Advanced Concepts

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Constraint Based Production Scheduling

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Key Points

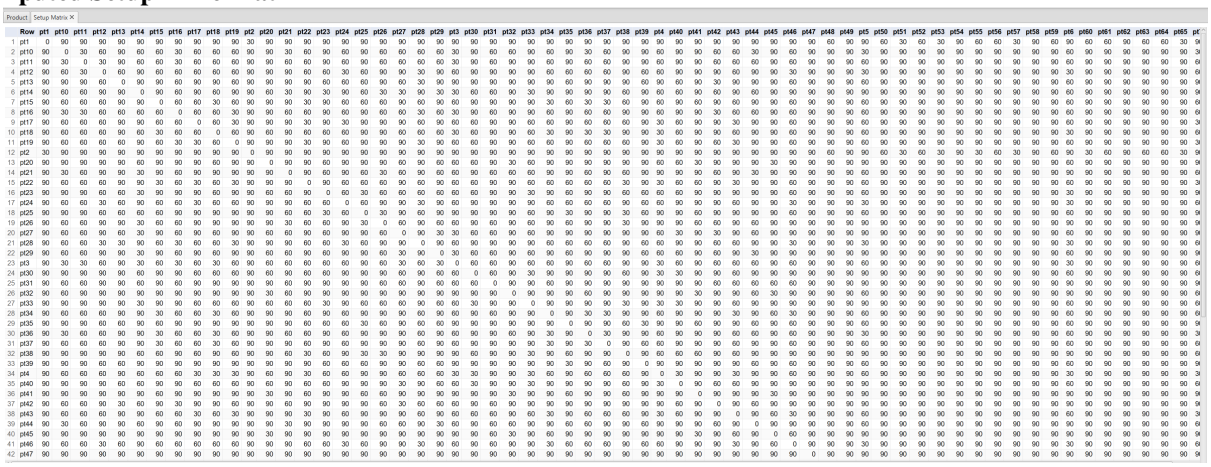
- We present some more advanced concepts in scheduling
- These occur in more specialized problem areas
- Typically require more work on modelling
- Solver support may be limited

1 Sequence Dependent Setup-Time

Sequence Dependent Setup-Time ✓

- Our usual disjunctive resource model assumes we can change easily from one task to the next
- There might be a cleaning/setup time required
  - This is part of the fixed duration part of a processStep description
- In some cases it is more complex
  - On some machines there is a setup-time required which depends on both the previous and the next product
  - This time varies significantly between product combinations
  - Typically, the time depends on some properties of the products
- The setup time is non-productive, and should be avoided when possible

Computed Setup-Time Matrix



- This needs to be computed from first principles, not maintained by hand!
- Available as input data in JSON format

