON-CAB--1530	Power cable laying	30-Apr-12 A	01-May-12 A	Cables- 33 kV,
272-CON-CAB--1540	FO cable UPVC pipe laying	02-May-12 A	03-May-12 A	Cable Pulling L
272-CON-CAB--1550	Sand backfilling and tiles laying	05-May-12 A	10-May-12 A	General Unskill
272-CON-CAB--1560	Backfilling upto warning tape	11-May-12 A	14-May-12 A	General Unskill
272-CON-CAB--1570	Final Backfilling and markers	15-May-12 A	20-May-12 A	General Unskill

Figure 3 - Updated schedule in Primavera used for project tracking

The existing system formed a layout conducive to be modeled in to a Location Based System as the present WBS itself could be directly used as a LBS. The conversion of the WBS to the required LBS is as depicted in Figure 4. Based on the LBS each circuit was allocated one crew of specialized manpower and necessary equipment in the same format as it was allocated on site. In addition to the resources, the quantity of work to be executed per section was calculated. The productivity rates of all the resources involved in various activities were calculated based on actual on-site observations. The productivity rates were averaged based on site data gathered over a fortnight.

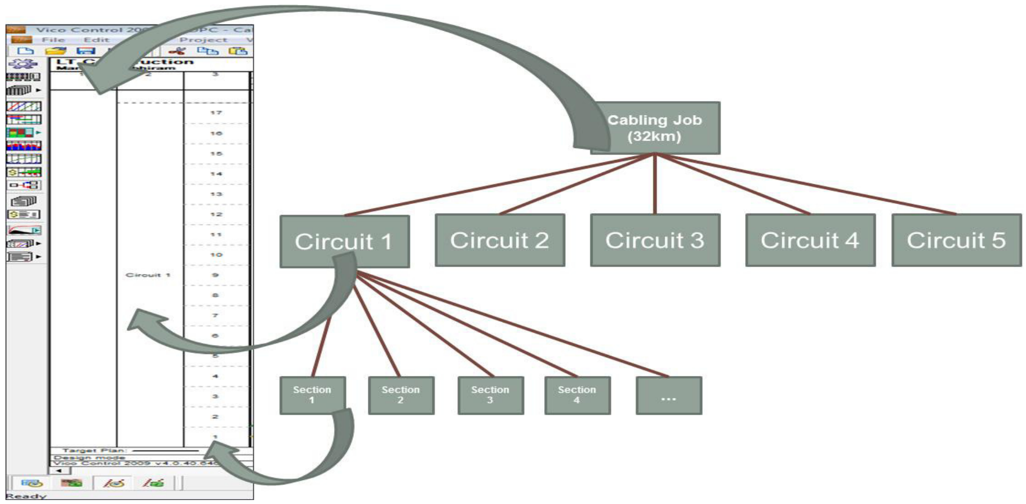


Figure 4 - Location Breakdown Structure of the Cabling Job

The corresponding schedule modeled using Vico is as shown in Figure 5. The logic and data used for modeling the system was taken directly from the CPM based schedule. The calendar used in Vico was same as the calendar used in the CPM based tools and hence the working hours were maintained same as in the original schedule. The logical relationships between the activities were modeled and the duration of the activity was input directly based on the information from the original schedule. The model gives a flow line representation of the activities which makes it easier to understand the flow of activities and the corresponding resource requirement. Each activity is represented by an individual flow line spread over time and locations which helps in the visualization of the resource requirement and also to identify and resolve any clashes both in terms of schedule and resources. Traditional activity based schedules such as CPM based and PERT based schedules fail to provide information in such a flow. Resource integrated flow is crucial for projects with one set of activities repeated a large number of times since the same set of resources need to be used multiple times in the same sequence.

The flow-line output revealed the inherent waste in the existing CPM schedule. We can observe that all activities show discontinuity between locations. This could result in poor utilization of resources/crew. Some of the significant observations from this schedule are –

- Consider excavation, where one excavator is being used as a resource. In the CPM schedule the duration for excavation has been fixed as 7 days, based on which each of the sections have been scheduled. But from the above flow-line view of the existing schedule, it is evident that the excavator cannot move continuously between locations and hence renders the existing schedule meaningless.

- For the same excavation even if we consider two excavators working in parallel in two sections, the schedule will still not allow a smooth flow of the excavator between sections.

