Simulative Comparison of Scheduling at Krones AG with Shortest Slack

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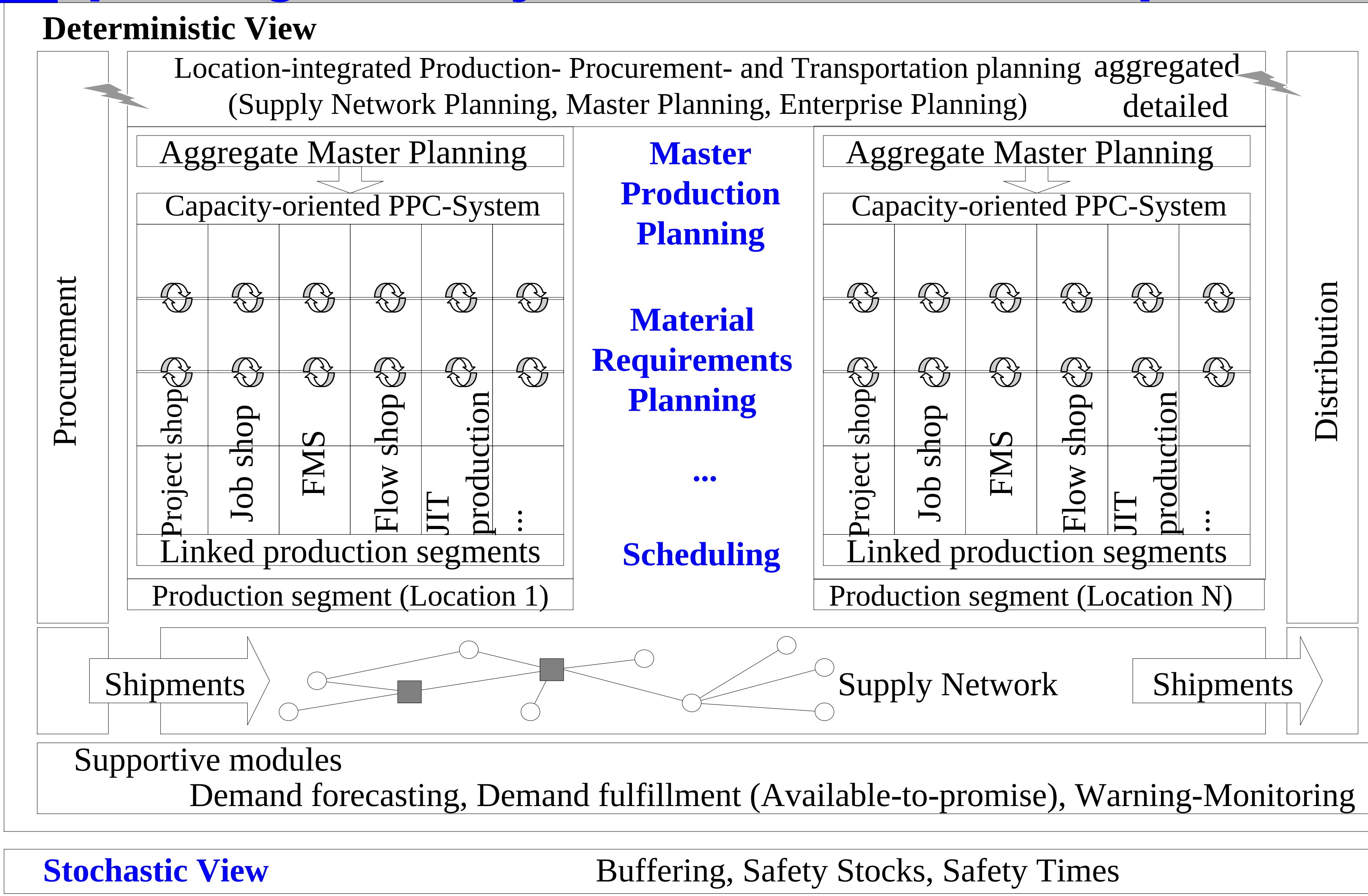
Special Track: Simulation and Modelling in Supply Chains, along with 13th International Conference on Advances in System Simulation, SIMUL 2021, October 03 – 07, 2021 in Barcelona, Spain.

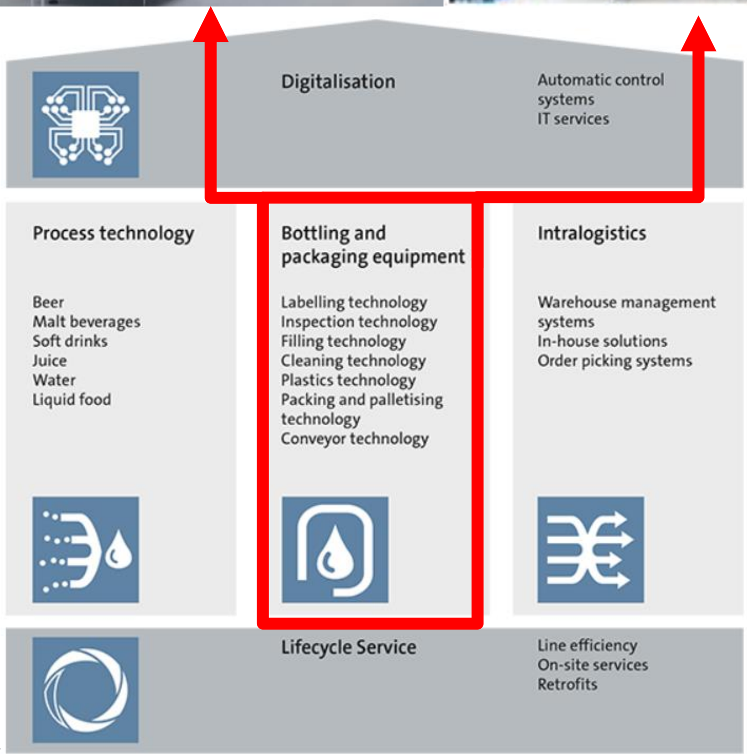
Improvement of procedures and parameters for planning in ERP systems used in industrial practice



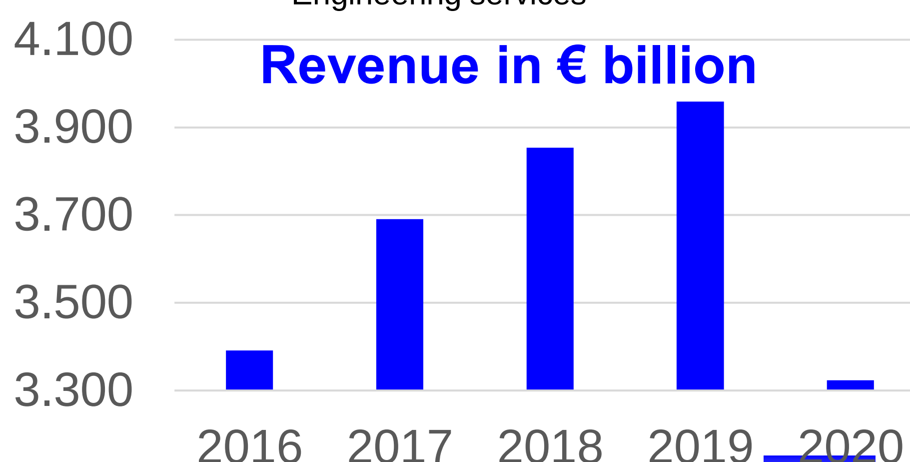
Krones AG

Krones introduction

Krones bottling machines in customer production (left) and manufacturing (right)