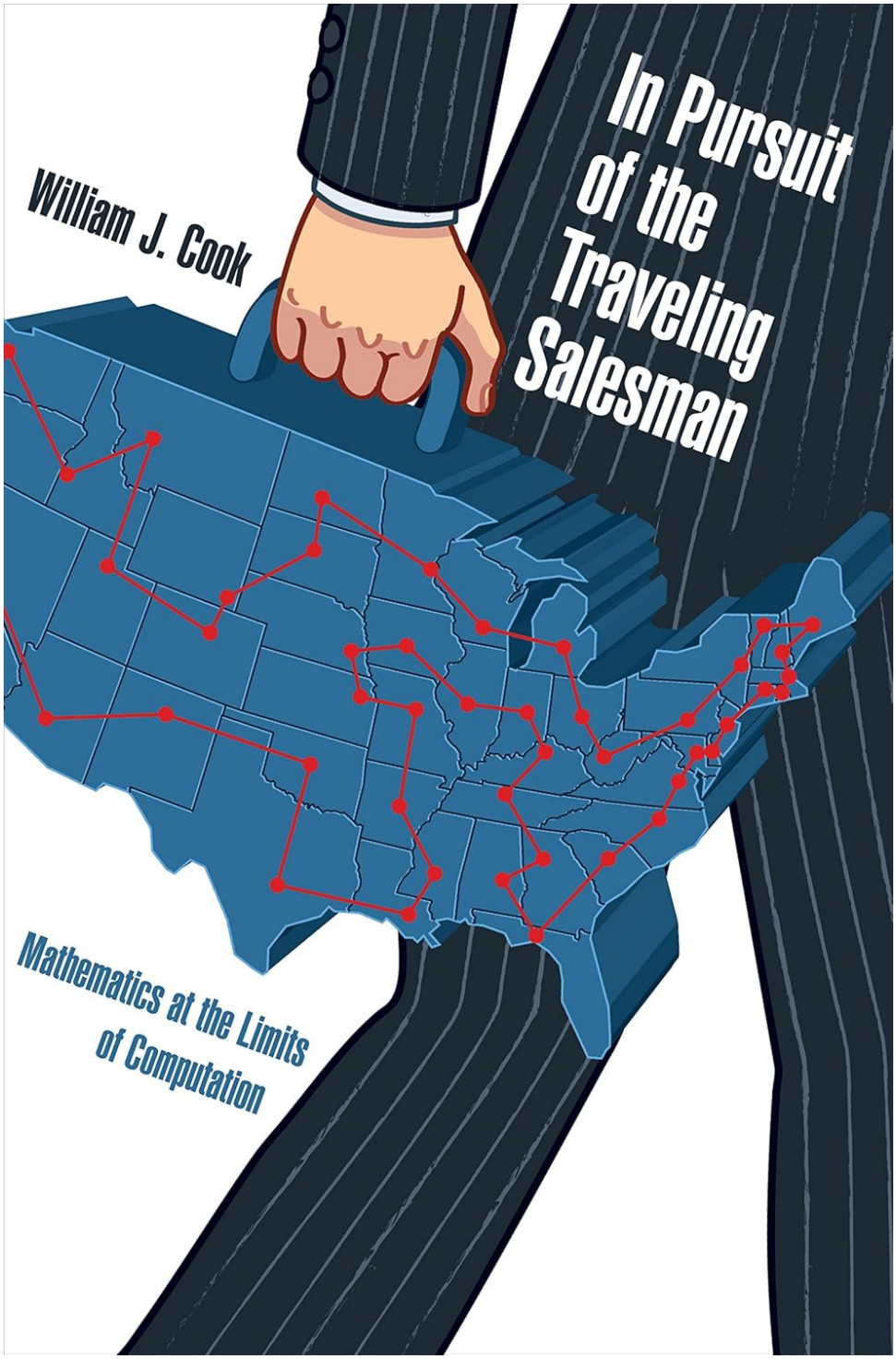
Relation to TSP

- Computing the optimal sequence of setup times is a variant of the *Travelling Salesman Problem (TSP)*
- Another of the classical hard combinatorial problems
- Due to the structure of the data, setup-time problem often are simpler to solve
  - Changing between very similar products needs no setup-time

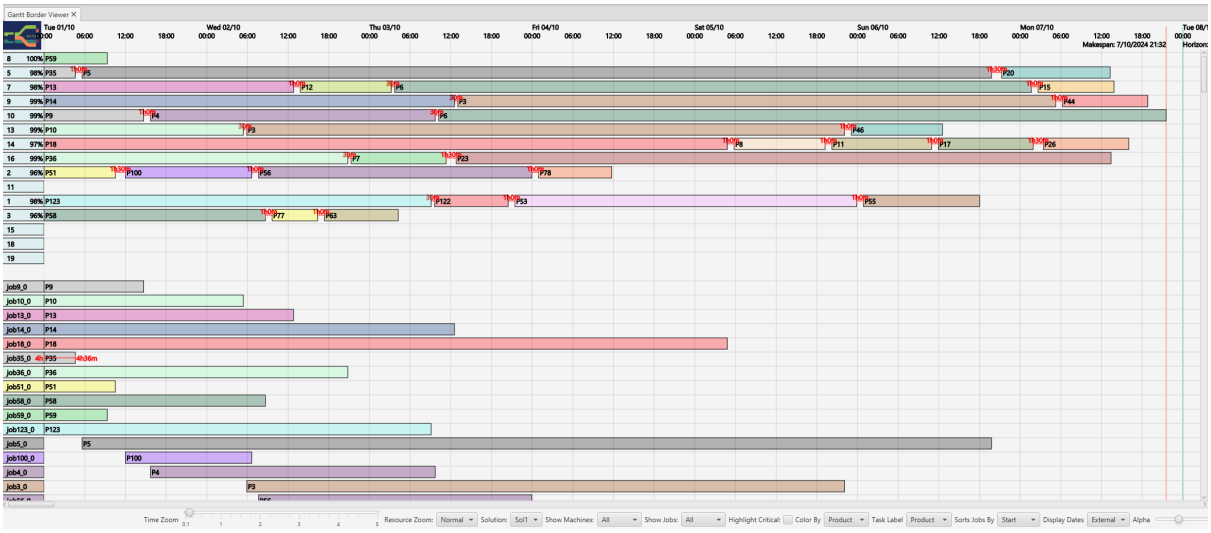
  - Using a simple rule about product compatibility produces best results
  - Example: dark-chocolate → milk chocolate → white chocolate → milk chocolate → draw chocolate
- Problems get more difficult when release/due dates need to be respected
- This is the equivalent to the *VRPTW (Vehicle Routing Problem with Time Windows)*

