Computational Methods for Supply Chain Optimization

PD Dr. Timo Berthold
Director, Mixed-Integer Optimization

Dr. Jakob Witzig
AI & Optimization Algorithm Architect

Dr. Gregor Hendel
Senior Software Engineer

Who Are We?

Timo Berthold

- Master's (2006) and PhD (2014) at TU Berlin
- Working in Computational Optimization since 2005
  - SCIP developer until 2013
  - FICO Xpress Developer since 2014
  - Leading Mixed-Integer Optimization R&D team since 2023
- Habilitation and PD at TU Berlin in 2022
  - Teaching one course per year
  - Goal: Bring academic research and teaching together with industrial research and practices

Who Are We?

Jakob Witzig

- Student Assistant at ZIB (2010 – 2014)
- M.Sc. Mathematics (2014) and Ph.D. in Mathematics at TU Berlin / ZIB (2021)

- Developer SCIP until 2020
  - Restart mechanism with Branch-and-Bound
  - Heuristics
  - Conflict and dual proof analysis for MIP/MINLP

- Developer at SAP's SCM Optimization team (2020 – 2024)
- Leading Architect at SAP's SCM Optimization & Data Science team (since 2024

Who Are We?

Gregor Hendel

- Senior Engineer FICO Xpress Optimization (since 2020)
- Ph.D. in Mathematics at TU Berlin / ZIB (2021)
- M.Sc. Mathematics (2014)
- Student Assistant at ZIB (2009 – 2014)
- SCIP main developer until 2020
  - Adaptive solver behavior for mixed-integer programming

And You?

Optimization in
Digital Supply Chain

Dr. Jakob Witzig
AI & Optimization Algorithm Architect

Customers of SAP Optimization …

… produce more than 80% of the coffee and tea we drink each day.

… produce 75%+ of the world's beauty and fragrance products.

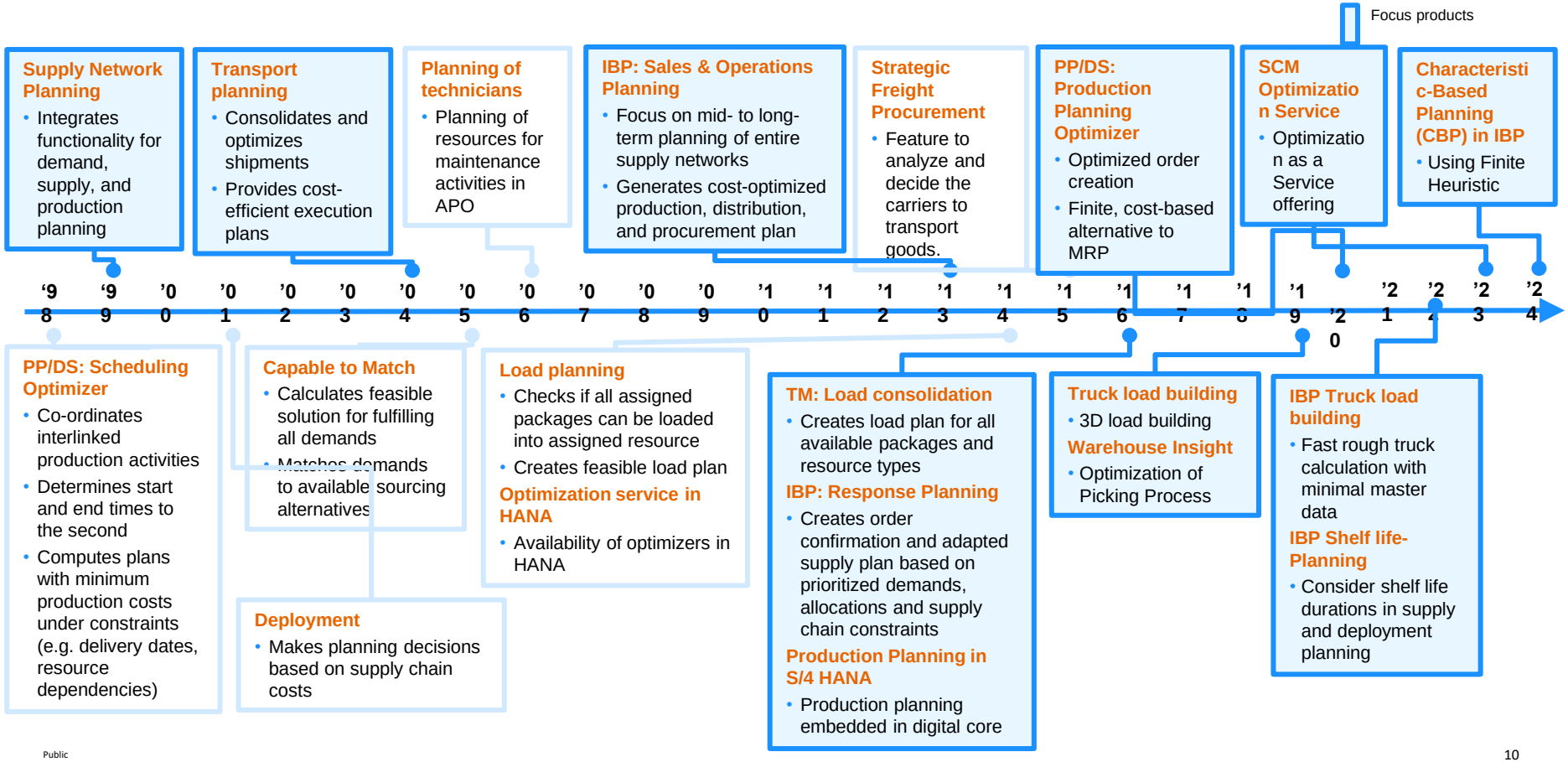
… produce more than 85% of the world's athletic footwear.