- **Founded in Neutraubling 1951 by Dr. Hermann Kronseder**
- **Full-range supplier for the complete value chain of**
  - Beverage industry and
  - Liquid food industry solutions
- **Machines and Machine lines for the**
  - Process technology
  - Bottling and Filling technology
  - Packaging technology and packaging equipment technology
  - Planning of complete factories
- **Further products of the Krones subsidiaries**
  - Intralogistics solutions
  - Used machines
  - Engineering services



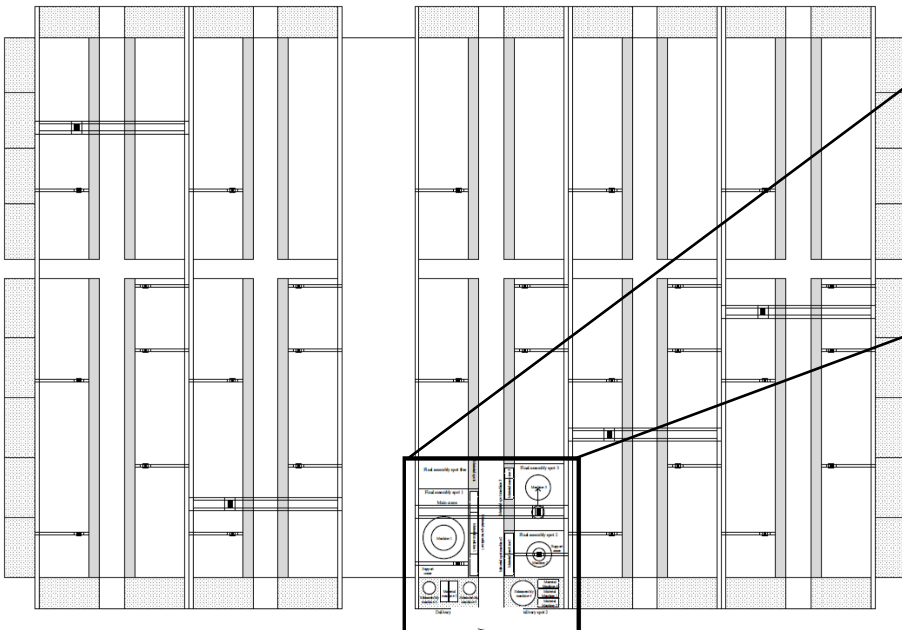
Dynamic line planning and scheduling

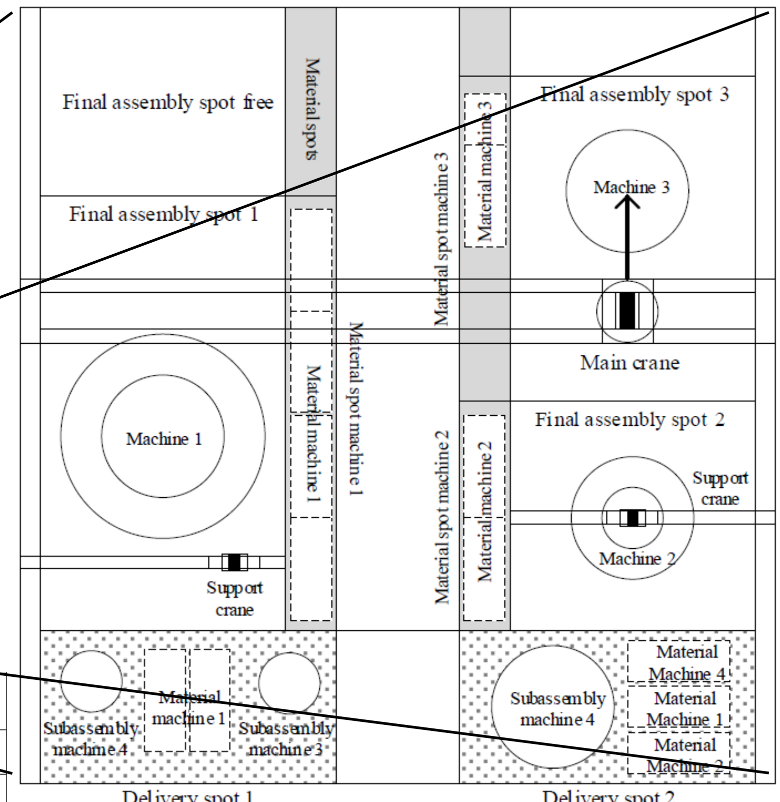
- Krones is still growing by revenue and employees since foundation 1951.
- No expansion possible in Neutraubling: very limited space.
- **Very large plants with diameters up to 7.2 m in large assembly hall.**

Assembly Hall

Dynamic layout planning and scheduling under strong technological restrictions

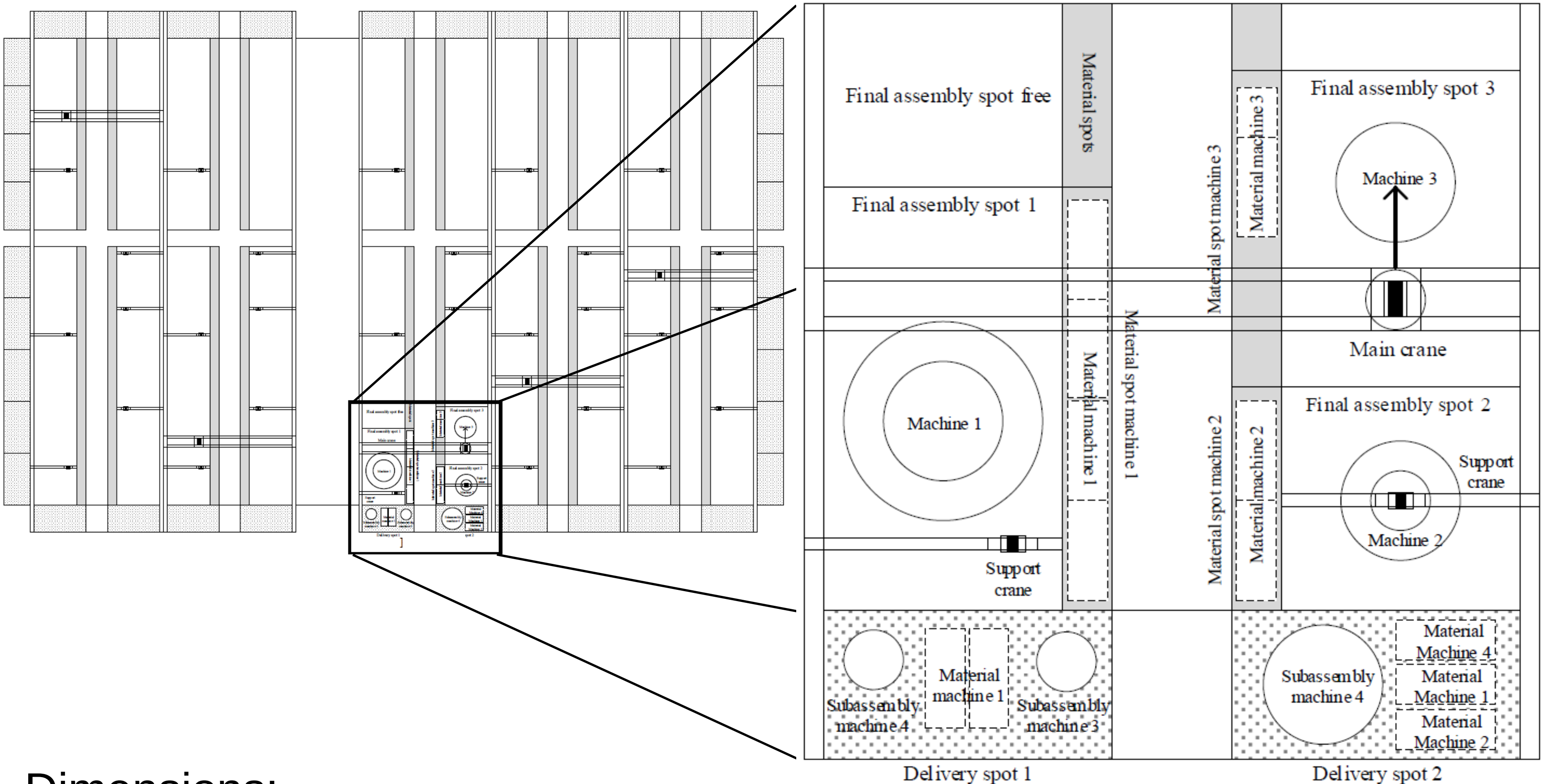
Planning problem: A lot of machines are manufactured in an assembly shop in the same hall and time.





