

# ASSISTANT SE Case Study

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## Constraint Based Production Scheduling

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# Acknowledgments



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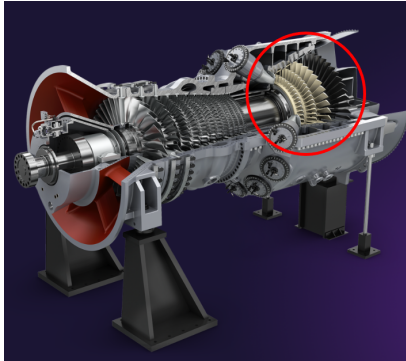
Part of this work is based on research conducted within the ASSISTANT European project, under the framework program Horizon 2020, ICT-38-2020, Artificial intelligence for manufacturing, grant agreement number 101000165.

# 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



## Use Case Scenarios

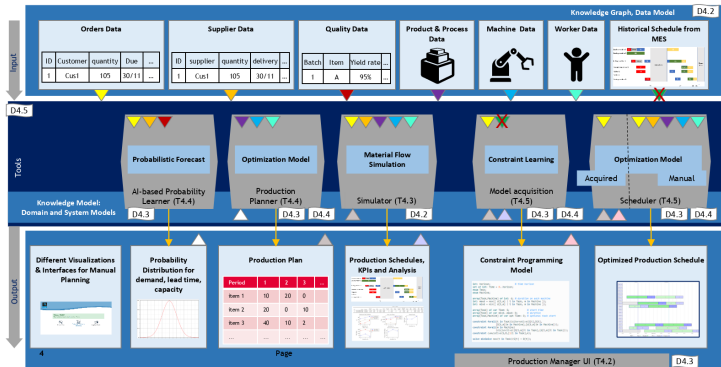
- Schedule *validation* of gas turbine blades and vanes manufacturing operations in Berlin plant
- Schedule *optimization* to manage short-term, mid-term and long-term load fluctuations
- Generate *Make-or-Buy proposals* for workload balancing within the manufacturing network

# ASSISTANT Project Overview

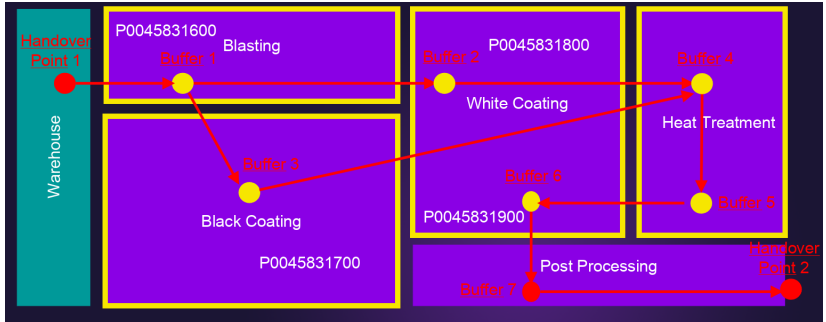


## Intelligent digital twin for process planning and scheduling

ASSISTANT



# SE Product Routing



# Test Datasets



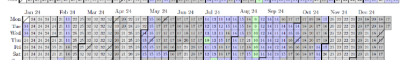
## Full Scale Datasets

Berlin06: 96 orders, 9 months horizon, previous review

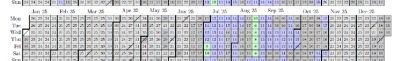
Berlin07: 450 orders, 4 years horizon

Berlin08: 559 orders, Christmas gap added

Berlin08a: 670 orders, filling gaps

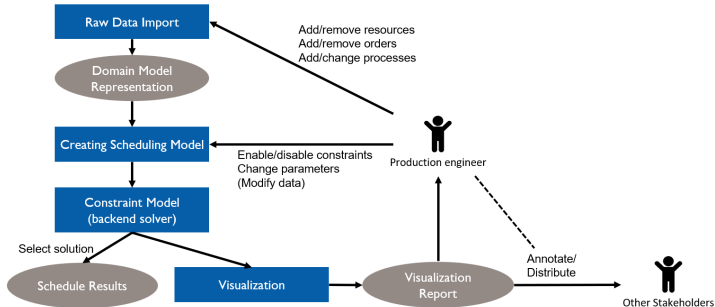


Value in cell indicates active orders  
Yellow and red colors indicate low order volume