- The flow lines are the most staggered for excavation and protection tile laying activities. They are the activities which require strict adherence to specifications and hence take the maximum time.

- Excavation and protection tile laying form the crux of the entire project and therefore the flow needs to be managed with utmost care.

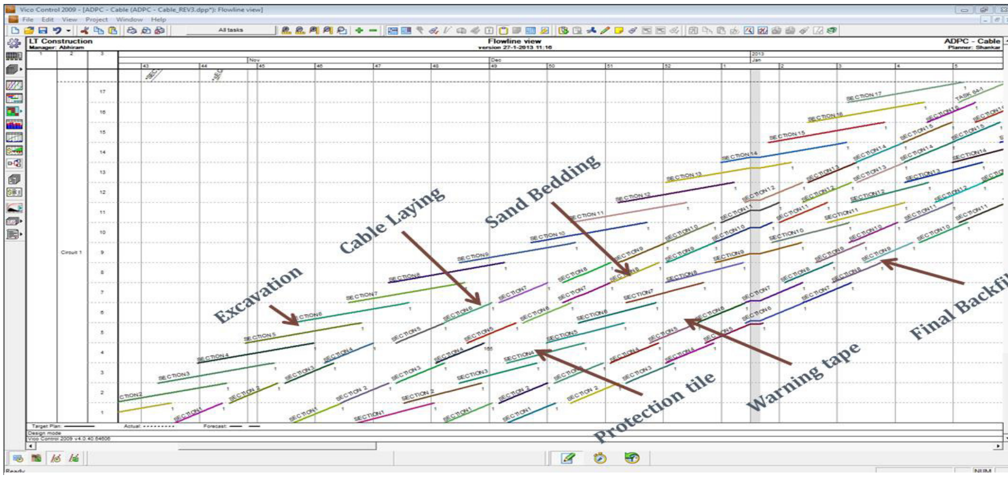


Figure 5 - Flow-line view of the CPM based plan

- Other activities, i.e. cable laying, sand bedding, warning tape and final backfilling are represented by flow lines with a slightly better overall synchronization but still do not form a continuous flow.

Another factor that caused discontinuity was the varied productivity factors of different activities which resulted in different durations for each activity. This in turn resulted in a lot of idle/waiting time between locations. Consider a standard productivity rate of ‘X’ days for each activity. Excavation requires the longest duration becomes the key factor that derives the entire chain. Consider excavation occurring at rate of ‘1.3X’ days with a certain estimation of productivity i.e. excavation requires a longer duration per section. But cable laying is much faster and simpler in terms of methodology and hence occurs at a rate of ‘0.8X’ days. If these activities were made continuous at the existing rate along with their CPM logic, it would lead to either a time space conflict at another location because the activity that is occurring at a faster rate, i.e. cable laying here, will go ahead of the excavation or induce a waiting time for the cable laying crew for their front and thus inducing waste in the system. Figure 6 represents the above mentioned scenario as it appears in terms of flow line.