	2017-01	2017-02	2017-03	2017-04	2017-05	2017-06	2017-07	2017-08	2017-09	2017-10	2017-11	2017-12	Ø
Built Machines	64	106	68	56	62	41	38	61	53	75	89	98	68
Final Assembly Spots [m²]	89%	148%	113%	69%	74%	50%	49%	94%	76%	103%	102%	165%	94%
Material Spots [m²]	89%	147%	116%	69%	74%	52%	49%	91%	76%	103%	103%	165%	95%
Delivery Spots [m²]	92%	152%	111%	71%	77%	53%	50%	96%	78%	97%	109%	158%	95%
Total Space [m²]	90%	149%	113%	70%	75%	51%	49%	94%	76%	102%	103%	164%	95%

Assembly Hall - Hall 5



Dimensions:

105 m x 30 m = 2208 m² (usable).

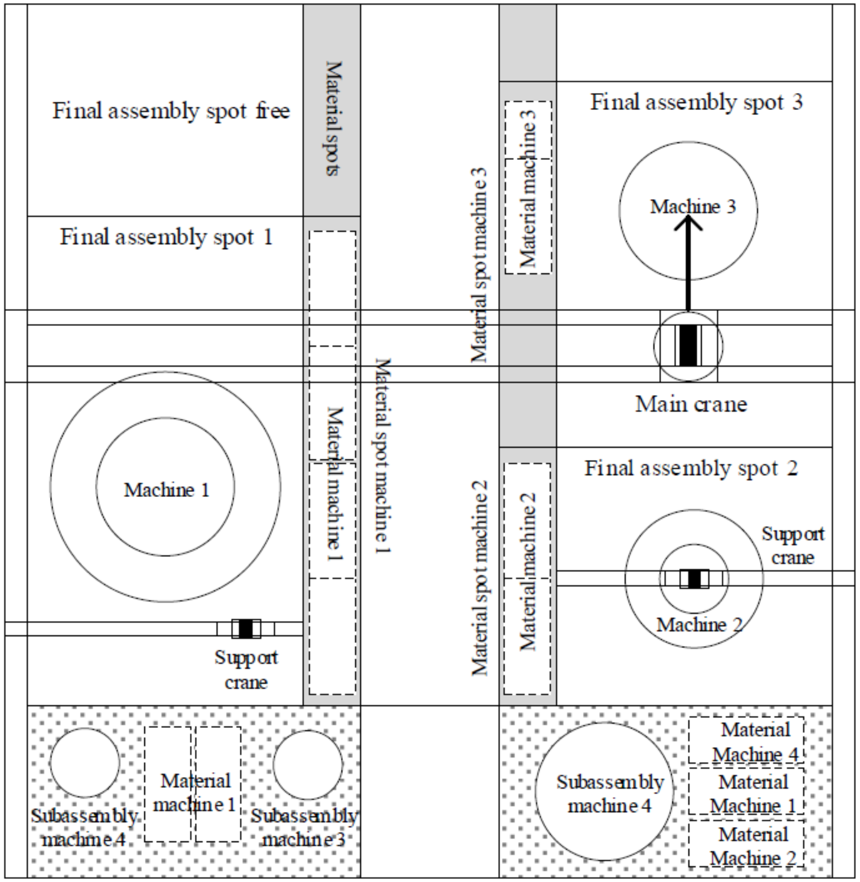
1 machine at a time enter/leave

load in the plant hall: enough space.

Representative for the entire plant:

3 fillers are to be assembled.

Hall 5

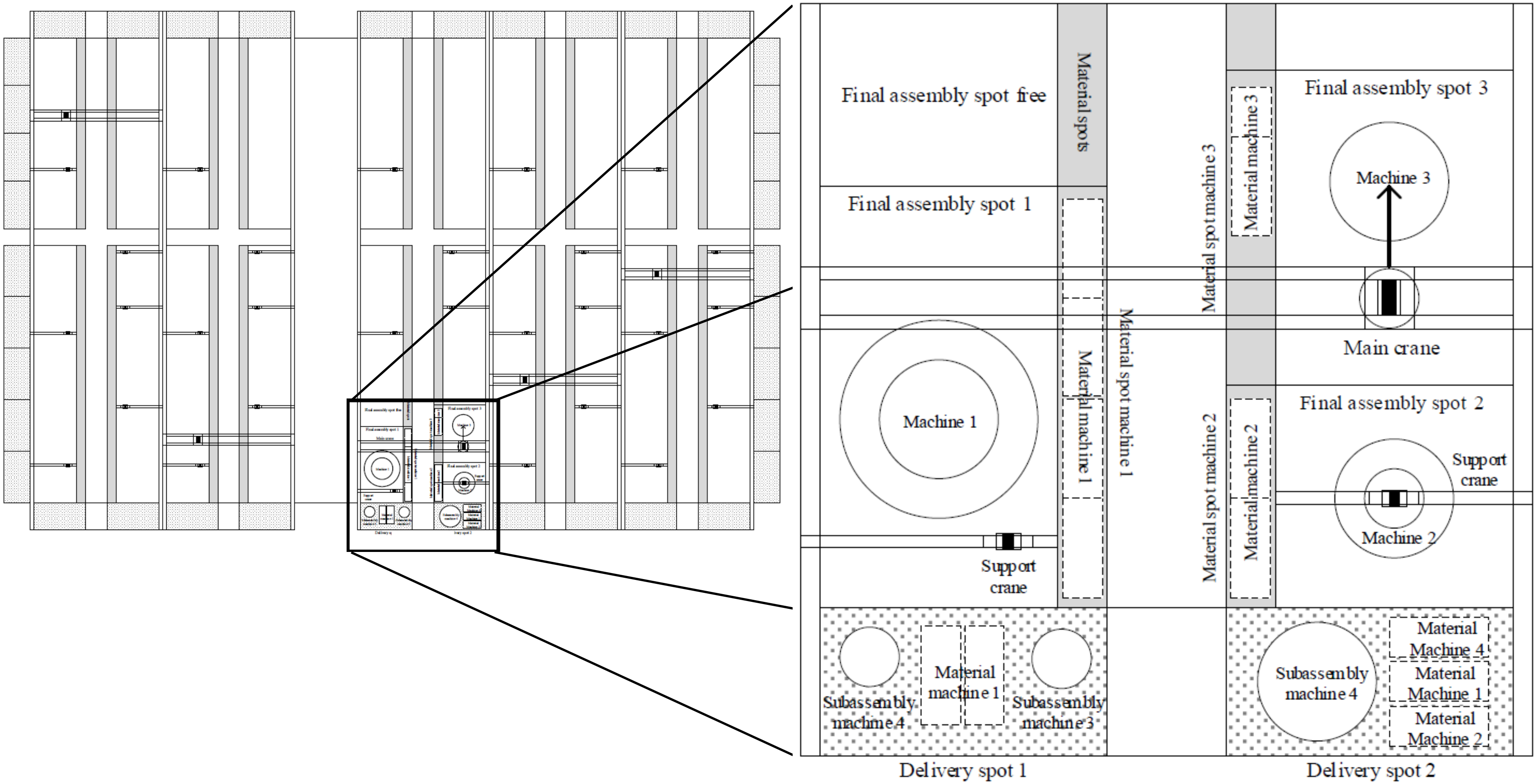


Delivery outdoor spot, limited space, all sub-assembly parts and materials of all machines & to mix materials from various machines and sub-assemblies.
Machine-specific storage space, indoor-spot

Transportation :
main crane: due to design a./o. weight.
trolleys or bins: auxiliary crane

Leaving hall: Main crane.
No blocking of cranes.