# 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

ASSTANT Project Services Energy Use Case - Insight SFI Centre for Data Analytics

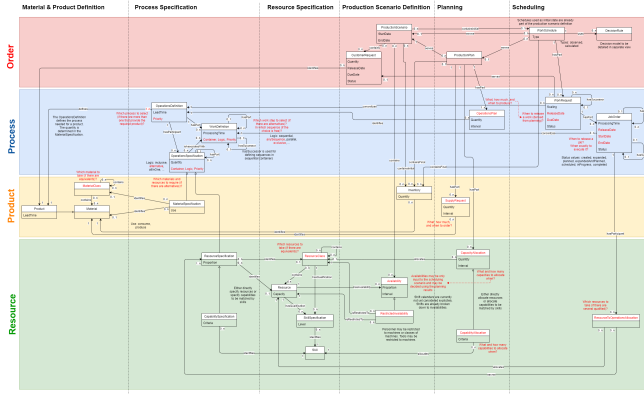
File Edit Scenarios View Window Help

Worksheet: X

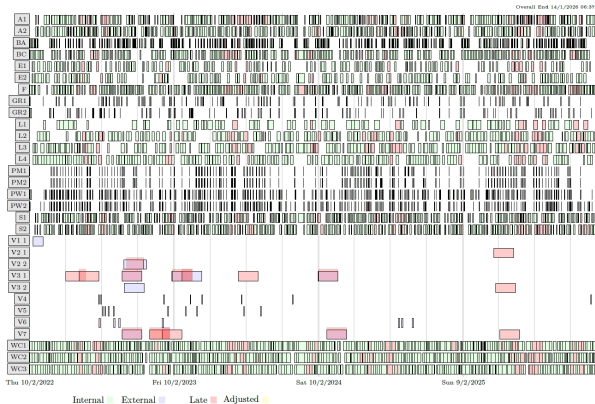
Name	Severity	Sheet	Row#	Col#	Description
Issue1	Major	L_Load	129	11	DateTime not formatted correctly, found 2022-02-2000000000 format yyyy-MM-ddTHH:mm:ss
Issue2	Minor	L_Products	1	15	Extra Empty Header
Issue3	Minor	L_Availability	1	8	Extra Empty Header
Issue4	Minor	L_Unavailability	1	8	Extra Empty Header
Issue5	Minor	L_SHH_Segments	1	8	Extra Empty Header
Issue6	Major	L_SHH_Segments	1	1	TimeOnly not formatted correctly, found 0.220000, format H:mm:ss
Issue7	Major	L_SHH_Segments	1	2	TimeOnly not formatted correctly, found 0.001233, format H:mm:ss
Issue8	Major	L_SHH_Segments	2	1	TimeOnly not formatted correctly, found 0.291967, format H:mm:ss
Issue9	Major	L_SHH_Segments	2	2	TimeOnly not formatted correctly, found 0.502051, format H:mm:ss
Issue10	Major	L_SHH_Segments	3	1	TimeOnly not formatted correctly, found 0.458233, format H:mm:ss
Issue11	Major	L_SHH_Segments	3	2	TimeOnly not formatted correctly, found 0.470967, format H:mm:ss
Issue12	Major	L_SHH_Segments	4	1	TimeOnly not formatted correctly, found 0.581933, format H:mm:ss
Issue13	Major	L_SHH_Segments	4	2	TimeOnly not formatted correctly, found 0.591967, format H:mm:ss
Issue14	Major	L_SHH_Segments	5	1	TimeOnly not formatted correctly, found 0.686967, format H:mm:ss
Issue15	Major	L_SHH_Segments	5	2	TimeOnly not formatted correctly, found 0.677000, format H:mm:ss
Issue16	Major	L_SHH_Segments	6	1	TimeOnly not formatted correctly, found 0.770833, format H:mm:ss
Issue17	Major	L_SHH_Segments	8	2	TimeOnly not formatted correctly, found 0.791967, format H:mm:ss
Issue18	Major	L_SHH_Segments	7	1	TimeOnly not formatted correctly, found 0.596967, format H:mm:ss
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Issue20	Major	L_SHH_Segments	8	1	TimeOnly not formatted correctly, found 0.000000, format H:mm:ss
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Issue22	Major	L_SHH_Segments	9	1	TimeOnly not formatted correctly, found 0.081233, format H:mm:ss
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Issue25	Minor	L_SHH_Segments	12	0	First Column Empty
Issue26	Minor	L_SHH_Segments	13	0	First Column Empty
Issue27	Minor	L_SHH_Segments	14	0	First Column Empty
Issue28	Minor	L_SHH_Segments	15	0	First Column Empty
Issue29	Minor	L_SHH_Segments	16	0	First Column Empty
Issue30	Minor	L_SHH_Segments	17	0	First Column Empty
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Issue33	Minor	L_SHH_Patterns	7	0	First Column Empty
Issue34	Minor	L_SHH_Patterns	8	0	First Column Empty

Filter

# Domain Model - Knowledge Graph



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



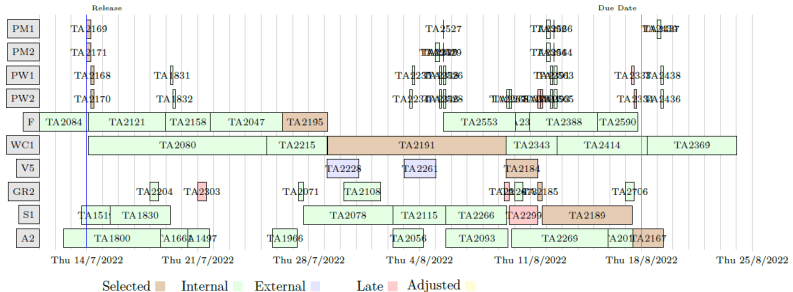


- Requirement capture done inside project
- Data checking/cleaning most time consuming aspect
- Some specified functionality was rejected by Betriebsrat
- Built in Java
- Uses IBM's CPOptimizer back-end
- 120k LoC, 110k generated, 3k solver
- Outperforms both
  - Current in-house tool
  - Simulation 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





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