

ASSISTANT SE Case Study

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Constraint Based Production Scheduling

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Key Points



- Scheduling/Planning tool for manufacturing industry
- Developed as part of European ASSISTANT project
- Focused on key make-or-buy decisions
- Complex manufacturing process with alternative process paths
- Outperforms both current in-house tool and commercial simulator
- Key Technology: Optimization and Constraint Programming

Assistant Siemens Energy Use Case



A detailed 3D cross-section of a gas turbine engine. The engine is shown from a front-three-quarter perspective, revealing its internal components. A prominent red circle highlights the compressor section, which is located at the front of the engine. The engine is mounted on a dark base.

Use Case Scenarios

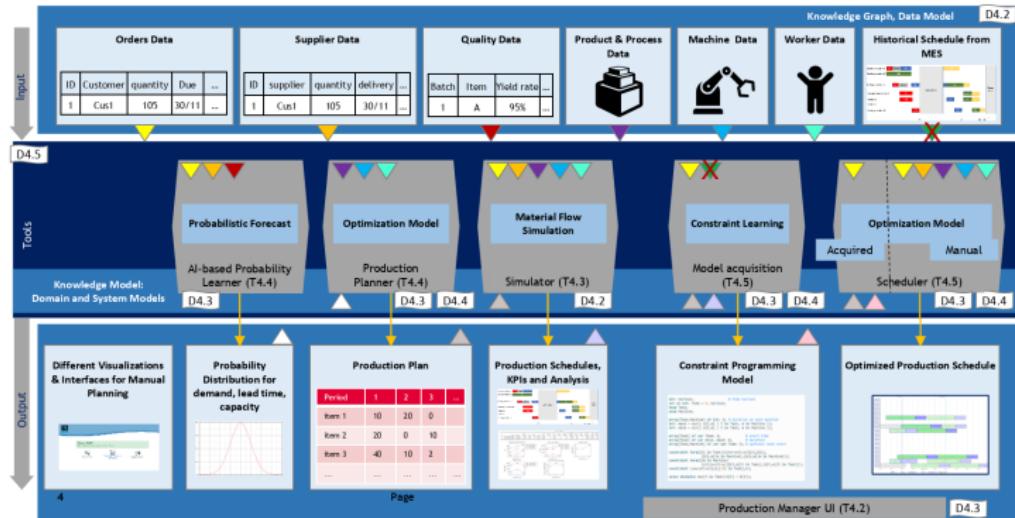
- Schedule *validation* of gas turbine blades and vanes manufacturing operations in Berlin plant
- Schedule *optimization* to manage short-term, mid-term and long-term load fluctuations
- Generate *Make-or-Buy proposals* for workload balancing within the manufacturing network

