Job Shop Scheduling for Construction Projects with Repetitive Activities

Applicability, Adequacy and Versatility

By

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One of the major challenges in a construction project

Creating a meaningful schedule and finding opportunities for improving project duration and project management.

Methods for scheduling projects include:

- Critical Path Method - The most widely used method for scheduling projects over 7 decades
- Critical Chain
- Last Planner System
- Linear scheduling (including location-based scheduling)
- Finite capacity scheduling
- Etc.

Critical Path Method (CPM)

CPM is the first scientific, generic method developed for scheduling projects and is most widely used in project management world.

Salient features of CPM include:

- Supporting effective project management
- Estimation of project completion time
- Documentation of precedence relations among activities
- Prediction of workflow
- Identification of critical activities
- Determination of floats which can be used for dealing with uncontrollable variation
- Helping with communication of project plans.

A vast majority of project management software use CPM for project scheduling.

Input data for CPM:

- Activity list and activity durations
- Precedence relations among activities
- Temporal constraints on start or finish times of activities.

CPM Drawbacks:

- Difficulty to comprehend the workflow of a project through CPM schedule
- Unable to show activity schedules location wise and resource wise for a better understanding of the project
- Unable to exploit any special structure of precedence network for improvement purpose
- No reliable guidance to the workers over short periods
- Less reliable estimation of project completion time
- Lack of support for what-if analysis of schedule with respect to production rates.

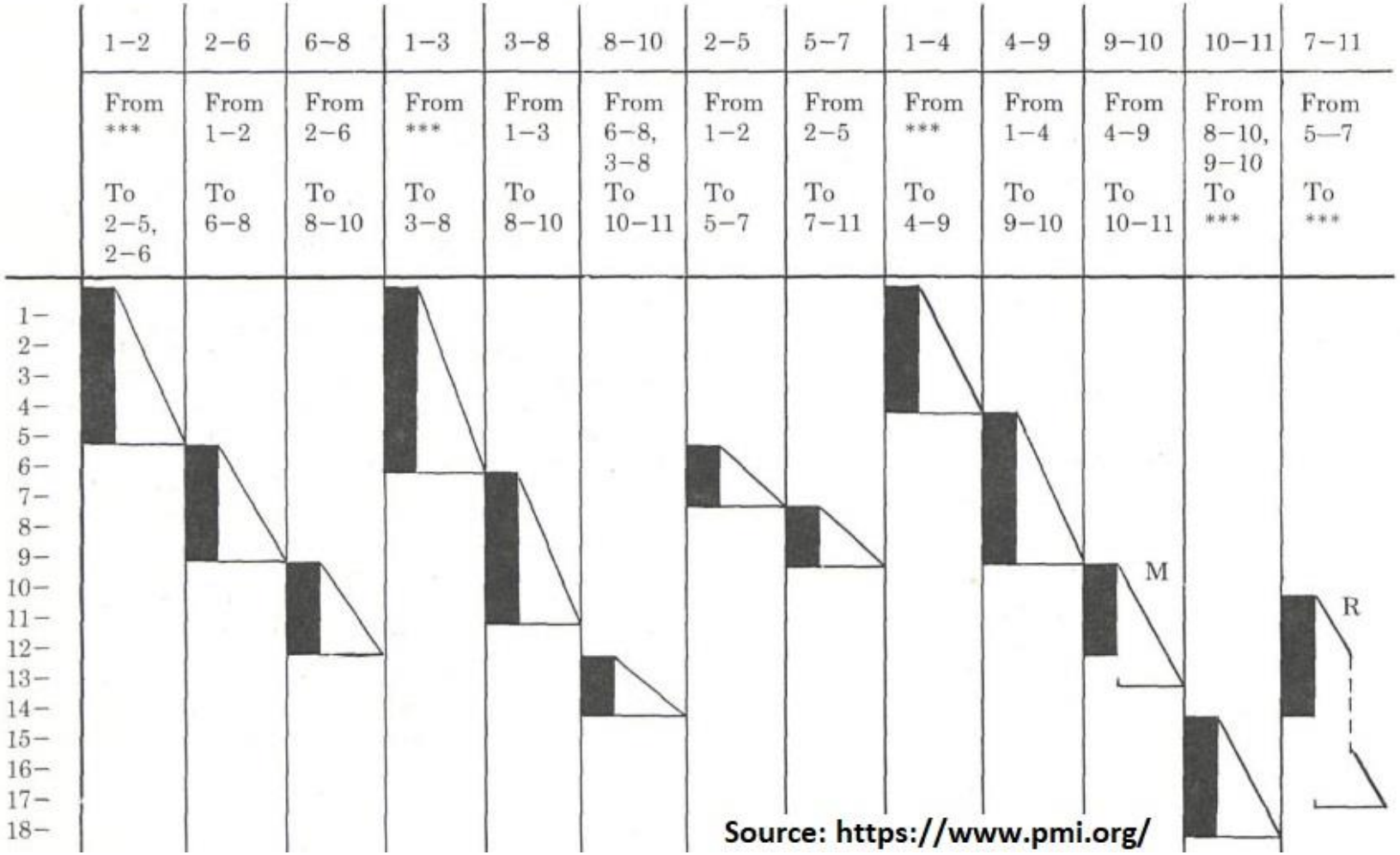
Location-based scheduling (LBS) methods for construction projects with repeated activities

