Scheduling I.

Construction management 2.
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26.03.2014.

Scheduling in construction

Aims and purposes of scheduling
• To forecast the events/activities in the project
• To expose likely difficulties of the future, and help to solve them
• To forecast the requirements of money and other resources
• To minimize the unproductive time of men and machines
• To lay down deadlines
• To use as a control tool
Scheduling in construction

Affecting factors:
- Technology:
  - Time span of actual work;
  - Time span of technical breaks;
- Law, regulation (e.g. working hours...);
- Financing (incomes – expenses, ...);
- Location (limited space/accessibility, ...);
- Time period (weather conditions, holidays...);
- ...

Scheduling in construction

• Types of schedules (during a building project)
  - It has to be detailed (and accurate) enough for the actual use – project manager, construction manager, general foreman, skilled workers, etc. ⇒ contents, time unit
  - The later it is made, the more accurate and detailed it can be
Scheduling in construction

- **Information in a schedule**
  - The *time needed* for each construction process (in some cases the available time span)
  - Technical content to each construction process
  - Connections between processes in time, in space
  - Chronological order *(sequence)* depending on technology
  - Time span of the project/construction
  - Starting/finishing date
  - Resources needed during the construction processes → during the whole construction
  - Together with the cost calculation: costs of each activity → costs during the construction

Scheduling in PM

- Project time management
  - Activity definition
  - Activity sequencing
  - Activity duration estimating
  - Schedule development
  - Schedule control
“Time planning”

Basic information

• Determine what is to be done: OUTCOMES
• Work Breakdown Structure (WBS)
• List of operations (tasks)
  • Production process (realising a building)
  • Building processes (realising e.g. the substructure)
  • Technology processes (realisation of structures, e.g. a r.c. slab)
  • Activities (processes made in one time, at one place, by one group of workers, e.g. making the reinforcement for a slab)
• Relations between activities
  • Technological conditions
  • Organisational conditions

“Time planning”

Basic information

• Assigning resources
  • Material (construction material, auxiliary structures, ...)
  • Human (management, skilled workers – labour)
  • Equipment (machines, heavy equipment, power tools, ...)
  • Area
  • Money
• Quantities for each task
• Standards: tools for estimating time required for the processes
  • Performance standard [time/ unit] (h/m³, h/m²...)
  • Standard output [unit/time] (m³/h, pcs/h)
“Time planning”

Estimating time: the duration of the processes

\[
\text{Work [time]} = \frac{\text{Volume [unit]}}{\text{Standard output [unit/time]}} \quad \text{Work: time of process for one unit of resource}
\]

\[
\text{Work [time]} = \text{Volume [unit]} \times \text{Performance standard [unit/time]}
\]

\[
\text{Duration [time]} = \frac{\text{Work [time]}}{\text{Allocated resource [unit]}} \quad \text{Duration: time of process for the allocated units of resource}
\]

Result information:
- Operation (task), Quantity
- Labour / equipment, quantity
- Duration

„Time planning”

**LOGICAL FRAMEWORK**

<table>
<thead>
<tr>
<th>DURATION</th>
<th>OUTCOMES</th>
</tr>
</thead>
<tbody>
<tr>
<td>QUANTITY</td>
<td>(VOLUME)</td>
</tr>
</tbody>
</table>

**NETWORK**

<table>
<thead>
<tr>
<th>RESOURCES</th>
</tr>
</thead>
<tbody>
<tr>
<td>QUALITY</td>
</tr>
<tr>
<td>TECHNOLOGY</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ORGANISATIONAL CONDITIONS</th>
<th>TECHNOLOGICAL CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOGICAL FRAMEWORK</td>
<td></td>
</tr>
</tbody>
</table>

**ACTIVITY**

**DURATION**

**SCHEDULE REPRESENTATION**

**APPROPRIATE?**

**YES**
Schedule representations

- **Timetable (tabular or alpha-numerical schedule)**
  - It is accurate
  - Hard to see the current status at the first sight