ASSISTANT Project Overview

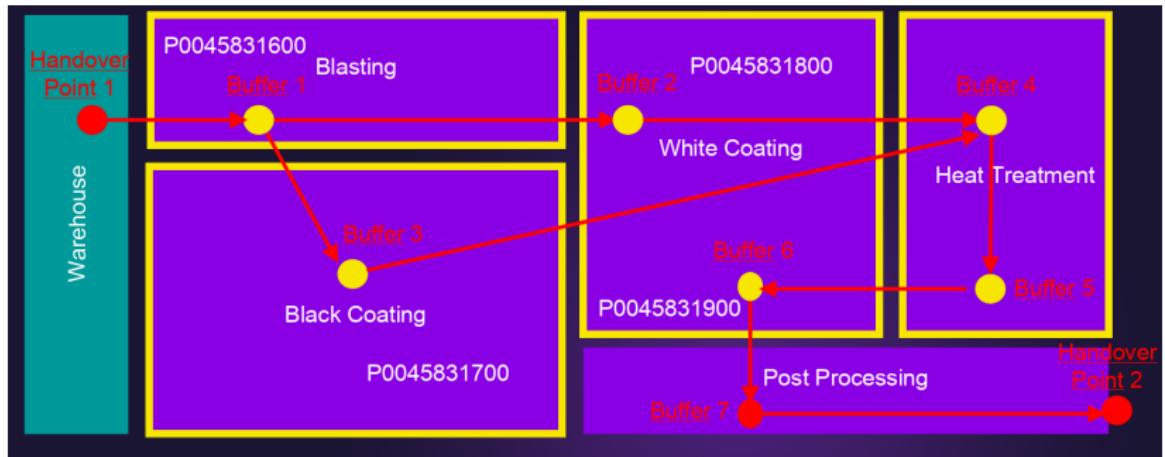


Intelligent digital twin for process planning and scheduling

ASSISTANT



SE Product Routing

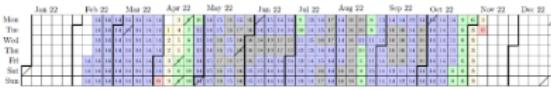


Test Datasets



Full Scale Datasets

Berlin06: 96 orders, 9 months horizon, previous review



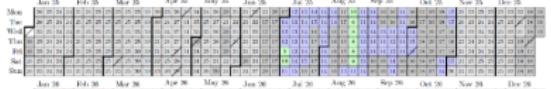
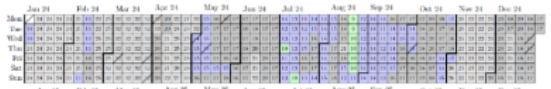
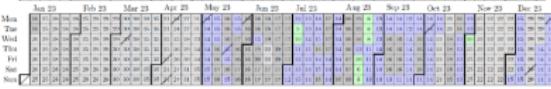
Berlin07: 450 orders, 4 years horizon



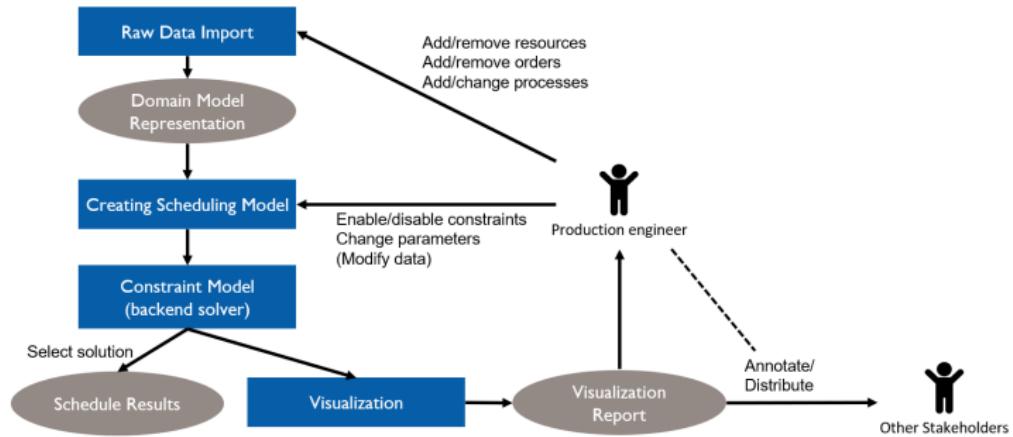
Berlin08: 559 orders, Christmas gap added

Berlin08a: 670 orders, filling gaps

Value in cell indicates active orders
Yellow and red colors indicate low order volume



Optimizer High Level Structure



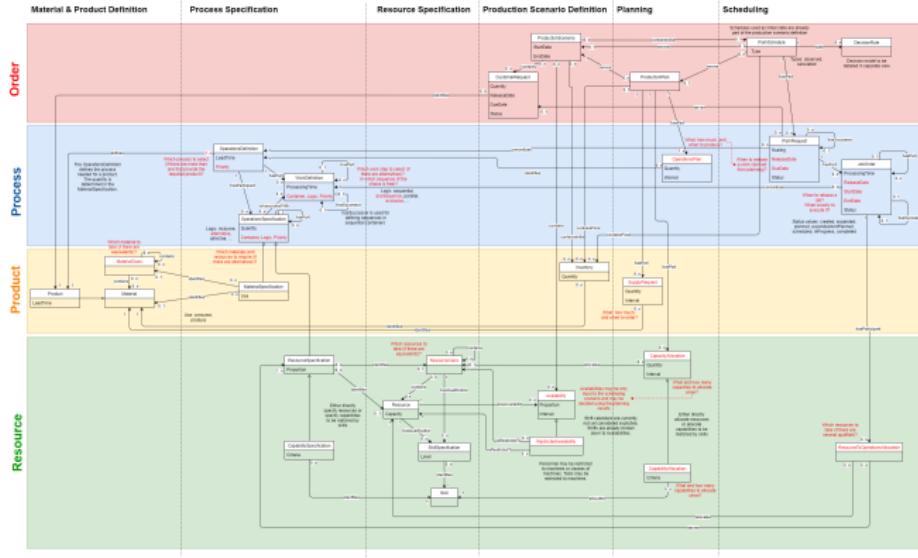
Raw Data - Manual Data Entry Causes Problems