Hall 5

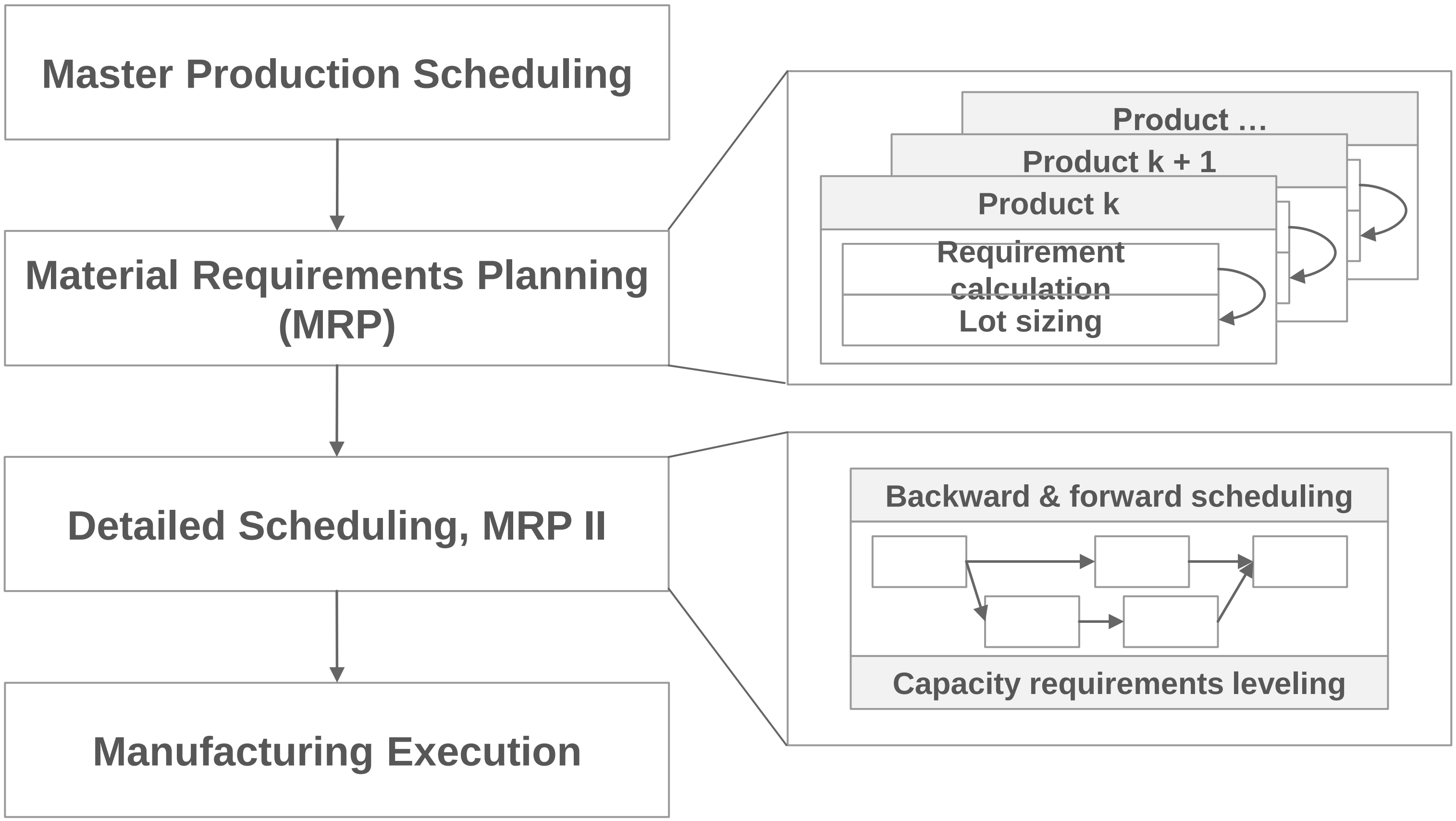


2020: Assembly of 145 machines
– more in future.

Processing time: 6 - 19 weeks; mean: 10.24 weeks & deviation of 2.5 weeks.

Leave: end of week

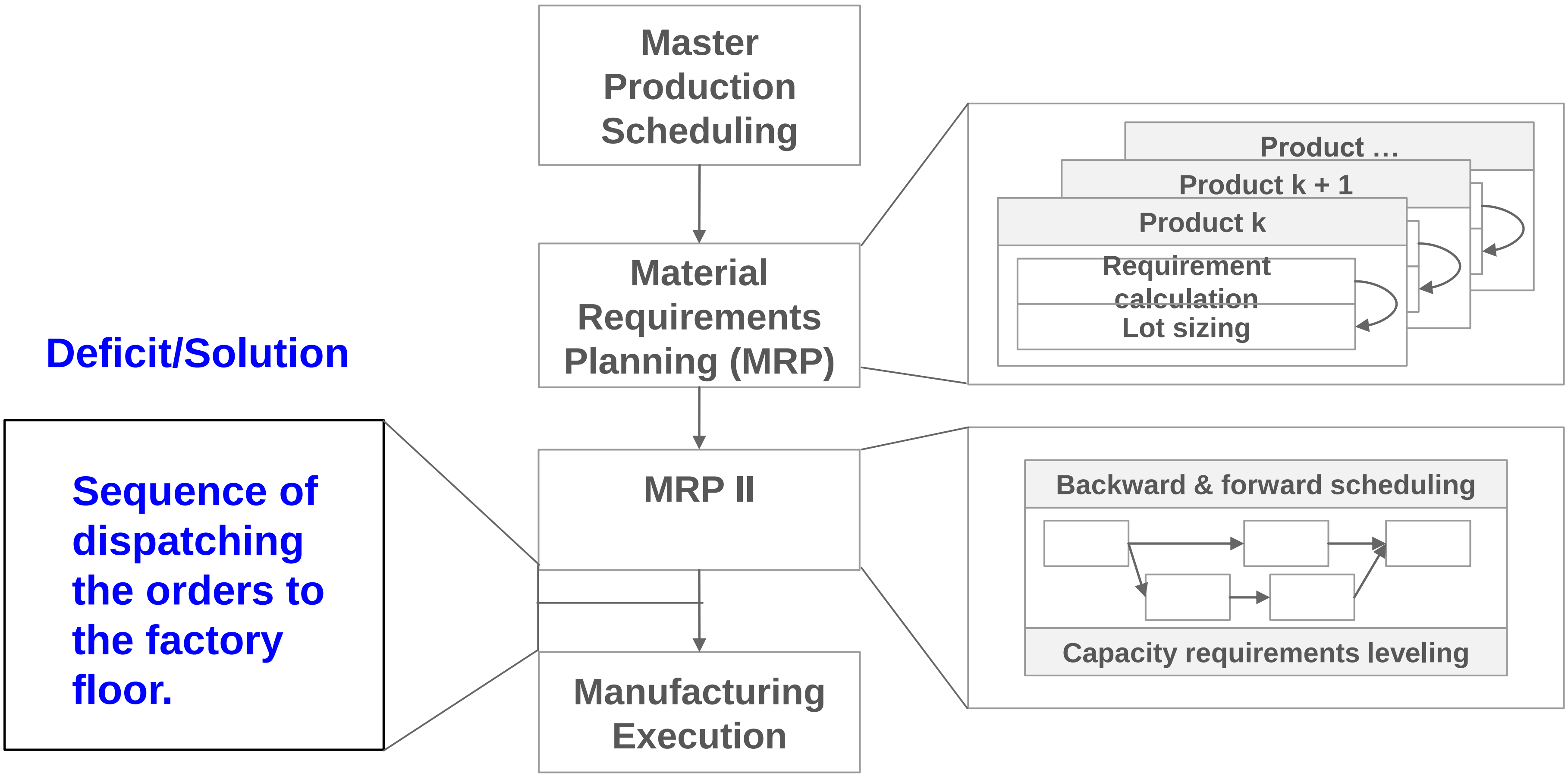
Hierarchical production planning in the SAP® ERP system