Example: a retaining wall

<table>
<thead>
<tr>
<th>ID</th>
<th>Activity</th>
<th>Time</th>
<th>Start</th>
<th>Finish</th>
<th>Labour</th>
<th>Machine</th>
<th>Cost</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Demolish top soil</td>
<td>2 d</td>
<td>02-04-10</td>
<td>03-04-10</td>
<td>1</td>
<td>build.</td>
<td>€...</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Excavating trench</td>
<td>2 d</td>
<td>04-04-10</td>
<td>05-04-10</td>
<td>3</td>
<td>labr.</td>
<td>€...</td>
<td>15% labr.</td>
</tr>
<tr>
<td>3</td>
<td>Blinding</td>
<td>3 d</td>
<td>06-04-10</td>
<td>08-04-10</td>
<td>5</td>
<td>labr.</td>
<td>€...</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Formwork (foundation slab)</td>
<td>3 d</td>
<td>08-04-10</td>
<td>10-04-10</td>
<td>2</td>
<td>carp.</td>
<td>€...</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Reinforcement (foundation slab)</td>
<td>5 d</td>
<td>08-04-10</td>
<td>12-04-10</td>
<td>4</td>
<td>steel.</td>
<td>€...</td>
<td>35% prefabr.</td>
</tr>
</tbody>
</table>

Schedule representations

- **Bar chart – Gantt chart**
  - Most widely used technique
  - It consists of a scale – units of time (e.g. days, weeks,...) and a list of project elements (+other information)
  - Easy to see the current status – „today”
Schedule representations

- Bar chart – Gantt chart
  - Resource management: workers, equipment

<table>
<thead>
<tr>
<th>ID</th>
<th>Activity</th>
<th>Time</th>
<th>Labour</th>
</tr>
</thead>
</table>
| 1  | Demolish top soil              | 2 d  | 3 labr.
| 2  | Excavating trench              | 2 d  | 3 labr.
| 3  | Blinding                       | 3 d  | 5 labr.
| 4  | Formwork (foundation slab)     | 3 d  | 2 carp.
| 5  | Reinforcement (foundation slab)| 5 d  | 4 steel.

- Bulldozer 2 d
- Backhoe 2 d
- Labour

Schedule representations

- Linear schedule – Cyclogram
  - Used usually by construction of linear objects or repeating tasks
  - It shows spatial progress
  - It consists of two scales – one for time (e.g. days, weeks,...) and one for space (+tabular info)
Schedule representations

Network diagrams

Activity on arrow network
- 1957. Kelley and Walker – CPM
- (1958. NASA – PERT)

Activity on node network
- 1959. B. Roy - MPM

Characteristics of networks

• Models
  • Networks contain information about relations between activities

<table>
<thead>
<tr>
<th>Network</th>
<th>Node</th>
<th>Arrow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity</td>
<td>Activity on node (MPM)</td>
<td>Activity on arrow (CPM)</td>
</tr>
<tr>
<td>Event</td>
<td>Event on node (PERT)</td>
<td></td>
</tr>
</tbody>
</table>

• Basic elements:
  • Durations: time of processes, time of operations
  • Events (milestones): Project start, project end, activity start, activity end, deadlines, etc.
Characteristics of networks

Basic elements of AON networks

- Nodes: activities, significant events (deadlines, checkpoints...)
  - Task name or ID
  - Early start
  - Late start
  - Duration
  - Early finish
  - Late finish
  - Slack = LS - ES = LF - EF

- Arrows: relations between activities
  - Single, minimum relations
    - SSz
    - FFz
    - FSz
    - SFz
    - z ≥ 0
Characteristics of networks

• Arrows: relations between activities
  • Single, maximum relations

• Combined relations
  Critical succession
  Strict/forced succession (z<v)
  Special case: z=v
  Immediate succession
Characteristics of networks

- Directed edges (arrows)
- Positive durations
- All activities appear only once
- Connected (coherent)
- No loops are allowed
- Only one starting node \( \leftarrow \) Source
  - A node being origin of at least one arrow, but not terminal point of any arrows.
- Only one end node \( \leftarrow \) Sink
  - A node being terminal point of at least one arrow, but not origin of any arrows.