Xmas Shopping Hint

- W. Cook. In Pursuit of the Travelling Salesman. Princeton University Press, 2011
- Entertaining general science presentation of the TSP and related issues



Setup Times Constraints can be Included in Model



- Shown in Machine Gantt chart, enable display in `Layout` tab
- So far, only in CPO, not in CPSat model

Related Problem: Forbidden Transitions ✗

- For safety reasons, it may be forbidden to change from some product to some specific other products
- Contamination risk is considered too high
- Examples
  - In food production: Is this product peanut free?
  - In food production: Directly changing from dark to white chocolate is not allowed
  - In chemical plants: Contamination may lead to explosions
- These transitions are called *forbidden*, and must be avoided
- Careful, it is easy to paint yourself into a corner!

2 Transportation Time

Dealing with Transportation Times

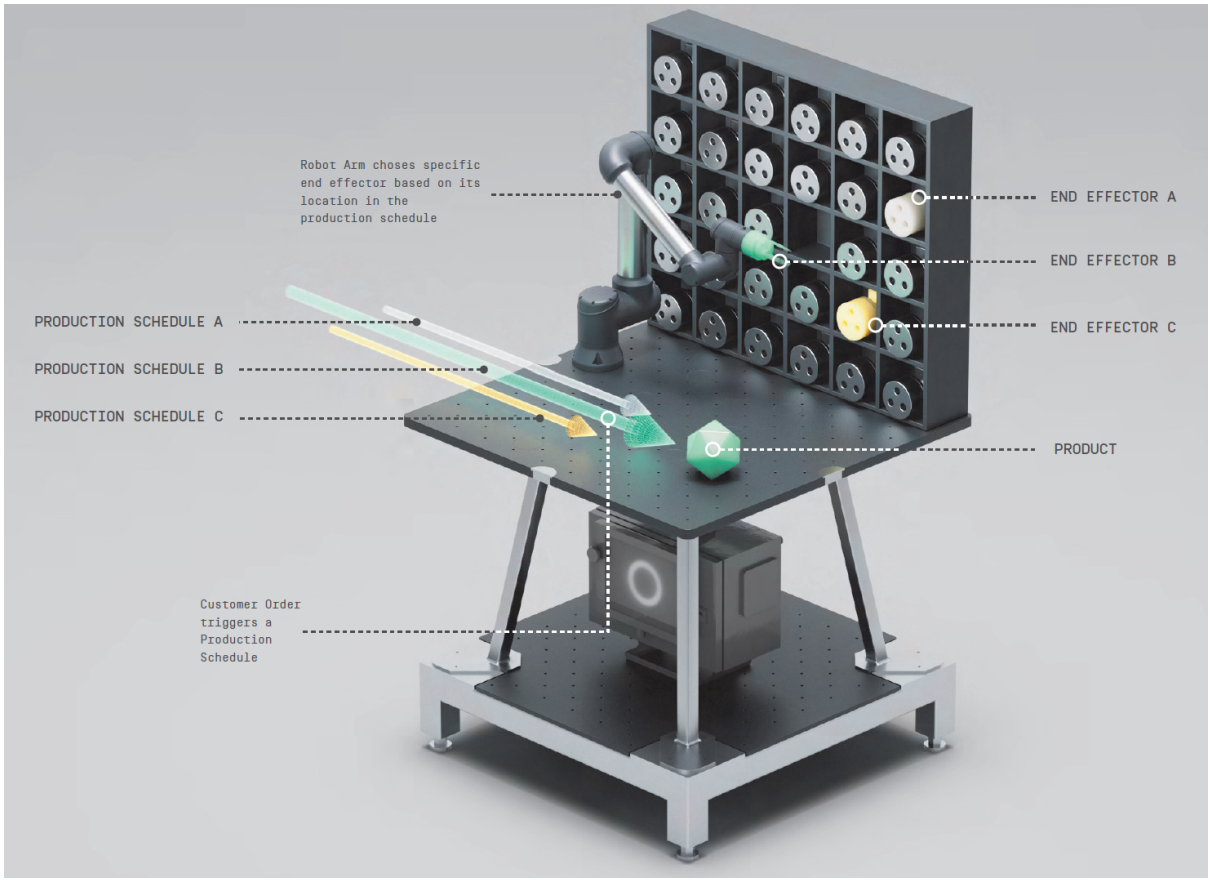
- Really two different Problems
  - In one, the resources are in fixed locations, and we transport the jobs between the locations
  - In the other, the tasks are in fixed locations, and we transport the resources between them