Main service: ensuring the availability of materials.
Results: Unordered orders per day.

Planung bei der Krones AG 1/2

Hierarchical production planning in the SAP® ERP system



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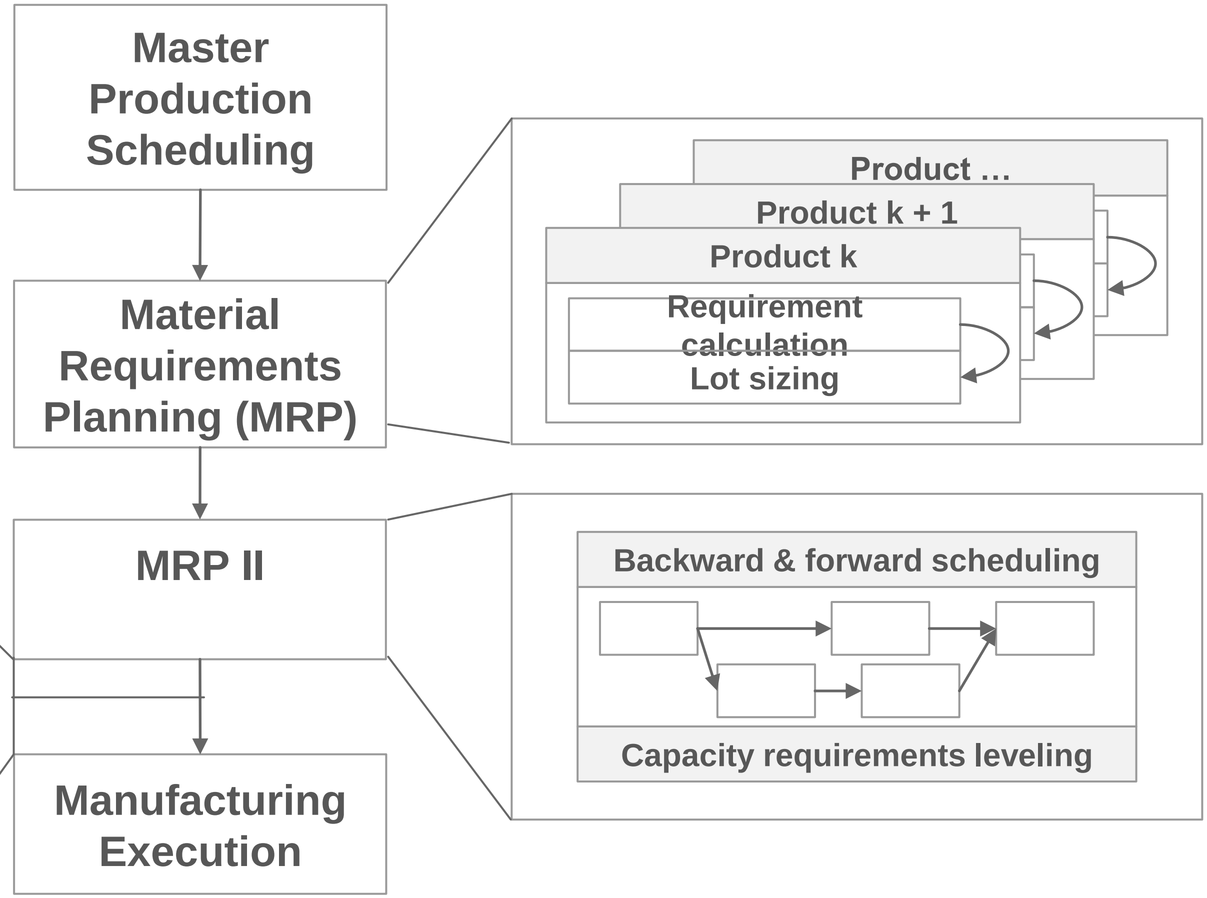
Planung bei der Krones AG 1/2

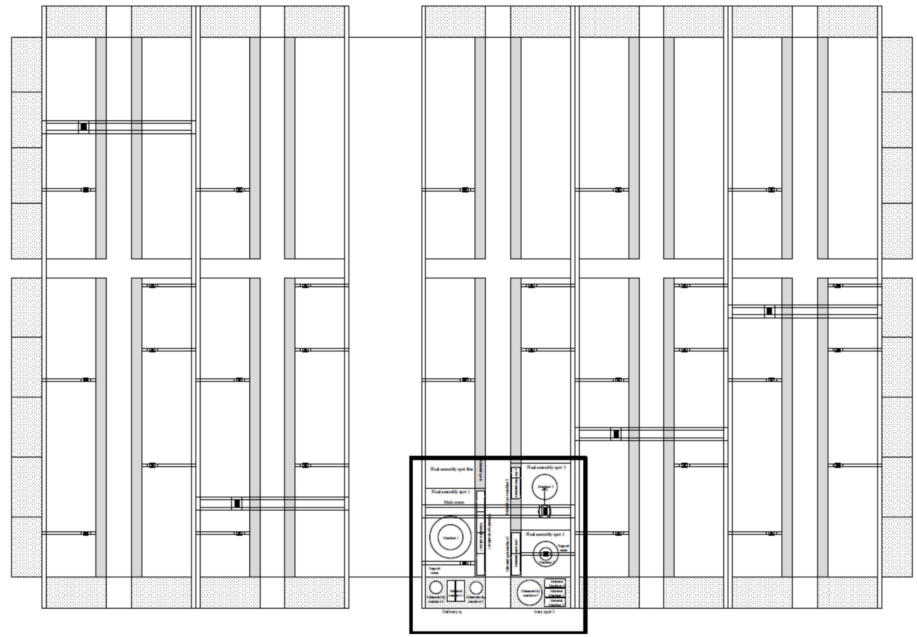
Hierarchical production planning in the SAP® ERP system



Planner: Order orders per week. Large area requirements / processing times compared to small ones. Smaller values easier to plan.