If these conditions are not met, the algorithm cannot be used.

Composing an MPM network

- Placing the shields
  - Loadbearing structures
  - Building installations
  - Finishing works

<table>
<thead>
<tr>
<th></th>
<th>I.</th>
<th>II.</th>
<th>III.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="image1.png" alt="Cells" /></td>
<td><img src="image2.png" alt="Cells" /></td>
<td><img src="image3.png" alt="Cells" /></td>
</tr>
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<td></td>
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</tbody>
</table>
Composing an MPM network

• Visualising technological conditions

I. Loadbearing structures
   FS0

II. Building installations
    CR3

III. Finishing works
     FS0

• Visualising organisational conditions

I. Loadbearing structures
   FS0

II. Building installations
    CR3

III. Finishing works
     FS0
Composing an MPM network

• Checking network

Loadbearing structures

Building installations

Finishing works

End

Composing an MPM network

• Adding durations

Loadbearing structures

Building installations

Finishing works

End
Time analysis

• Calculating forwards - starting
  I. Loadbearing structures
  II. Building installations
  III. Finishing works

End

Time analysis

• Calculating forwards – in the direction of the arrows
  I. Loadbearing structures
  II. Building installations
  III. Finishing works

End
Time analysis

• Calculating forwards – in the direction of the arrows

I.

Loadbearing structures

II.

Building installations

III.

Finishing works

End
Time analysis

• Calculating forwards – CR3??

I.

Loadbearing structures

0 4 4

FS0

Building installations

4 4 8

CR3

Finishing works

6

7

8

End

0

Time analysis

• Calculating forwards – CR3 → SS3

I.

Loadbearing structures

0 4 4

FS0

Building installations

4 4 8

FS0

CR3 (SS3)

Finishing works

7 6 13

CR3 (SS3)

End

0

II.

III.
Time analysis

Calculating forwards – choosing the maximum

<table>
<thead>
<tr>
<th>I.</th>
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<tbody>
<tr>
<td>Loadbearing structures</td>
<td>0 4 4</td>
<td>4 3 7</td>
</tr>
<tr>
<td></td>
<td>4 3 7</td>
<td>4 3 7</td>
</tr>
<tr>
<td>Building installations</td>
<td>4 4 8</td>
<td>8 4 12</td>
</tr>
<tr>
<td></td>
<td>8 4 12</td>
<td>8 4 12</td>
</tr>
<tr>
<td>Finishing works</td>
<td>7 6 13</td>
<td>11 7 18</td>
</tr>
<tr>
<td></td>
<td>11 7 18</td>
<td>11 7 18</td>
</tr>
<tr>
<td>End</td>
<td>13 0 23</td>
<td>15 0 23</td>
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Calculating backwards

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<tbody>
<tr>
<td>Loadbearing structures</td>
<td>FS0</td>
<td>FS0</td>
</tr>
<tr>
<td></td>
<td>4 4 8</td>
<td>12 4 16</td>
</tr>
<tr>
<td>Building installations</td>
<td>FS0</td>
<td>CR3 (SS3)</td>
</tr>
<tr>
<td></td>
<td>CR3 (SS3)</td>
<td>CR3 (SS3)</td>
</tr>
<tr>
<td>Finishing works</td>
<td>7 6 13</td>
<td>11 7 18</td>
</tr>
<tr>
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<td>11 7 18</td>
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<tr>
<td>End</td>
<td>13 0 23</td>
<td>15 0 23</td>
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SAME ORDER OF STEPS!