Customers of SAP Optimization …

… produce more than 77% of the world's beer.

Optimization
in SAP Digital Supply Chain

SAP has developed and delivered optimization solutions in SCM for 25+ years



Optimization @ Digital Supply Chain

Expertise

Customers

- ~2000 customers
- Different industries
- Optimization engines as standard software
- Included in cloud & on-premise solutions

Algorithms

- Linear and mixed-integer Programming
- Meta-Heuristics (Genetic Algorithms, Evolutionary local search,..)
- Integrated ML (data cleaning, parameter setting)
- Problem dictates algorithm (not the other way around)

Partners

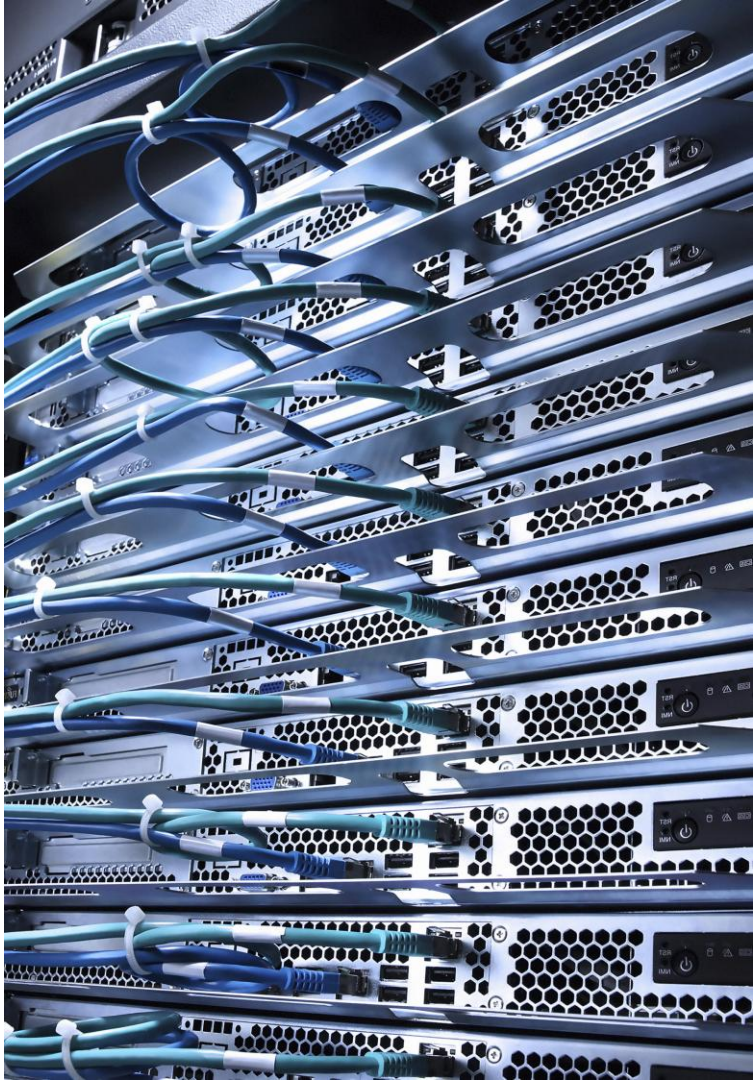
- Gurobi strategic optimization partnership
- Zuse Institute Berlin

