



Enterprise  
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**EDIH** | European  
Digital Innovation  
Hubs Network



# Concepts

**Helmut Simonis**

## Constraint Based Production Scheduling



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# Key Points



- We introduce the core concepts used in scheduling
- Different layers of description
  - Why we are scheduling (orders, products, processes)
  - What we are doing (jobs, tasks)
- Temporal Relations
- Process description
- Problem classification
- Visualization

# Outline



Core Concepts

Jobs and Tasks

Orders, Products, Processes

Temporal Relations

Processes, Bill of Materials

Problem Classification

Key Visualization Methods

Summary

# Most basic description of scheduling problem



- Job
  - Collection of activities required to manufacture one object/lot/order
  - Overall start/end determined by starts and ends of its tasks
- Task
  - Individual activities required for manufacture
  - Have defined start, end (typical: variables) and duration (sometimes fixed)
  - Often performed on one specific resource (more on that later)
- Very compact representation of scheduling problem
- But, where does the data come from?

# Outline



Core Concepts

Temporal Relations

Relations between Tasks

Relation between Tasks and Jobs

Jobs: Release and Due Date

Processes, Bill of Materials

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# Temporal Relations

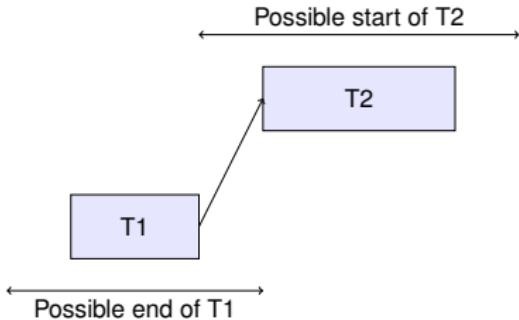


- Temporal constraints between tasks and/or jobs
- Defined by the manufacturing process
- In simple cases, a single sequence of process steps performed in that order
- Each task must finish before the next one can start

# The Most Common Relation: EndBeforeStart



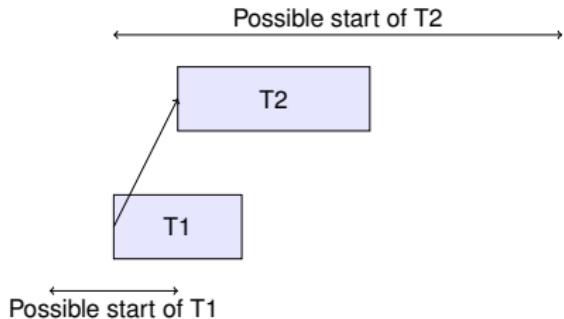
- States that one task (T1) must end before the next one (T2) can start
- Typical for manufacturing process based on the same item
- Addition: offset
  - For example cooling, drying time outside a machine



# Less Common: startBeforeStart



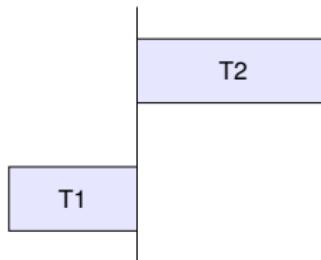
- States that one task (T2) can start any time after the start of another task (T1)
- Uncommon in manufacturing, occurs in project management
- Example later on on assembly line balancing





- Sometimes, two steps must follow each other immediately
- The item made would spoil
- Product specific
- There is no space to hold item
- Machine specific, buffers
- End of one task (T1) must be equal to start of next task (T2)
- May mean delay of start of task T1

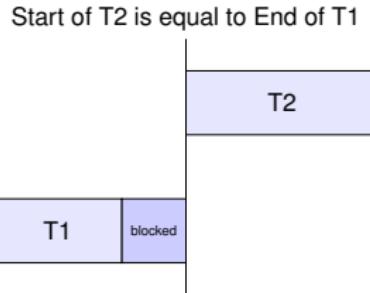
Start of T2 is equal to End of T1





# Blocking

- Sometimes, two steps must follow each other immediately
- There is no space to hold store item between machines
- Keep item on previous machine until needed
- That machine is now blocked
- Duration of task T1 is extended
- Use with caution!



# More General: Relations between Intervals



- First introduced by Allen (1983)
- 13 relations between intervals
- Allows composition of relations
- Constraint reasoning on sets of relations

Relation	Illustration	Interpretation
$X < Y$	$\underline{\hspace{1cm} X \hspace{1cm}}$	X precedes Y
$Y > X$	$\underline{\hspace{1cm} \hspace{1cm} Y}$	Y is preceded by X
$X \text{ m } Y$	$\underline{\hspace{1cm} X \hspace{1cm}} \underline{\hspace{1cm} Y}$	X meets Y
$Y \text{ mi } X$	$\underline{\hspace{1cm} \hspace{1cm} Y} \underline{\hspace{1cm} X}$	Y is met by X ( <i>i</i> stands for <i>inverse</i> )
$X \text{ o } Y$	$\underline{\hspace{1cm} X \hspace{1cm}} \underline{\hspace{1cm} Y}$	X overlaps with Y
$Y \text{ oi } X$	$\underline{\hspace{1cm} \hspace{1cm} Y} \underline{\hspace{1cm} X}$	Y is overlapped by X
$X \text{ s } Y$	$\underline{\hspace{1cm} X \hspace{1cm}}$	X starts Y
$Y \text{ si } X$	$\underline{\hspace{1cm} Y \hspace{1cm}}$	Y is started by X
$X \text{ d } Y$	$\underline{\hspace{1cm} X \hspace{1cm}} \underline{\hspace{1cm} Y}$	X during Y
$Y \text{ di } X$	$\underline{\hspace{1cm} \hspace{1cm} Y} \underline{\hspace{1cm} X}$	Y contains X
$X \text{ f } Y$	$\underline{\hspace{1cm} Y \hspace{1cm}} \underline{\hspace{1cm} X}$	X finishes Y
$Y \text{ fi } X$	$\underline{\hspace{1cm} \hspace{1cm} Y} \underline{\hspace{1cm} X}$	Y is finished by X
$X = Y$	$\underline{\hspace{1cm} X \hspace{1cm}} \underline{\hspace{1cm} Y}$	X is equal to Y

from Wikipedia: <https://en.wikipedia.org/wiki/>

Allen%27s\_interval\_algebra

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Core Concepts

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Problem Classification

Job-Shop

Flow-Shop

Open-Shop

RCPSP

$\alpha, \beta, \gamma$  Notation

Key Visualization Methods

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- We introduced the key concepts for scheduling problems
- Orders, products, processes
- Jobs and tasks
- Existing problem classifications
  - Academic
  - Limited practical usefulness
- Key visualization methods