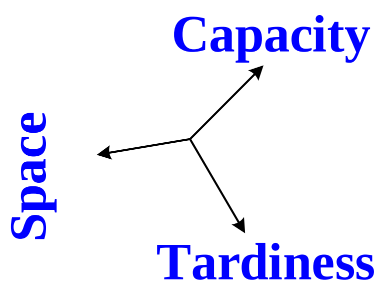
Main service: ensuring the availability of materials.
Results: Unordered orders per day.

Approaches and literature review



Hierarchical production planning in the SAP® ERP system

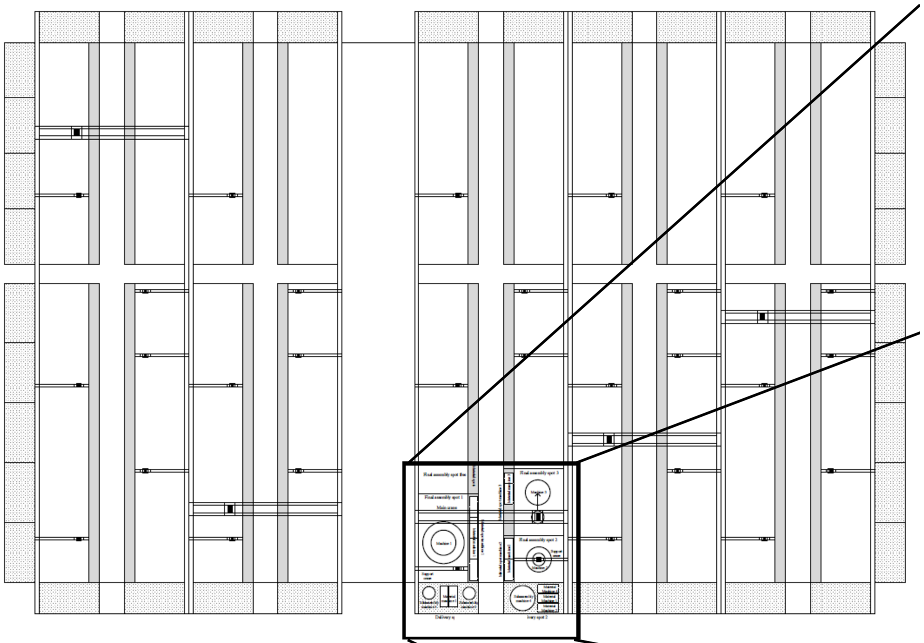
Sequence of loading orders into the factory hall

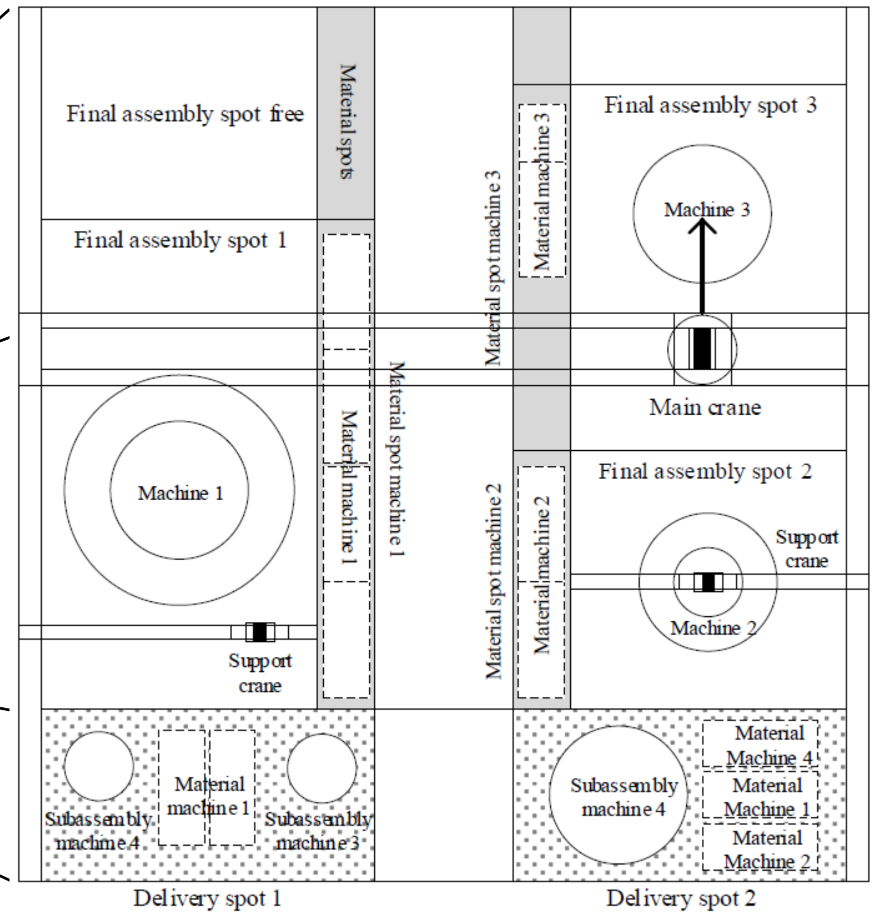


Mayer, G., Pöge, C., Spieckermann, S., & Wenzel, S. (2020). Ablaufsimulation in der Automobilindustrie. Springer Verlag.

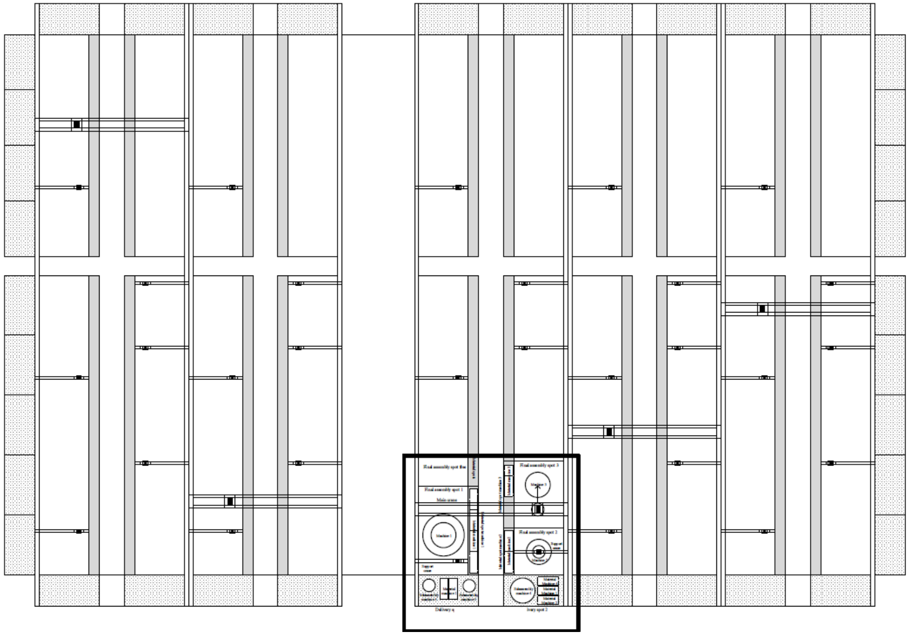
Pinedo, M. (2016). Scheduling: Theory, Algorithms and Systems, Fifth Edition. New York, USA: Springer Science+Business Media.

