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LINEAR SCHEDULING METHODS (LSM)

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TCM Framework: 7.2 – Schedule Planning and Development

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TABLE OF CONTENTS

May 16, 2023

1. INTRODUCTION

Project planning and scheduling professionals use a variety of project scheduling methods depending on the type, size, and nature of projects. Linear scheduling methods (LSM) are typically used on projects wherein the majority of the scope is made up of highly repetitive work elements along a horizontal or vertical alignment. Examples of these projects include pipeline, tunnel, airport runway, highway, transmission line, road resurfacing, railroad, or high-rise construction projects. An LSM schedule (also known as a linear schedule, march chart, or time chainage diagram) is the graphical output of the LSM. Linear schedules use velocity diagrams, which are described below, to represent each activity and the progress rate to be achieved (or the progress actually achieved) over time. The schedule format typically provides planned and/or actual production rates on a time-scaled, linear format.

This recommended practice (RP) is intended to serve as a guideline, not a standard. As a recommended practice of AACE International, the main objectives of this recommended practice (RP) are to increase LSM usage and enhance project management practices by:

- Providing an overview of the LSM.
- Defining characteristics and applications of the LSM.
- Delineating the steps and main considerations in developing, updating, and managing linear schedules.
- Highlighting main considerations in interpreting linear schedules.

2. USES AND APPLICATIONS

Schedules provide a basis for communication, coordination, monitoring, controlling, and reporting among project participants. They also provide a means for planning, recording, reporting, and assessing project progress as a platform for processing progress payment applications and contractual/change management.

Linear scheduling techniques allow project planning and scheduling practitioners not only to effectively model project activities that are repetitively performed but also to account for work locations or spatial aspects of the project. The added dimension of a linear schedule enables project management staff to identify and correct spatial conflicts and can reveal schedule compression opportunities not fully visible in a bar chart or critical path method (CPM) network.

The key in linear scheduling is how to optimally use time and space in tandem. This makes the approach of linear schedule development different from traditional project scheduling methods. The main difference is in the presentation of data. Traditional project scheduling methods illustrate the intended flow of work using a bar chart. Using these methods, the flow of the work is primarily driven by physical work dependencies. For example, in a typical building project, the work elements follow a scope-based sequence including excavation, foundation, slab, first floor, and subsequent floors. In linear construction projects, however, the primary considerations are location-based for each type of work (e.g., the work of each trade) and how the work needs to flow in an orderly manner from one location to the next.

In linear construction projects, the scope can mostly be visualized as highly repetitive work elements performed by separate resources. In these projects, a set of project activities are repeated in each location for the entire length of the project. Once an activity is started and/or ended in one location, it is repeated in another location. Linear construction projects typically fall into one of the following categories: [1]

1. **Repetitively-Linear Projects:** These projects are characterized by having an identical set of activities (unit network) that is uniformly repeated throughout the project (e.g., a multiple-building housing project in which similar floors or buildings are built in series).
2. **Physically-Linear Projects:** These projects are characterized by having a particular set of discrete activities that are performed across certain locations, stationed in a series; the locations are typically laid out linearly.

Examples include pipeline projects, highway construction, highway resurfacing and maintenance, airport runway construction and resurfacing, tunnels, mass transit systems, and railroad projects. Locations may also be expressed in other forms, including survey stationing. Stations[1] are considered reference points placed along the horizontal measurement of a route centerline.

The two categories above offer a basis for classifying various techniques that are used to schedule each type of linear construction work. The next section classifies methods based on the types of linear projects.

3. METHODS CLASSIFICATION

To better satisfy the scheduling needs of linear construction projects, several methods have been utilized on projects and described in the literature.[2] These methods are also referred to as repetitive scheduling techniques and have common features. They are often categorized into the two main classes of line of balance (LOB) and LSM techniques. This recommended practice primarily focuses on the LSM but select techniques are described in the following for comparison purposes.

3.1. Scheduling Techniques for Repetitively-Linear Projects

3.1.1. Line of Balance (LOB)

Line of balance is a graphical display of production units versus location. The LOB technique starts with accounting for the end product and the target quantity to be produced. This information is reflected in the production plan, which is then used as an input to generate an overall project plan that delineates the amount of work to be delivered over time. This information is ultimately converted to an objective chart against which the actual progress is measured using the progress chart. The LOB technique uses the following types of charts to illustrate repetitive activities:

1. **Objective Chart:** This chart illustrates the cumulative calendar schedule of unit completion to illustrate or schedule the cumulative events of unit completion over time. Similar to LSM schedules that will be described in the next section, this chart uses time as one axis (typically as the horizontal axis), and some measure of production on the other axis (typically as the vertical axis). The main difference between the objective chart and a typical linear schedule is that unlike the objective chart that depicts one activity, the linear schedule illustrates multiple activities.
2. **Production Diagram/Plan (also referred to as unit network):** This diagram depicts activity dependencies and estimated time durations needed between the completion of each activity and the completion of the unit. This diagram is similar to a CPM activity-on-arrow (AOA) diagram with the special consideration that it targets only one specific unit.
3. **Progress Chart:** This chart depicts the actual number of units completed and thus, shows the completion trend of activities for each unit. In this chart, the actual number of units completed is compared with the