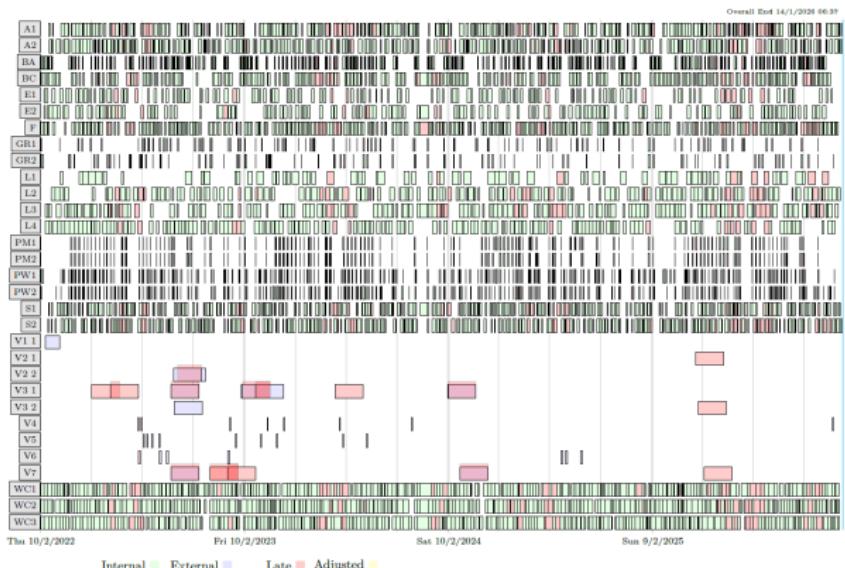
- Raw data come from spreadsheet
 - 20 tabs
- Excel is a particularly bad input data format
- Realistic, not real data
- Created by hand/automatically from existing test scenarios
- Series of files Berlin01 - Berlin05 were too inconsistent to run
- Berlin06 still contains some errors
- Optimizer explains all issues that it finds

Name	Severity	Sheet	RowNr.	ColNr.	Description
Issue1	Major	t_Load	129	11	Date/Time not formatted correctly, found 2022-02-28 00:00:00 format yyyy-mm-ddTHH:mm:ss
Issue2	Minor	t_Products	1	15	
Issue3	Minor	t_Availabilities	1	8	
Issue4	Minor	t_Uncertainties	1	8	
Issue5	Minor	t_Shift_Segments	1	6	
Issue6	Major	t_Shift_Segments	1	1	TimeOnly not formatted correctly, found 02/20000 format hh:mm:ss
Issue7	Major	t_Shift_Segments	1	2	TimeOnly not formatted correctly, found 03/20000 format hh:mm:ss
Issue8	Major	t_Shift_Segments	2	1	TimeOnly not formatted correctly, found 02/20000 format hh:mm:ss
Issue9	Major	t_Shift_Segments	2	2	TimeOnly not formatted correctly, found 04/20000 format hh:mm:ss
Issue10	Major	t_Shift_Segments	2	3	TimeOnly not formatted correctly, found 04/20000 format hh:mm:ss
Issue11	Major	t_Shift_Segments	2	4	TimeOnly not formatted correctly, found 04/20000 format hh:mm:ss
Issue12	Major	t_Shift_Segments	4	1	TimeOnly not formatted correctly, found 03/20000 format hh:mm:ss
Issue13	Major	t_Shift_Segments	4	2	TimeOnly not formatted correctly, found 03/20000 format hh:mm:ss
Issue14	Major	t_Shift_Segments	5	1	TimeOnly not formatted correctly, found 06/20000 format hh:mm:ss
Issue15	Major	t_Shift_Segments	5	2	TimeOnly not formatted correctly, found 06/20000 format hh:mm:ss
Issue16	Major	t_Shift_Segments	6	1	TimeOnly not formatted correctly, found 07/20000 format hh:mm:ss
Issue17	Major	t_Shift_Segments	6	2	TimeOnly not formatted correctly, found 07/20000 format hh:mm:ss
Issue18	Major	t_Shift_Segments	7	1	TimeOnly not formatted correctly, found 09/20000 format hh:mm:ss
Issue19	Major	t_Shift_Segments	7	2	TimeOnly not formatted correctly, found 02/20000 format hh:mm:ss
Issue20	Major	t_Shift_Segments	8	1	TimeOnly not formatted correctly, found 00/20000 format hh:mm:ss
Issue21	Major	t_Shift_Segments	8	2	TimeOnly not formatted correctly, found 07/20000 format hh:mm:ss
Issue22	Major	t_Shift_Segments	9	1	TimeOnly not formatted correctly, found 00/20000 format hh:mm:ss
Issue23	Major	t_Shift_Segments	9	2	TimeOnly not formatted correctly, found 01/20000 format hh:mm:ss
Issue24	Minor	t_Shift_Patterns	10	0	
Issue25	Minor	t_Shift_Patterns	11	0	
Issue26	Minor	t_Shift_Patterns	12	0	
Issue27	Minor	t_Shift_Patterns	13	0	
Issue28	Minor	t_Shift_Patterns	14	0	
Issue29	Minor	t_Shift_Patterns	15	0	
Issue30	Minor	t_Shift_Patterns	16	0	
Issue31	Minor	t_Shift_Patterns	17	0	
Issue32	Minor	t_Shift_Patterns	18	0	
Issue33	Minor	t_Shift_Patterns	1	9	
Issue34	Minor	t_Shift_Patterns	7	0	
Issue35	Minor	t_Shift_Patterns	8	0	

