

# ASSISTANT SE Case Study

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## Constraint Based Production Scheduling



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# Acknowledgments



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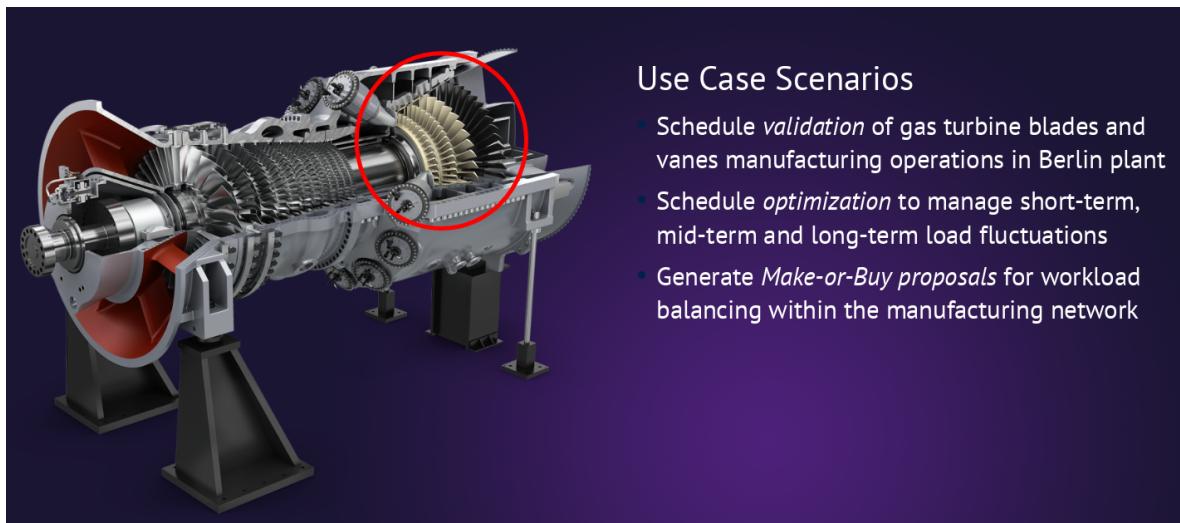
Part of this work is based on research conducted within the ASSISTANT European project, under the framework program Horizon 2020, ICT-38-2020, Artificial intelligence for manufacturing, grant agreement number 101000165.

## 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



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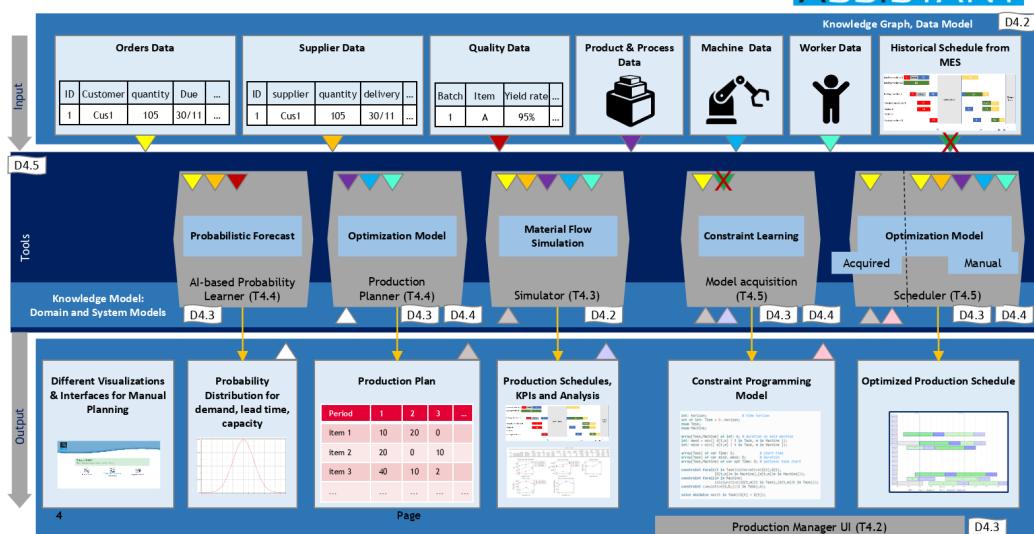
Slide 5