[1] There are two systems for stationing. Where the imperial system is used, 100 feet make up a highway station; therefore, the beginning point would be 0, Station 1 (which is 100 feet from the beginning) will be written as 1+00, Station 2 will be written as 2+00, and so on. Where the metric system is used, 1000 meters make up a highway station, and Station 1 corresponding to a kilometer, is typically written as 1+000.
[2] Examples of these methods include linear scheduling method (LSM), line of balance (LOB), vertical production method (VPM), time couplings method (TCM), repetitive project modelling (RPM), repetitive construction (REPCON), repetitive scheduling method (RSM), flowline, time-distance chart, time location chart, march charts, velocity diagrams, and time chainage chart in which the location and timeline of the activities or tasks are shown.

May 16, 2023

line of balance. Given the duration and dependency requirements set forth by the production plan, the line of balance represents the number of units that must be completed over time to meet the unit completion schedule established by the objective chart.

A line of balance example is shown in Figure 1.

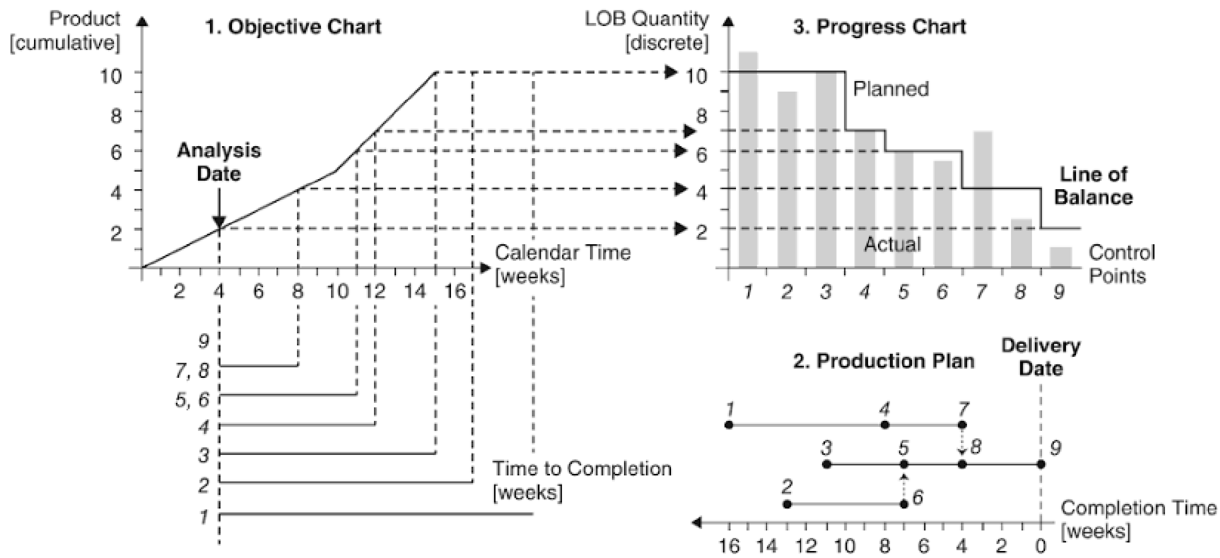

Figure 1. A Line of Balance Example[3]

The method is based on mathematic algorithms [3] and is often used in the construction industry [4][5]; however, this method is not among the commonly-used methods for linear construction projects partly because a) modeling of an entire project by the sole use of repeating unit network activities is typically challenging, and b) production rates have to be estimated accurately based on man-hour requirements, and inaccuracies may be magnified through repetition. [4]

3.1.2. Linear Line of Balance (LLOB)

Because LLOB can clearly represent differing production rates in different locations, it can be the best way to portray a production rate imbalance that may exist between similar operations in differing locations [6]. An activity in a LLOB chart shows production of a controlling unit over time in terms of percent complete. [6]

Completion percentage enables activities with disparate units of measure to occupy the same graph. Figure 2 demonstrates that an activity measured in feet (such as duct bank installation) and an activity measured in units (such as light fixtures) can be represented as activities in an LOB schedule using completion percentage as their common unit.

The LLOB charts of successive units or sub-projects can be stacked on top of each other, using their project completion percentage as an overall *y*-axis which can scale against each unit's completion percentage.

[3] Figure 9.10 in Halpin et al. [2, p. 144]. Used with permission. Copyright (C) 2017, 2014, 2011, 2007 John Wiley & Sons, Inc. All rights reserved.