- LBS methods are better suited for scheduling construction projects with repeated activities.
- Successful applications of LBS in projects predate the development of CPM in late 1950s.
- Propagation of LBS methods is curtailed by the popularity and extensive use of CPM.
- LBS was developed as a simple graphical method for scheduling such projects and for displaying the schedule in a concise and coherent manner.
- LBS methods involve creation of a time location chart that displays the entire project schedule on a single page through straight lines or zig-zag lines for resources or horizontal bars for activities.

The Origin of Location-Based Scheduling in Manufacturing Environment

- In early 20th century, a Polish professor **Karol Adamiecki** developed a graphical method called **Harmonogram** to **schedule production of a set of products in a production system** in manufacturing environment without violating resource constraints and technically imposed precedence constraints among production operations.
- Harmonogram displays production operations as vertical bars on a chart with operations on X-axis and time on Y-axis.
- Harmonogram is more sophisticated than the graphical scheduling method developed by Henry Gantt for production scheduling.

Karol Adamiecki's Harmonogram Representing A Production Schedule



Source: https://www.pmi.org/

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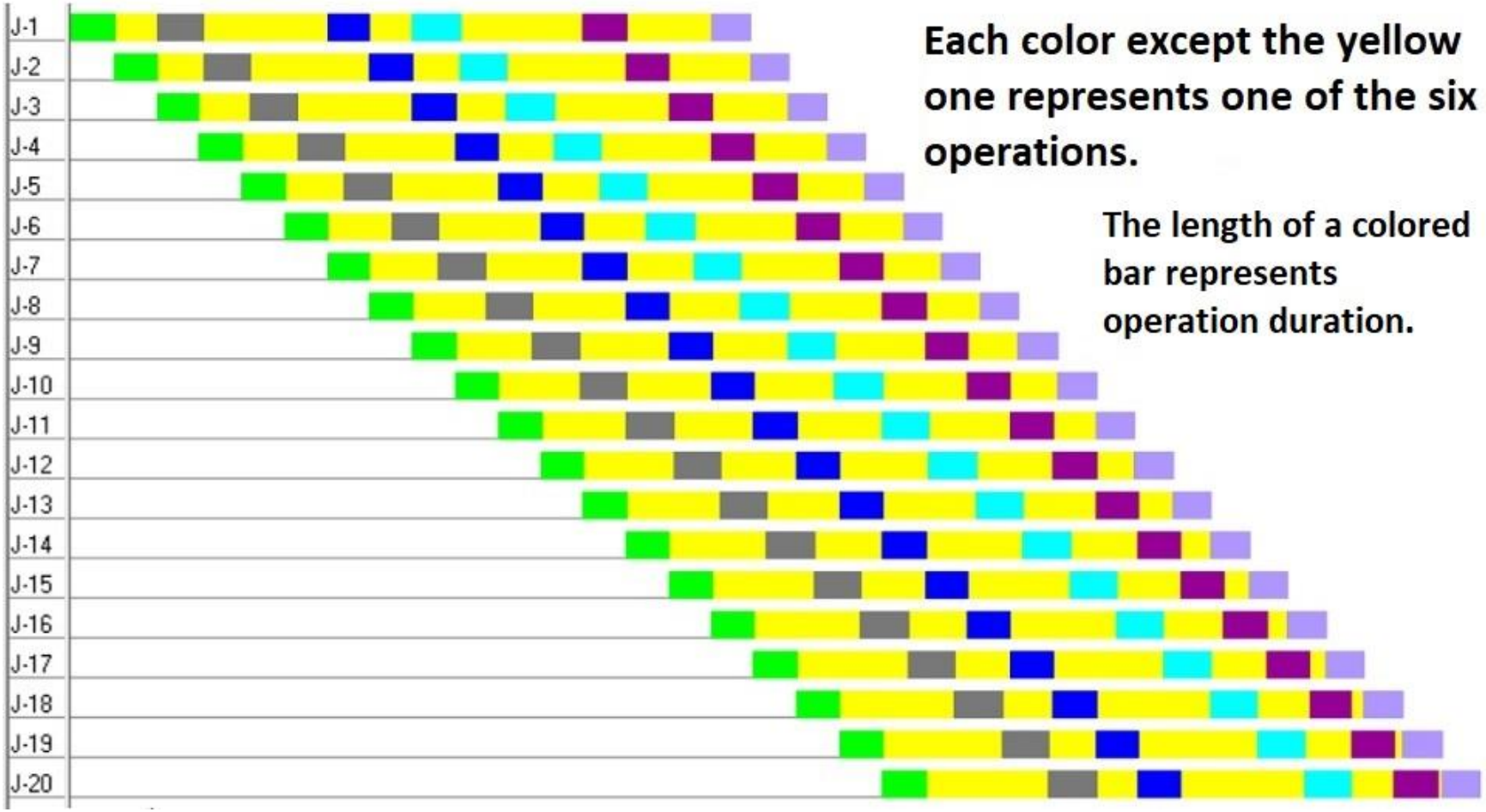
A production schedule of 20 jobs on a production line with 6 operations



Each color except the yellow one represents one of the six operations.

The length of a colored bar represents operation duration.

Karol Adamiecki's Harmonogram

- Preparation of Adamiecki's harmonogram involves use of paper strips (vertical) each of which represents a production operation.
- Adamiecki considered production rates as a leverage to get an optimal production schedule and higher productivity.
- Adamiecki's production scheduling method was an innovative, manual production scheduling method during his time.

Adamiecki is one of the pioneers of production scheduling and control.

Location-based scheduling (LBS) method

- LBS is a graphical method involving creation of a time-location chart for generating and displaying a project schedule.
- LBS is similar to the production scheduling method developed by Adamiecki in manufacturing environment.
- Adamiecki's method can be taken as the foundation of LBS approach in project environment.
- LBS is simpler and more appropriate than CPM to create a meaningful schedule for projects with repetitive activities.
- LBS usually generates a project schedule without resource overloading in an automatic fashion.

Location-based scheduling (LBS) method

- LBS optimizes the sequencing and coordination of activities based on the spatial information of activities.
- Work progress in any location can be tracked on a horizontal line in time-location chart of LBS.
- Improvement of workflow and project duration can be seen as a direct consequence of production rates of resources.
- It is much easier to find opportunities for improving work flow and duration of a project.

The first recorded successful application of LBS method took place in Empire State Building project in 1941.