## ASSISTANT Project Overview



Intelligent digital twin for process planning and scheduling

ASSISTANT

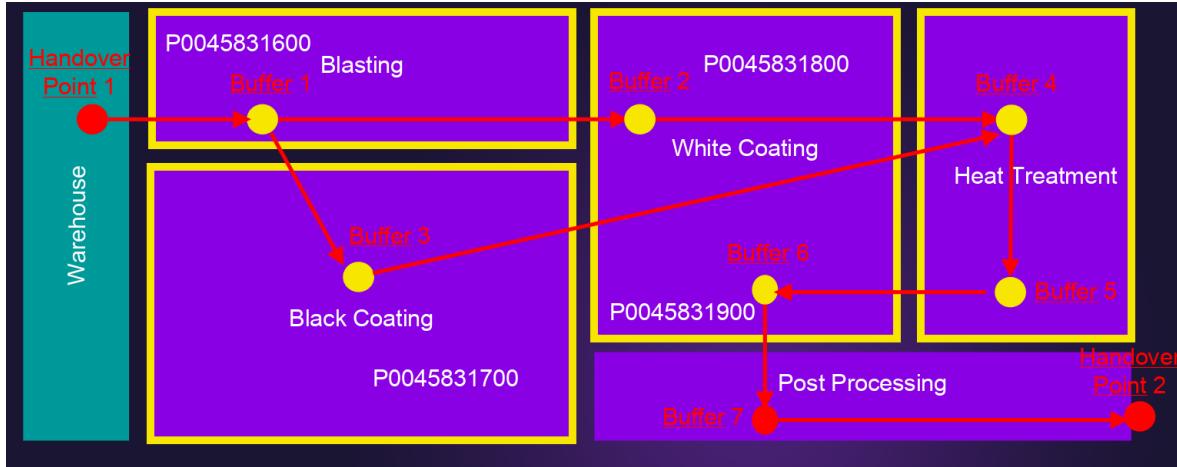


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Slide 6

# SE Product Routing



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Slide 7

## Test Datasets



### Full Scale Datasets

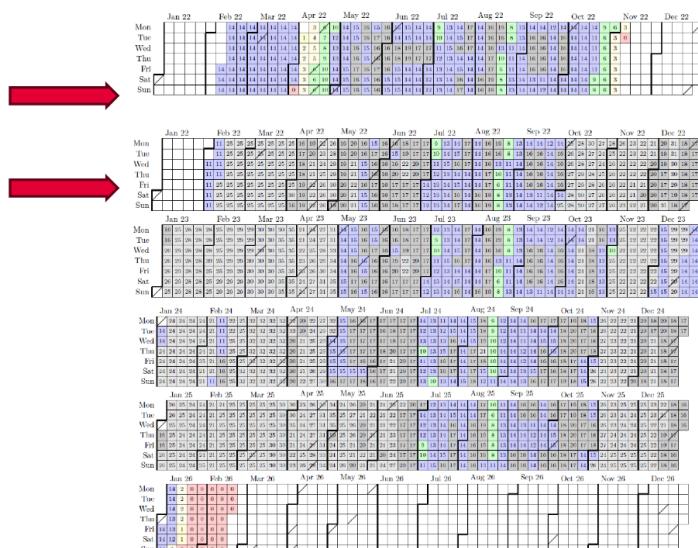
Berlin06: 96 orders, 9 months horizon, previous review