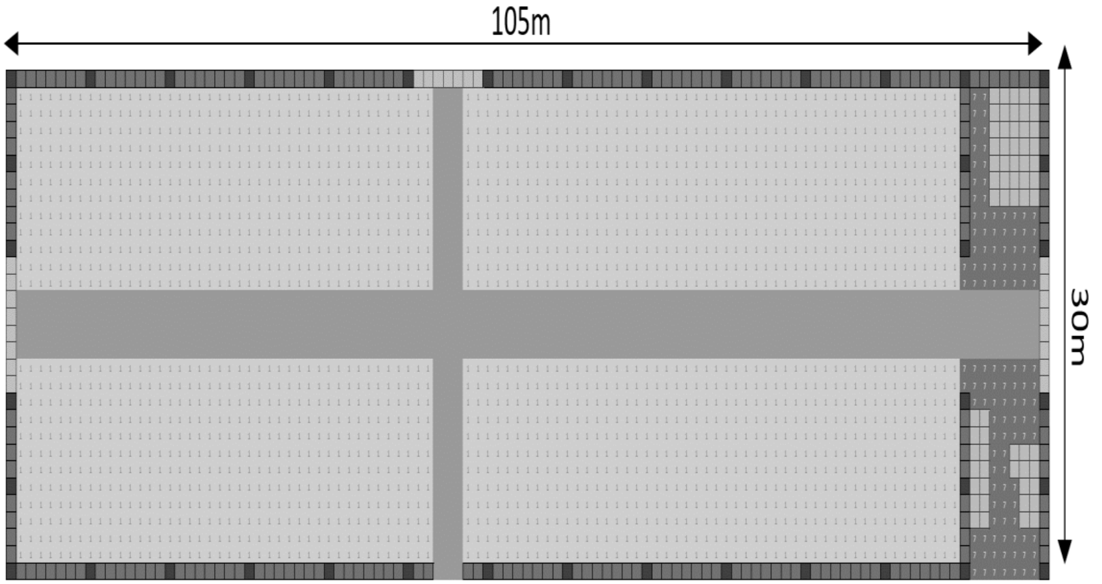
Y. Ge and A. Wang, “Spatial scheduling for irregularly shaped blocks in shipbuilding”, in Computers & Industrial Engineering Volume 152 Issue November 2020, p. 1–14, 2020.



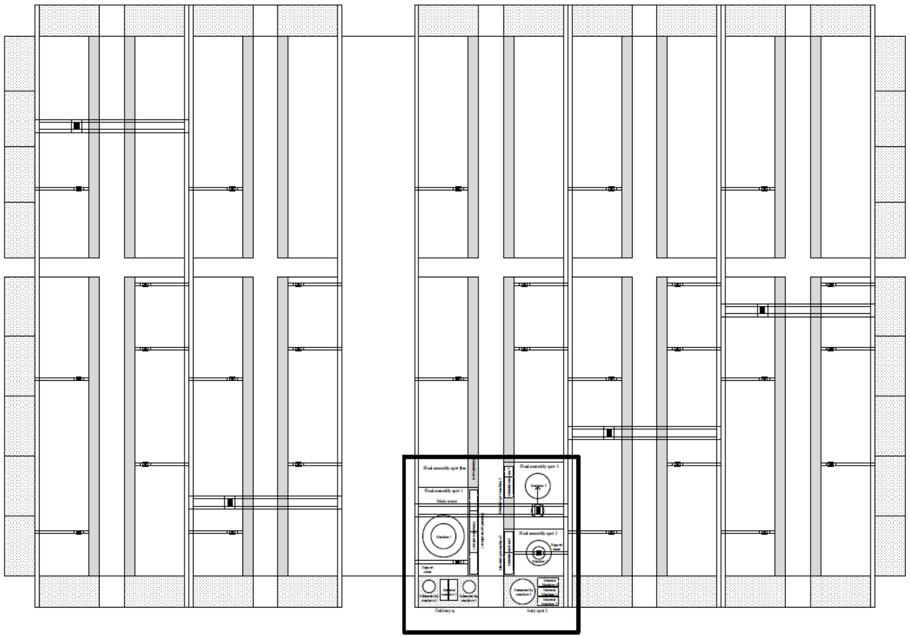


Sequence simulation of storage and retrieval as well as machining with all restrictions: Technomatix Plant Simulation.

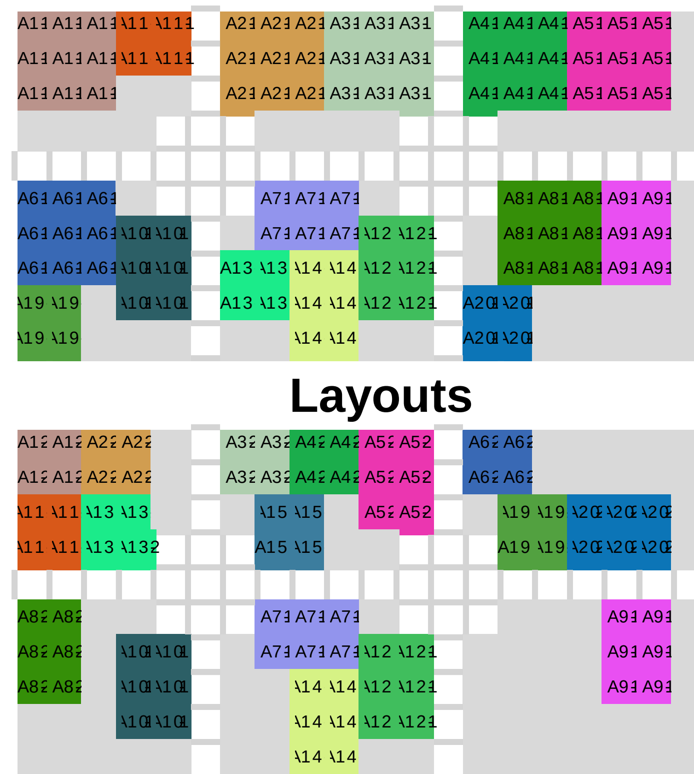




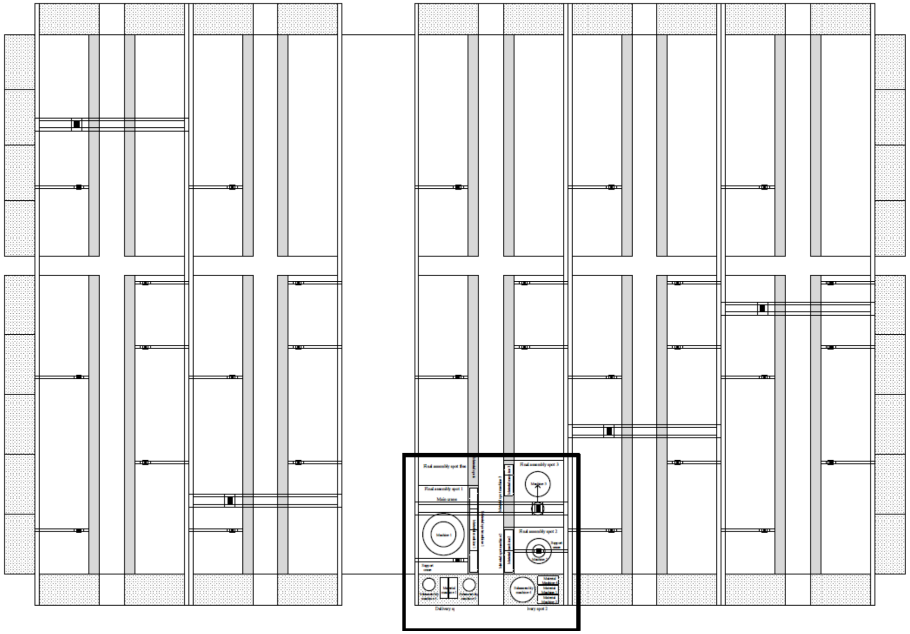
Needed: Occupancy of the area.