2.1 Transportation of Materials

Transportation of Jobs

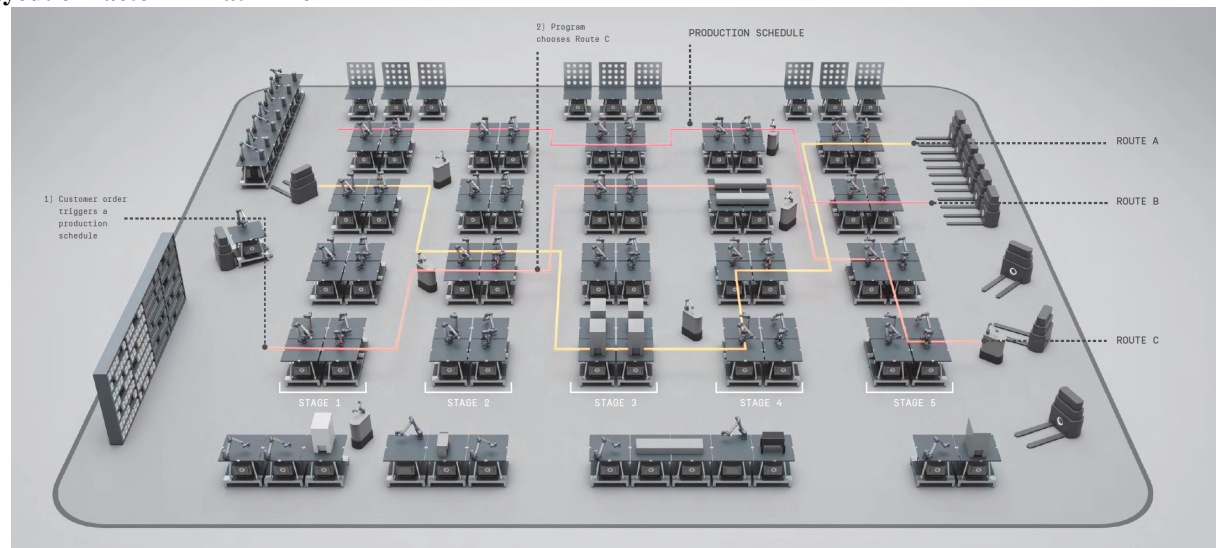
- Example from a project with J&J in Limerick
- Considering a *factory of the future* based on agile machines
- Robots that can be configured to perform many different tasks
- These robots may be inside one or more factories

- How to arrange them to minimize impact of transport on production



from J&J

Layout of Factor in Matrix Form



- Materials are transported between stations by moving robots
- Layout of factory determines delay caused by transport

Inclusion in Model (✓)