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

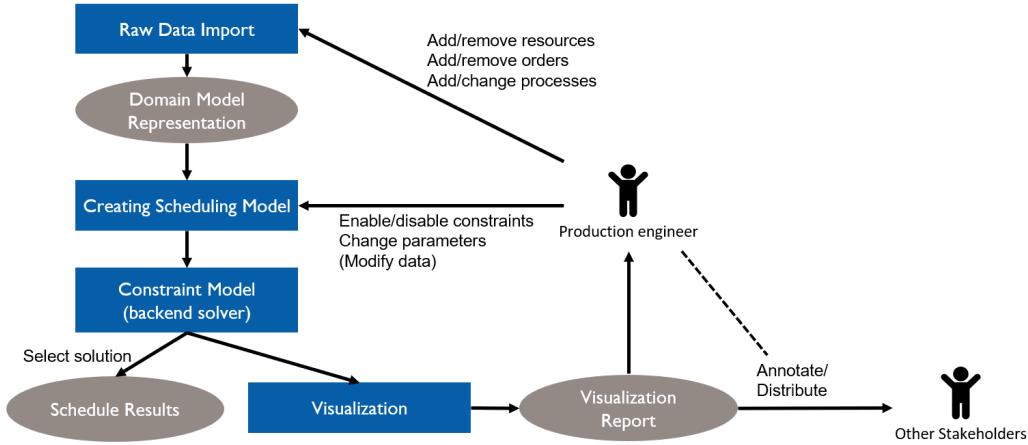


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# Optimizer High Level Structure



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## 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

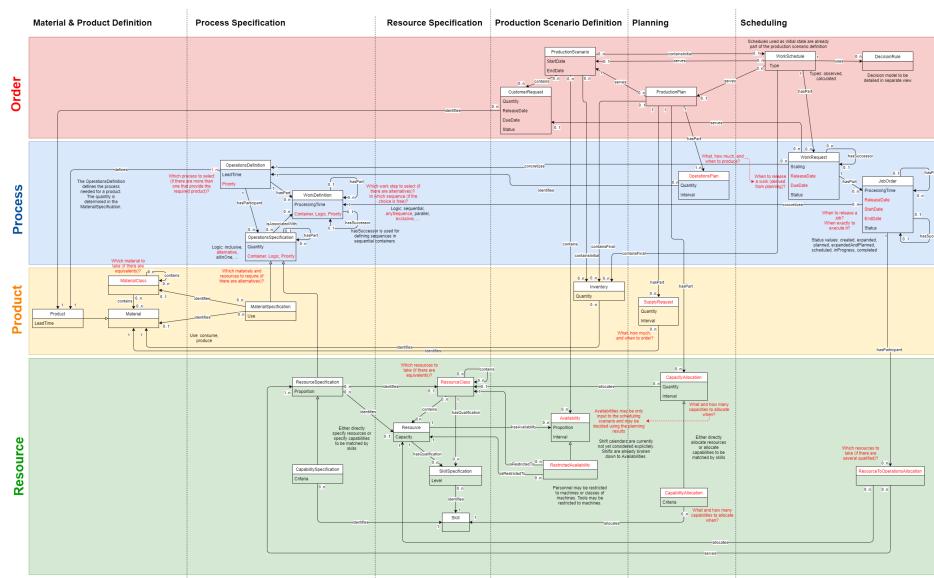
Name	Severity	Sheet	RowNr.	ColNr.	Description
Issue1	Major	t_Load	129	11	DateTime not formatted correctly, found 2022-02-2800:00:00 format yyyy-MM-dd'T'HH:mm:ss
Issue2	Minor	t_Products	1	15	Extra Empty Header
Issue3	Minor	t_Availabilities	1	8	Extra Empty Header
Issue4	Minor	t_Unavailabilities	1	8	Extra Empty Header
Issue5	Minor	t_Shift_Segments	1	6	Extra Empty Header
Issue6	Major	t_Shift_Segments	1	1	TimeOnly not formatted correctly, found 1.000000, format Hm:ss
Issue7	Major	t_Shift_Segments	1	2	TimeOnly not formatted correctly, found 1.000000, format Hm:ss
Issue8	Major	t_Shift_Segments	2	1	TimeOnly not formatted correctly, found 1.291667, format Hm:ss
Issue9	Major	t_Shift_Segments	2	2	TimeOnly not formatted correctly, found 1.320303, format Hm:ss
Issue10	Major	t_Shift_Segments	3	1	TimeOnly not formatted correctly, found 1.459333, format Hm:ss
Issue11	Major	t_Shift_Segments	3	2	TimeOnly not formatted correctly, found 1.479167, format Hm:ss
Issue12	Major	t_Shift_Segments	4	1	TimeOnly not formatted correctly, found 1.583333, format Hm:ss
Issue13	Major	t_Shift_Segments	4	2	TimeOnly not formatted correctly, found 1.916667, format Hm:ss
Issue14	Major	t_Shift_Segments	5	1	TimeOnly not formatted correctly, found 1.666667, format Hm:ss
Issue15	Major	t_Shift_Segments	5	2	TimeOnly not formatted correctly, found 1.677083, format Hm:ss
Issue16	Major	t_Shift_Segments	6	1	TimeOnly not formatted correctly, found 1.770833, format Hm:ss
Issue17	Major	t_Shift_Segments	6	2	TimeOnly not formatted correctly, found 1.791667, format Hm:ss
Issue18	Major	t_Shift_Segments	7	1	TimeOnly not formatted correctly, found 1.916667, format Hm:ss
Issue19	Major	t_Shift_Segments	7	2	TimeOnly not formatted correctly, found 1.250000, format Hm:ss
Issue20	Major	t_Shift_Segments	8	1	TimeOnly not formatted correctly, found 1.000000, format Hm:ss
Issue21	Major	t_Shift_Segments	8	2	TimeOnly not formatted correctly, found 0.010417, format Hm:ss
Issue22	Major	t_Shift_Segments	9	1	TimeOnly not formatted correctly, found 1.083333, format Hm:ss
Issue23	Major	t_Shift_Segments	9	2	TimeOnly not formatted correctly, found 1.04167, format Hm:ss
Issue24	Minor	t_Shift_Segments	10	0	First Column Empty
Issue25	Minor	t_Shift_Segments	11	0	First Column Empty
Issue26	Minor	t_Shift_Segments	12	0	First Column Empty
Issue27	Minor	t_Shift_Segments	13	0	First Column Empty
Issue28	Minor	t_Shift_Segments	14	0	First Column Empty
Issue29	Minor	t_Shift_Segments	15	0	First Column Empty
Issue30	Minor	t_Shift_Segments	16	0	First Column Empty
Issue31	Minor	t_Shift_Segments	17	0	First Column Empty
Issue32	Minor	t_Shift_Segments	18	0	First Column Empty
Issue33	Minor	t_Shift_Patterns	1	9	Extra Empty Header
Issue34	Minor	t_Shift_Patterns	7	0	First Column Empty
Issue35	Minor	t_Shift_Patterns	8	0	First Column Empty