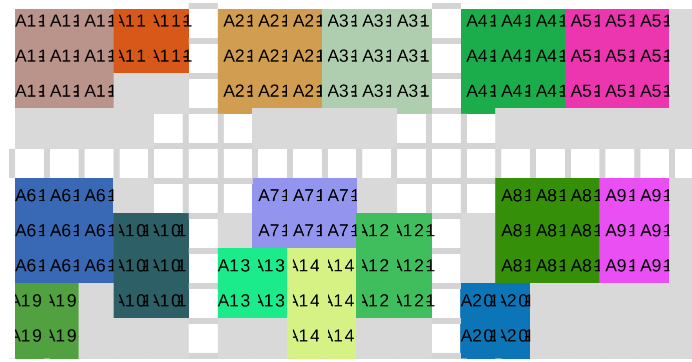


Simulation of the occupancy of the required area via Excel.

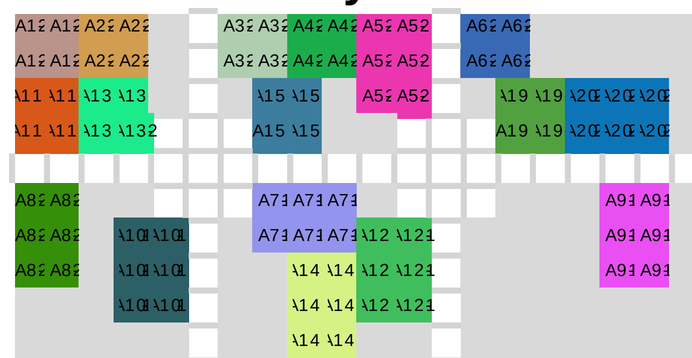


Code occupancy of 1 m^2 fields.



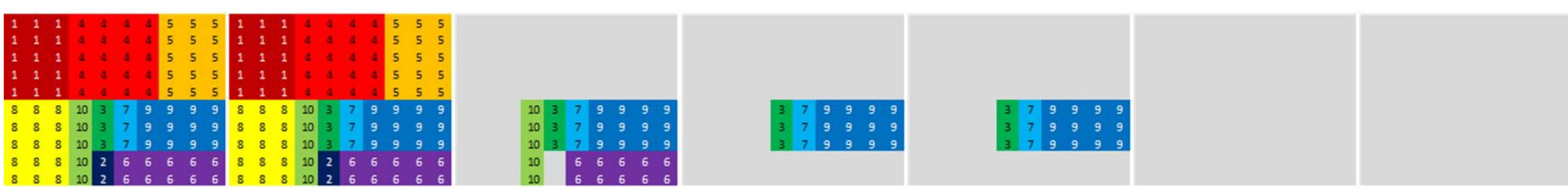


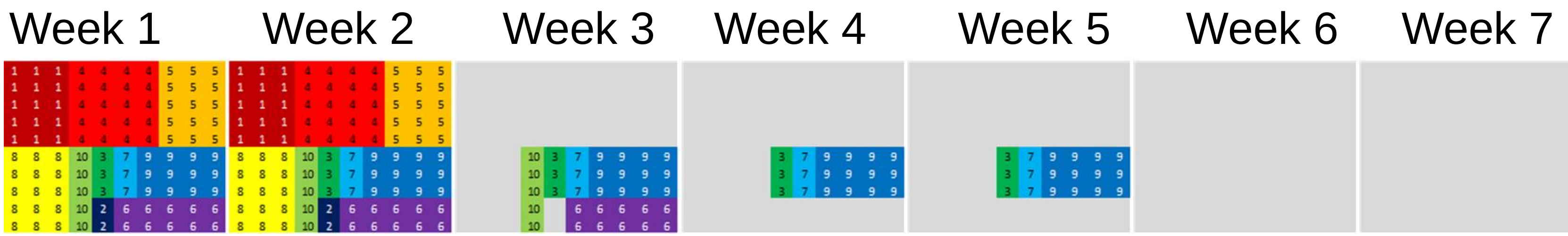
Layouts



Simulation of the occupancy of the required area over weeks / sheets in Excel.

Week 1 Week 2 Week 3 Week 4 Week 5 Week 6 Week 7





Example of a result of a simulated process.

Row ID [#]	Order ID [#]	Worklist [sequence]	Processing time [period]	Product [#]	Production hall [#]	Product width [unit]	Product length [unit]	Product rotation R090	Release date [period]	Due date [period]	Starting date [period]	End date [period]	Hall distance length [unit]	Hall distance width [unit]	Simulation time [second]
1001	1001	1001	14	1	1	12	12	N	1	5	1	14	2	2	1
1002	1002	1002	15	2	1	13	12	N	1	6	1	15	2	6	3
1003	1003	1003	13	3	1	10	12	N	1	5	1	13	2	10	1
1004	1004	1004	12	4	1	7	9	N	1	4	1	12	2	14	2
1005	1005	1005	12	5	1	7	9	N	1	4	1	12	2	23	2
1006	1006	1006	13	6	1	11	12	N	1	5	1	13	2	32	2
1007	1007	1007	12	7	1	7	9	N	1	5	1	12	2	36	2
1008	1008	1008	10	8	1	8	11	N	1	3	1	10	2	40	2

Basis: Order data from the year 2020.

→ Direct use: very high deviation of delay and occupied area.

→ No statistically significant results.

Reasons:

- Weeks: Final date - possible start time >> Net processing time

  → Final deadlines: easy to meet.

- vailable time versus net processing time ≈ 1 or < 1.

  → Delay: difficult to achieve or unavoidable.

low

high

Time pressure

2 classes of work loads.

Time pressure

low high

Workload	WL1	WL2
Number of orders	50	50
Processing time: minimum / maximum / mean / standard deviation in [weeks]	6 / 17 / 9.1 / 2.0	8 /19 /11.4 / 2.5
Product width: minimum / maximum / mean / standard deviation in [meter]	3 / 15 / 7.2 / 2.7	3 / 18 / 8.5 / 2.9
Product length: minimum / maximum / mean / standard deviation in [meter]	3 / 12 / 8.9 / 2.1	3 / 12 / 10.2 / 2
Due date: minimum / maximum / mean / standard deviation in [weeks]	11 / 23 / 14.3 / 2.8	11 / 23 / 14.3 / 2.8

Same key figures for the final deadlines.

Higher processing times in WL2: high due date pressure.

Required areas for the orders in WL2 somewhat higher than in WL1.

Simulation experiments – Results

Dispatching via Shortest Slack Time (slack)

	WL1		WL2	
	Planner	slack	Planner	slack
cumulative tardiness [weeks]				
mean	74.3	77.6	290.5	270
standard deviation	2.37	2.76	3.50	2.70
cumulative unused space [meter²]				
mean	20392	24808	29197	25885
standard deviation	1040.86	2753.86	2208	1104
total processing time in [weeks]				
mean	23.6	25.6	36	34.5
standard deviation	0.47	1.25	1.00	0.50
mean unused space per week [meter²]				
mean	861.09	963.55	809.95	749.98
standard deviation	27.21	61.69	38.83	21.13

High deadline pressure (generally: unclear quantity of orders): Planners prefer space requirements to deadline compliance options.
Conversely: better hall utilisation → faster processing of orders.

Summary and Outlook

Summary :

- Simulation of final assembly planning at Krones AG.
- Planning final assembly: simple priority rule better for planning situations with high time pressure.

Future investigations:

- Simultaneous planning of limited machine capacity and limited space.
- Literature: Two disjunctive problem classes.
- Development and simulation-based analysis of combinations of rules for meeting due dates with rules for avoiding unused space.