Calculating forwards

- Early dates
- Appointed starting date
- Proceeding in the direction of the arrows
- Maximal values

Calculating backwards

- Late dates
- Appointed finishing date
- Proceeding against the arrows
- Minimal values
Time analysis

- Calculating backwards – appointing finishing date
  
  I. Loadbearing structures
     0 4 4 FS0
     4 4 8 FS0
     7 6 13 CR3 (SS3)
     23 0 23
   
  II. Building installations
     4 3 7 FS0
     8 4 12 FS0
     11 7 18 CR3 (SS3)
     23 0 23
   
  III. Finishing works
     7 5 12 FS0
     12 4 16 FS0
     15 8 23 CR3 (SS3)
     23 0 23
   
  End

Time analysis

- Calculating backwards – against the arrows
  
  I. Loadbearing structures
     0 4 4 FS0
     4 4 8 FS0
     7 6 13 CR3 (SS3)
     23 0 23
   
  II. Building installations
     4 3 7 FS0
     8 4 12 FS0
     11 7 18 CR3 (SS3)
     23 0 23
   
  III. Finishing works
     7 5 12 FS0
     12 4 16 FS0
     15 8 23 CR3 (SS3)
     23 0 23
   
  End
Time analysis

- Calculating backwards – against the arrows

I. Loadbearing structures

- Calculating backwards – choosing the minimum

I. Loadbearing structures

- Calculating backwards – against the arrows

I. Loadbearing structures

- Calculating backwards – choosing the minimum

I. Loadbearing structures
Time analysis

• Checking the network

• Getting back 0 as the starting date

• Late date ≥ early date

Analysing the network

• Float – total float

Loadbearing structures

Building installations

Finishing works

End
Analysing the network

• Critical nodes

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<th>Finishing works</th>
<th>I.</th>
<th>II.</th>
<th>III.</th>
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<tbody>
<tr>
<td>7 6 13</td>
<td>FS0</td>
<td>11 7 18</td>
<td>15 8 23</td>
</tr>
<tr>
<td>17 10 23</td>
<td>FS0</td>
<td>16 5 23</td>
<td>15 0 23</td>
</tr>
</tbody>
</table>

End

Analysing the network

• Critical edges

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<th>I.</th>
<th>II.</th>
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<td>7 5 12</td>
</tr>
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<td>CR3 (SS3)</td>
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<th>I.</th>
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<td>FS0</td>
<td>16 5 23</td>
<td>15 0 23</td>
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</tbody>
</table>

End
Analysing the network

• Critical path

I. Loadbearing structures

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>FS0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

II. Building installations

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>FS0</td>
<td>4</td>
</tr>
<tr>
<td>0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>CR3 (SS3)</td>
<td>7</td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
</tr>
</tbody>
</table>

III. Finishing works

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>FS0</td>
<td>7</td>
</tr>
<tr>
<td>0</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
</tr>
<tr>
<td>CR3 (SS3)</td>
<td>17</td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td></td>
</tr>
</tbody>
</table>

End

<table>
<thead>
<tr>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>23</td>
</tr>
</tbody>
</table>

Modifying the network

• When?
  • During the planning phase
  • During the construction – according to actual data

• Why?
  • To reduce the total duration
  • Delay in the preceding activities → keeping end deadline

• How?
  • Changing activity durations in the critical path
  • Changing relations in the critical path
    • Allowing greater overlapping
    • Using more resources (e.g. labour) → eliminating relations
MPM network → bar chart

References

- Lepel Adrienn – *Basics of construction – Basics of scheduling*  
  [http://www.ekt.bme.hu/ArchEng/Basics%20of%20scheduling.pdf](http://www.ekt.bme.hu/ArchEng/Basics%20of%20scheduling.pdf)
- Dr. Vattai Zoltán – *Construction management – decision support*, Network techniques I-II  
Exercise

• What happens if the duration of activity B is changed from 4 to 5?

\[
\begin{array}{c}
A \quad 3 \\
\rightarrow \quad \text{FS0} \\
B \quad ? \\
\rightarrow \quad \text{FS0} \\
C \quad 5 \\
\end{array}
\]

\[
\begin{array}{c}
A \quad 3 \\
\rightarrow \quad \text{SS3} \\
B \quad ? \\
\rightarrow \quad \text{SS3} \\
C \quad 5 \\
\end{array}
\]

\[
\begin{array}{c}
A \quad 3 \\
\rightarrow \quad \text{FF3} \\
B \quad ? \\
\rightarrow \quad \text{FF3} \\
C \quad 5 \\
\end{array}
\]