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# Domain Model - Knowledge Graph



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



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# 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

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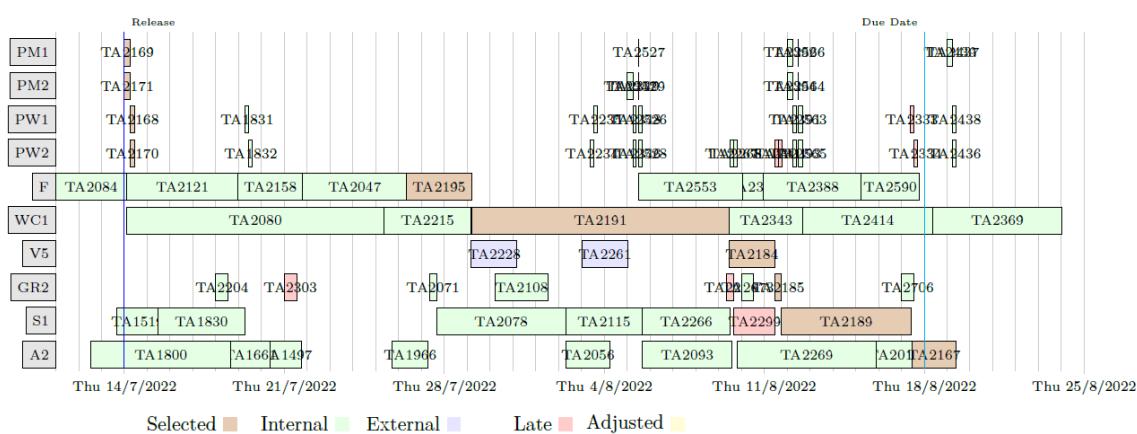
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## Explaining Late Delivery



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



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## 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

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## 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

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Slide 16

# Summary



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