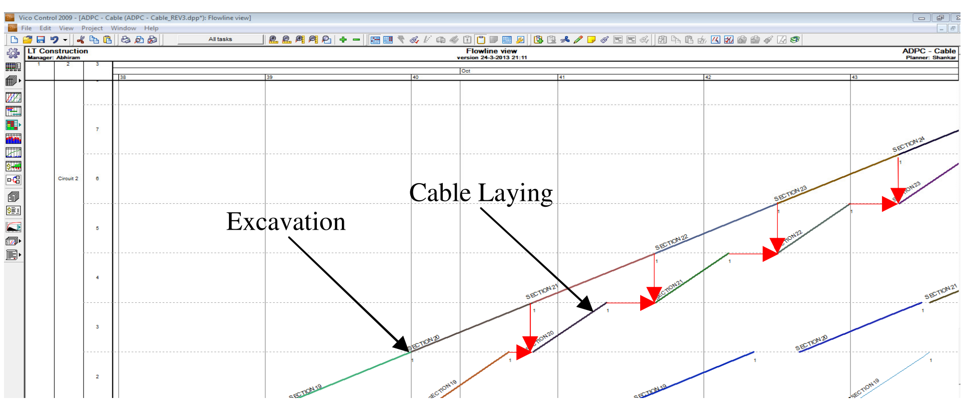


Figure 6 – Flow line with varying productivity rates

The Lean concept of using a “pull” system of demand and supply instead of a “push” system is applicable in this scenario. In a pull based system, the activity will pull the resources and thus the schedule. The pull concept that is illustrated here is slightly different from the conventional pull system. The conventional pull system usually has the first activity pushes the succeeding activities whereas in the case of location based pull the first activity (i.e. Excavation in this case) pulls the succeeding activity. Here we can expect two types of pull viz. an inter-location pull, i.e. the pull that is generated within each location and an intra-location pull, where the resources are pulled between locations. The activities such as excavation, cable laying etc. should pull the corresponding resources not just as they progress in time and space but also in synchronization with the activities immediately preceding and following the respective activity. The resources should be injected at the corresponding location only when required to prevent unnecessary inventory/waiting. But the resource allocation should not be delayed in order to prevent delay. The flow of resources needs to be monitored and adjusted continuously to match the productivity levels of the activity and the conditions and requirements of each location.

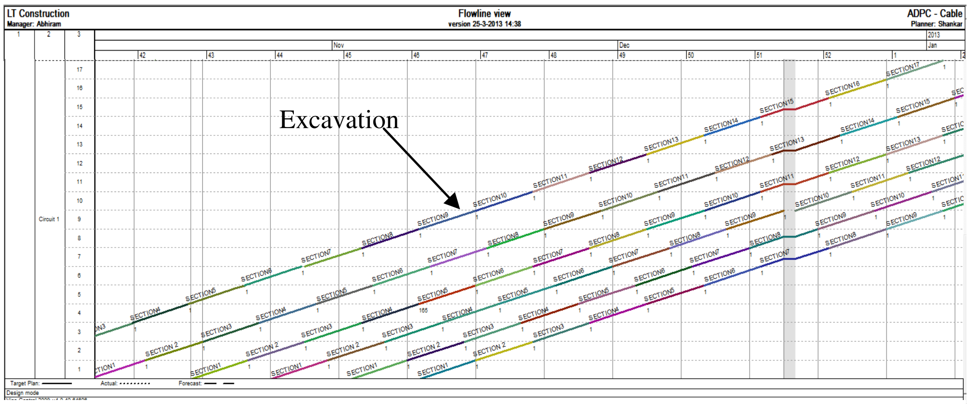


Figure 7 - Improved flow-line schedule for underground cabling

The same schedule was remodeled using the flow-line methodology. The productivity data that was calculated based on actual site observations was used as a benchmark for various activities. Based on this input data, an improved schedule for work and resource continuity was derived (Figure 7). The improvisation was done in such a way that the activities are sequenced and aligned based on a constant productivity rate in order to enable a continuous resource flow. Buffers have been introduced between activities in order to account for delays. Even though the model uses a constant productivity rate for each activity, it helps to achieve and maintain flow and thus eliminating inherent waste in the overall process. The overall schedule using LBMS also had an impact on the overall duration; the cycle time for one section could be improved from an average time of 41 days to a cycle of 35 days even after accounting for buffers. This reduction in project duration can be attributed to the fact that resources were sequenced at the right pace and thus eliminating aspects like waiting and idle time.

DISCUSSION AND CONCLUSIONS

It can be observed that LBMS can create a considerable difference to the project management scenario for PT&D projects, particularly in the case of repetitive projects like underground cabling. It enables effective practice of Lean principles like waste elimination, pull based system and the just in time concept. Repetitive projects are highly adaptable to the application of Lean principles such as waste elimination as the probability of the same waste repeating over multiple locations is much higher. Such waste can be easily identified and eliminated.

Effective and timely allocation of resources can ensure elimination of waste and reduction of inventory and waiting times. Use of LBMS will be effective only with appropriate background database on resources and their productivity for various construction methodologies. Further work will explore how this type of efficiency can be effectively applied for non-repetitive type of projects particularly in the PT&D sector for substation projects. In order to achieve a similar level of continuity in the case of non-repetitive projects, an LBS has to be selected such that it enables efficient flow of work and resources through various locations of the project. LBMS can also be used in parallel with existing project management systems and can form to be a very good platform for project control and monitoring and hence can be used effectively in the project control stage. LBMS also promises value to the Last Planner® system (O. Seppänen, Ballard, & Pesonen, 2010), when used together these two systems have the potential to form a powerful system for project control.

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