Research

- Cooperation with TU Munich
- Research Campus MODAL
- >120 student theses

Optimization Team

- 80+ optimization and AI/ML experts
- Located in Walldorf, Munich, Budapest and Montral



Optimization @ Digital Supply Chain

Challenges

Features & Function

- Need to cover multitude of different requirements across wide range of industries
- Divergent perceptions on critical features across customer base
- Extensibility to support additional requirements, also in cloud-based solutions

Performance / Runtimes

- Wide range of model sizes with varying degrees of complexity
- Tight runtime windows
- Increasing model scope and complexity as supply chains grow and business models evolve

Usability

- Productive use requires robust, fail-safe models and limited specialized knowledge on customer side
- Customers expect explanation of optimization results

Service & Support

- Fast delivery of new features and corrections
- Up- and downwards compatibility to reduce maintenance effort
- Extremely high reliability requirements for cloud-based on on-premise solutions
- 24/7 tiered support model

Package Building Optimization

Scenario

Consolidation of product/packages to create pallets in order to minimize number of pallets

Algorithm

Meta Heuristic, Evolutionary Local Search

Remarks:

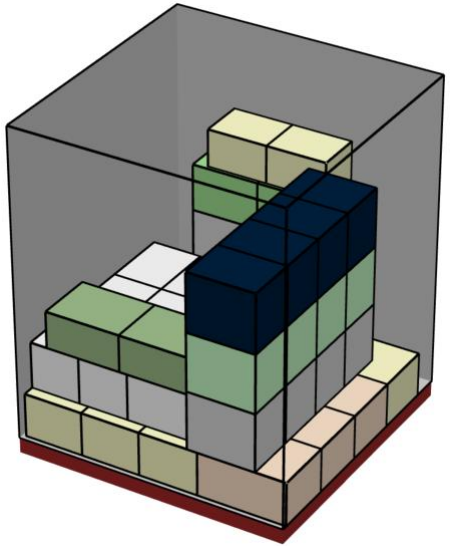
- Optimized pallet building
- Multi-level packaging
- Stackability matrix
- Incompatibilites (between products in mixed carton and in mixed pallet)
- Height, volume and weight constraints
- Orientation constraints of the products
- In combination with tour planning: cross-delivery packaging

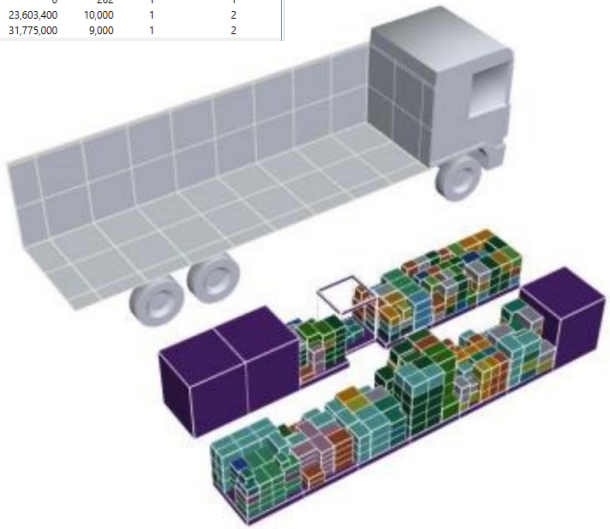
Package Building Optimization

Capacity list (1) | Used capacities tree (1)

Demand list (20 | 56)