Special features of time-location chart used in LBS

- Easy to create in comparison to Gantt chart of CPM schedule
- Shows the entire project schedule in a single view
- Shows all activities at every location on a separate horizontal line
- Shows workflow for each resource (trade)
- Shows the full schedule of each trade
- Helps people comprehend a project schedule very easily.

Special features of time location chart used in LBS

- Enables recognition of interactions and constraints between the activities and optimal sequencing of activities for having a smooth flow of work and higher efficiency
- A vertical straight line or a zig-zag line representing a repeated activity shows production rate of the corresponding resource
- The effect of changes in production rates can be seen quickly on this chart.

Job Shop Production and A Construction Project with Repetitive Activities

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Similarity between job shop production and a construction project with repetitive activities

- It can be seen from Karol Adamiecki's work on the development of a method for scheduling production in a manufacturing system and its similarity with LBS for construction projects.
- Production system considered by Adamiecki can be seen as a simple example of job shop.
- **From scheduling point of view, production of a set of products in a job shop is comparable to a construction project in which activities are repeated across locations**.
- In this comparison, each product is like a location, a production operation is like an activity repeated in several locations and a machine required for a production operation is like a trade.

Small differences between job shop production and a project in terms of physical flow of entities

- In job shops, resources (machines) are stationary and components move through resources. In contrast, locations are stationary and resources (trades) move through locations.
- Location sequence is fixed in a project while products/jobs are to be optimally sequenced in production.
- These small differences pose no serious problem in adopting job shop scheduling methodology for a construction project.

From logistics point of view, every project with repetitive activities can be viewed as job shop production.

Powerful scheduling methodology for general job shop production

- Several scheduling software vendors developed powerful, scientific scheduling logic for scheduling production operations in a complex job shop.
- The logic is known as Finite Capacity Scheduling (FCS) or Advanced Production Scheduling.
- It schedules the entire production subject to finite capacity of resources (like machines, workers, etc.) and all other relevant constraints.
- The same scientific, rigorous logic can be easily adopted for efficient scheduling of activities in any construction project subject to all relevant constraints.

A powerful, innovative job shop scheduling solution from Optisol LLC for construction projects

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A powerful, innovative scheduling solution for construction projects with repetitive activities

- Optisol LLC adopted software-aided job shop scheduling approach with a few modifications for efficiently scheduling construction projects with repetitive activities.
- This approach creates an optimal schedule for such projects quickly and easily and it graphically displays the schedule like time-location chart of LBS.
- It is more rigorous than CPM and carries the benefits of both CPM and LBS for construction projects with repetitive activities.

Objectives considered in the new scheduling solution

1. Create a schedule for a specified project completion date
2. Ensure smooth flow of work (continuous work) for each trade without a need for waiting between successive activities
3. Create time buffers in the schedule without any increase in project duration.

- *It is not easy to achieve these objectives using CPM for schedule generation*
- *LOB methods naturally aim at the first two objectives.*