Row	M0_0	M0_1	M0_2	M0_3	M0_4	M0_5	M0_6	M0_7	M0_8	M0_9	M1_0	M1_1	M1_2	M1_3	M1_4	M1_5	M1_6	M1_7	M1_8	M1_9	M2_0	M2_1	M2_2	M2_3	M2_4	M2_5	M2_6	M2_7	M2_8	M2_9	M3_0	M3_1	M3_2	M3_3	M3_4	M3_5	M3_6	M3_7	M3_8	M3_9
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M0_3	0	0	0	0	0	0	0	0	0	0	4	3	2	1	2	3	4	5	6	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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M0_9	0	0	0	0	0	0	0	0	0	0	10	9	8	7	6	5	4	3	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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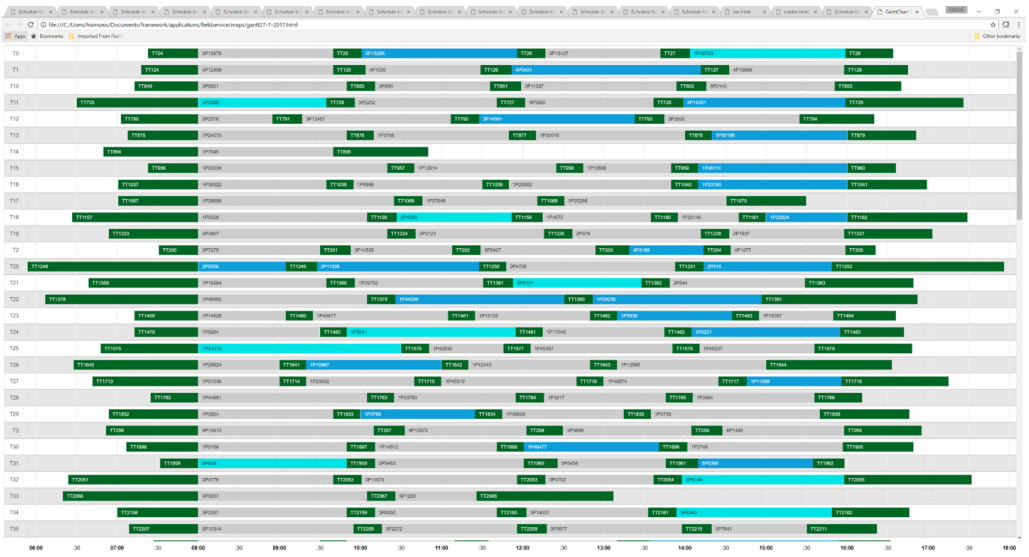
- Add location attribute to each resource
- Include transport time as element in temporal constraints

2.2 Transportation of Resources/Personnel

Scheduling Service Visits

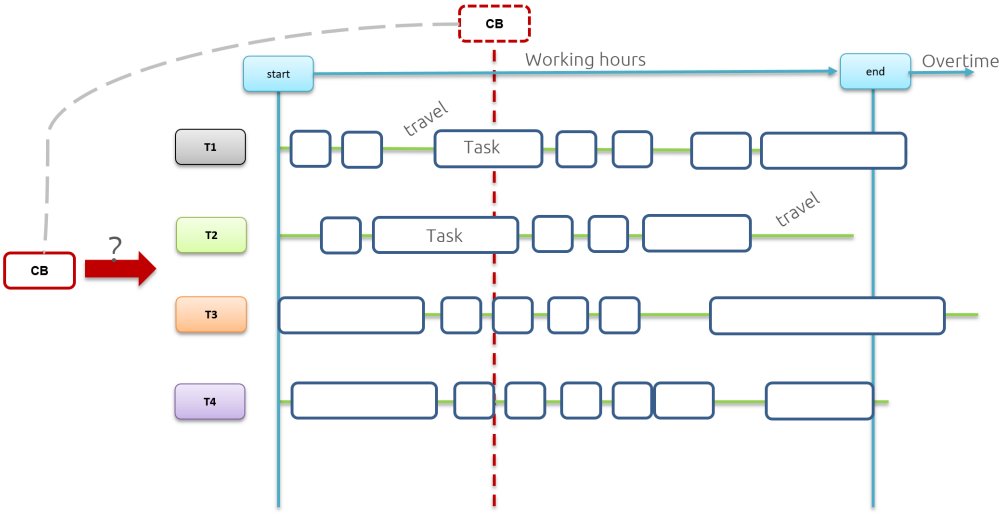
- Based on a project with UTRC-I, UTRC, OTIS
- Schedule visits to maintain equipment installed in customer premises
- Resources are the service engineers
- They have to travel between locations and perform work there
- The tasks are the maintenance operations required to keep equipment working
- Also called *Traveling Repair-person Problem*

Planning Maintenance Visits for Service Personnel



- Include single day trips, multi-day tours
- Most of the time spent at customer locations

Re-scheduling Problem



- How to react when a customer is trapped in an elevator
- All you engineers are on service calls
- Who you gonna call?

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- This will be described in more detail in a new course
- AI Fundamentals: Skill Development Program on Transportation Optimization
- Arriving in 2025 at this location

3 Summary

Summary

- We presented some more advanced topics
  - Sequence dependent setup
  - Transportation time
- Not available in every solver
- Useful concepts when dealing with specific scheduling problems
- Leading to another *Skills Development Program*