ID	Product	Name	Count	Length (mm)	Width (mm)	Height (mm)	Vol sum (mm³)	Weight (g)	Priority	Stack matrix grp	Stack fac
958752	0	250 TETRA X24 F/	1	219	308	136	9,173,472	6,640	1	1	
953218	0	500 PET X12 B BR	1	292	222	191	12,381,384	7,390	1	1	
952352	0	500 PET X12 B BR	1	292	222	191	12,381,384	7,390	1	1	
957603	0	390 PET X24 FANT	10	381	256	191	186,293,760	10,280	1	1	
953555	0	14G BAG X100 GR	2	325	250	160	26,000,000	1,570	1	1	
953685	0	600 FLO X12 P/AL	5	292	222	254	82,326,480	8,130	1	1	
954300	0	600 FLO X12 PADI	1	292	222	254	16,465,296	7,660	1	1	
950200	0	500 PET X12 NTE/	11	292	216	203	140,839,776	6,890	1	1	
950188	0	500 PET X12 NTE/	4	292	216	203	51,214,464	6,890	1	1	
952096	0	500 PET X12 NEST	2	292	216	203	25,607,232	6,890	1	1	
957963	0	350 PET X12 NB V	2	262	200	164	17,187,200	5,530	1	1	
957342	0	390 PET X24 VANI	1	381	256	191	18,629,376	10,280	1	1	
957602	0	390 PET X24 DIET	3	381	256	191	55,888,128	9,900	1	1	
958589	0	1.0KG BAG X1 GR	0	140	90	250	0	1,025	1	1	
958666	0	600 FLO X12 P/AL	4	292	222	254	65,861,184	8,130	1	1	
958668	0	600 FLO X12 P/AL	6	292	222	254	98,791,776	8,130	1	1	
958786	0	1.0KG BAG X1 GR	0	95	60	220	0	1,000	1	1	
						80	0	262	1	1	
						32	23,603,400	10,000	1	2	
						10	31,775,000	9,000	1	2	





Questions?

Seminar Guidelines

General Concept

- One paper per person
  - Read, understand, be able to explain
- Three (and a half) parts
  - Short, introductory talk (~5min)
    - May/June
    - Few(!) slides or sketches for the blackboard
    - Pitch your topic: Explain a fellow student in 5min what your seminar topic is about
    - Not graded, main purpose: feedback
  - Summary of the paper (4-5 pages, LaTeX!)
    - Two weeks before final meeting, 30% of grade
    - Add own illustrations, examples where possible
    - Proper academic writing (citations!), consult secondary literature where necessary

General Concept

- [...]
- Three (and a half) parts
  - Short, introductory talk (~5min)
    - [...]
  - Summary of the paper (5 pages, LaTeX!)
    - [...]
  - Final talk (30min presentation, 10min questions)
    - 17/18/22 July, 60% of grade
    - Slides, examples/pictures
    - Explain notation, don‘t overload slides
    - Target audience: Non-expert mathematician
  - Review (0.5-1 page)
    - Two weeks before the final meeting, 10% of grade
    - Your assessment of the paper: What was good, what was bad, what was missing?

Questions?

Choose a paper ☺

Paper selection

- Optimal planning in large multi-site production networks Naveed JW
- Production Scheduling and Rescheduling with Genetic Algorithms Sebastian GH
- A general heuristic for production planning problems Avaneesh GH
- MIP presolve techniques for a PDE-based supply chain model
- Tackling Industrial-Scale Supply Chain Problems by Mixed-Integer Programming Payel TB
- Modelling Practical Lot-Sizing Problems as Mixed-Integer Programs Onat TB
- Constrained Local Search for Last-Mile Routing Fabian JW
- Recent Advances in Mathematical Programming with Semi-continuous Variables and Cardinality Constraint Allan TB
- Heuristic algorithms for the three-dimensional bin packing problem Jan-Erik TB
- On alternative mixed integer programming formulations and LP-based heuristics for lot-sizing with setup times Alex GH
- MIP-based constructive heuristics for the three-dimensional Bin Packing Problem with transportation constraints Rei JW
- A genetic algorithm approach for multi-objective optimization of supply chain networks Anna JW

Dates

Paper selection

- July 17: full day 9-18 presentations
- July 3: deadline for summary/review submission
- June 2 4-6pm: 5min pitch

Thank You!