Domain Model - Knowledge Graph



Solution for Berlin 08a - Shows Only 20% of Tasks in Model



Implementation

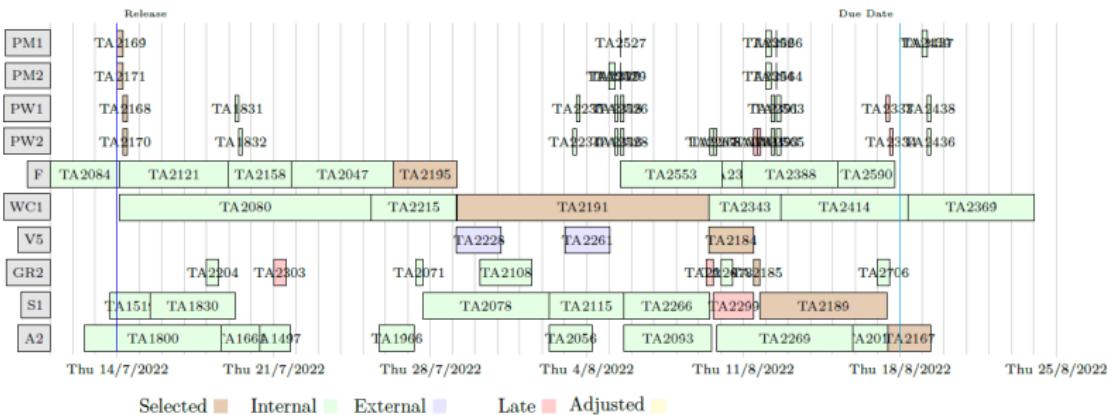


- Requirement capture done inside project
- Data checking/cleaning most time consuming aspect
- Some specified functionality was rejected by Betriebsrat
- Built in Java
- Uses IBM's CPOptimizer back-end
- 120k LoC, 110k generated, 3k solver
- Outperforms both
 - Current in-house tool
 - Simulation based tool based on commercial simulator
- System installed at SE site, but not in daily use

Explaining Late Delivery



- Explain why some orders are delivered late
- Find root-cause, show schedule in context



Evaluation - KPIs



KPI	Baseline	Optimizer
OTD	> 80 %	92 %
Bottleneck machine utilization	99.5 %	100 %
Manufacturing defects	10-15 %	< 10 %
Scenarios in 8 hours	15-20	> 100,000

Conclusion by Siemens Energy



“Within less than eight hours the ASSISTANT tools provided us thousands of manufacturing scenarios including different make-or-buy recommendations for making deliberate decisions on the way to proceed for strategic planning.”

from ASSISTANT final project review: Siemens Energy assessment

Summary



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