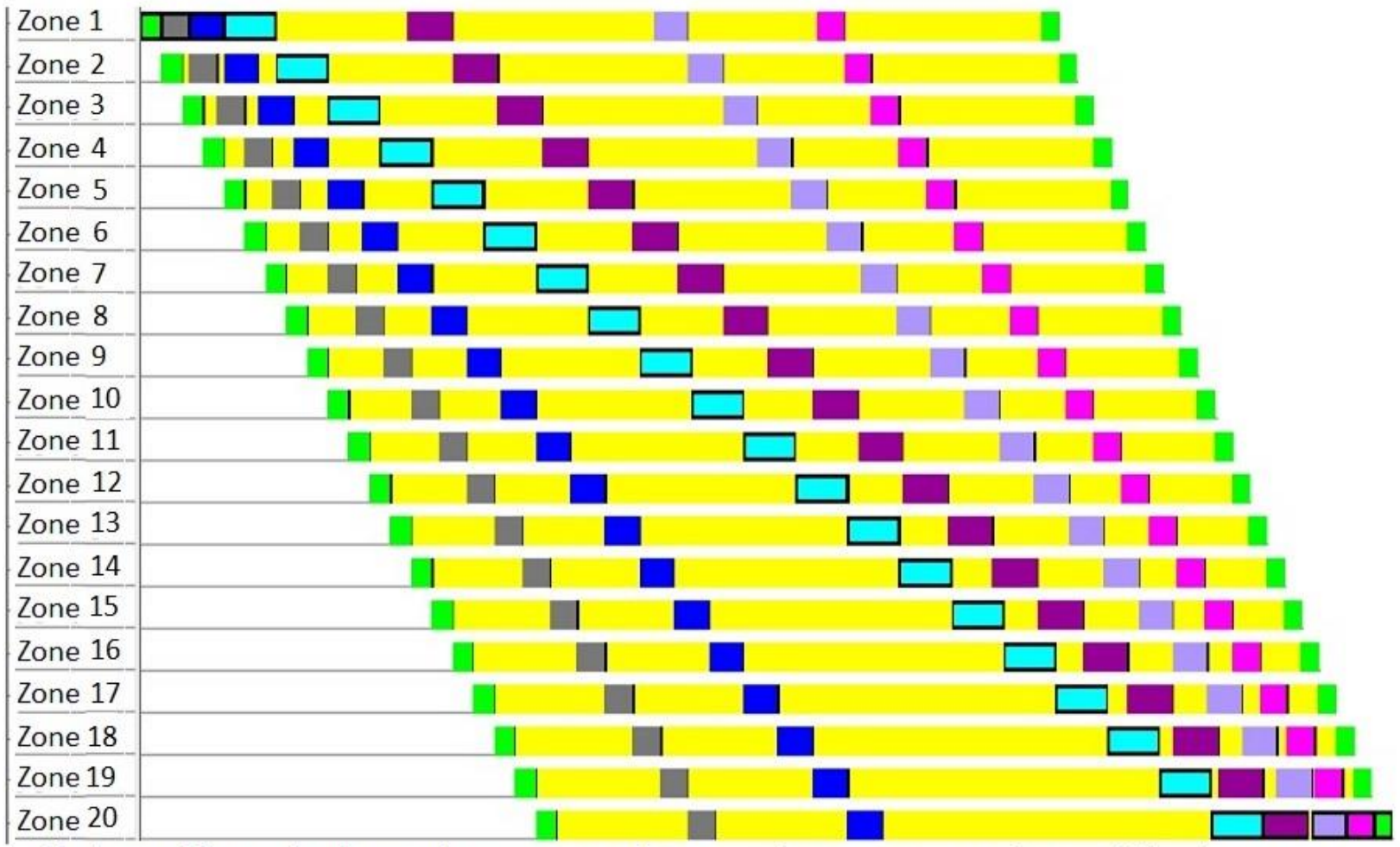
Variables in scheduling problem for construction projects

- Time points at which trades start respective activities in the first location
- Crew sizes for trades
- Weekly calendars for trades.

Constraints considered in job shop scheduling approach to construction projects

- Precedence relations among activities in each location
- Precedence relations across locations
- Temporal constraints on activity start times
- Maximum allowed crew size for each trade
- The longest possible calendars for trades.

An Optimal Schedule of A Project with Time Buffers



Horizontal bars of yellow color represent time gaps between successive activities in a zone.
Bars of other colors represent activity durations.

Fast, extensive and reliable what-if analysis of project schedule mostly by drag-drop operations

What-if analysis with respect to changes in the data such as:

- A change in the size of a crew for the entire project duration or for selected periods
- A change in crew available time (weekly calendar) for the entire project duration or for any selected periods
- A change in the available times of materials or drawings
- Etc.

Project schedule can be revised quickly and accurately in response to any unavoidable impact of uncertainty.

THANK YOU

for attending this session

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