

| Optimization @ Siemens

Research Group ORD (Operations Research for Decision Support)

Siemens Technology

Dr. Petra Bauer, Senior Key Expert Discrete Optimization

A Glance at Siemens

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My Background

University

Diploma in Mathematics / Computer Science, University of Augsburg, Germany (Prof. Grötschel)

PhD in Computer Science, focus: Integer Linear Programming, University of Cologne, Germany (Prof. Jünger)

PostDoc at the Georgia Institute of Technology, Atlanta, USA, studies in Integer Linear Programming (Prof. Nemhauser)

Siemens

Member of the Discrete Optimization / Operations Research Group since 1995

Main Projects:

- 1995 - 2009 Optimization for Printed Circuit Board Assembly (Siplace Machines / Lines / Production Sites)
- 2009 - 2012 **SUNNY – Tool for Optimized Layout of Large Photovoltaic Power Plants**
- 2012 - 2020 **SiMobility JustGo: Next Generation Ticketing**
- 2021 - Production Planning and Scheduling

A Glance at Siemens

Businesses and Services of Siemens AG

320,000

people worldwide work for Siemens¹

Industrial Business

Digital Industries



Smart Infrastructure



Mobility



Siemens Healthineers¹



Portfolio Companies



Siemens Advanta



Services

Siemens Financial Services



Siemens Real Estate



Global Business Services



¹ Publicly listed subsidiary of Siemens; Siemens' share in Siemens Healthineers is 75%

Research and Development at Siemens



€ 6.2 bn

Expenditures for R&D¹



50,000

R&D employees

**Inventions and patents –
Securing our future**



5,400

Inventions¹



2,900

Patent applications¹



Global research collaborations

16

Siemens Research and
Innovation Ecosystems

Technology (T)



2,150

Employees worldwide



1,755

Researchers

**Data Analytics &
Artificial Intelligence
(T DAI)**

> 235

Researchers

**Operations Research
& Decision Support
(T DAI ORD-DE)**

15

Researchers

¹ FY23

Our Work

Mission and Competences

Mission



Design and development of **tailored** optimization **algorithms** and software **solutions**.



Direct value creation for our company-internal customers and their end-customers.

Technologies



Mathematics

- (Non-)Linear & Mixed Integer Programming
- Graph Theory
- Discrete, Combinatorial & Stochastic Optimization



Software development competence

- Object Oriented Programming (C#, Java, Python, ..)
- Software Engineering (continuous Integration and deployment, testing, containerization, container orchestration ...)
- Software Architecture
- UI Development (TypeScript, Vue.js, Vuetify, ...)
- Cloud Services
- ...

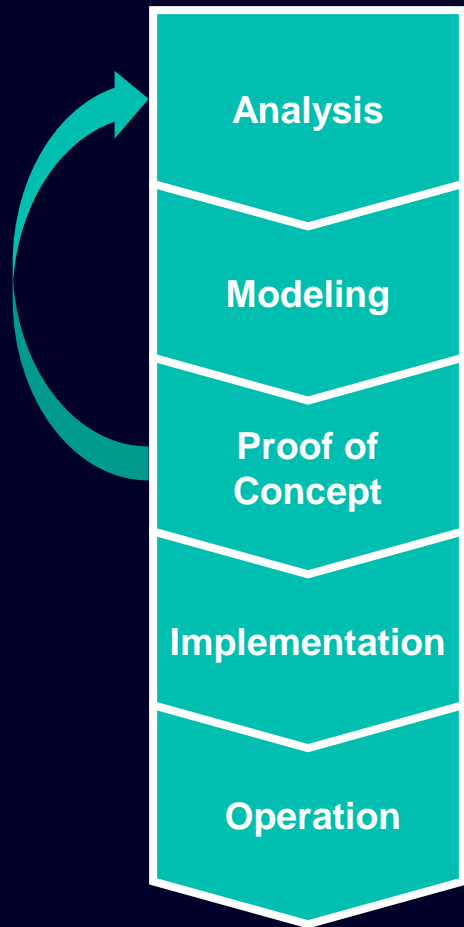


Tooling (Assets)

- tools that support rapid prototyping and development / deployment of productive solvers (model driven development)

Customized Decision Support Tools with Mathematical Optimization

Typical phases of the development process



- Detailed analysis of the real-world problem
 - Which decision should be automated?
 - Which solutions are feasible, which preferable?
- Transformation of the problem into mathematics
- Fast development of prototypes
 - Come up with calculated results quickly
 - Discuss “first decisions” with the customer and gain better understanding
- Efficient development based on sophisticated tools and experienced developers
- Helping to bring the tool into operation and to keep it alive: deployment, integration, optimization services, training of users, support

Project Domains

Project Domains of our Research Group

Industry



Infrastructure



Mobility



Healthcare



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Energy



ASM (Assembly Systems)



Semiconductor Manufacturing



...

**former
Siemens
businesses
/ others**

Project Examples: Next Generation Ticketing

XIXO - Next Generation Ticketing - Idea

“First Travel – then Pay” – Easy and Flexible Use of Public Transport



What ticket do I need? Does a day ticket pay off?

no need to worry

Idea:

- “swipe in” (Check-In) and enter vehicle
- - > app grants travel permission and records journey
- travel (vehicle may be changed)
- leave (Check-Out / Be-Out)
- - > trip reconstruction from data collected on the way (coordinates, beacon signals, ...)
- do more trips
- -> best price ticket the next day (Post Price Ticketing)

Benefit:

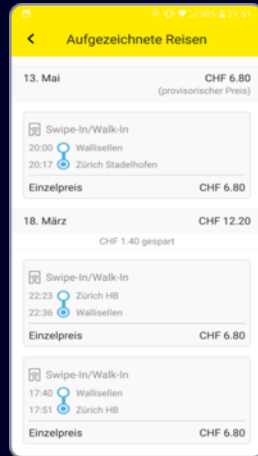
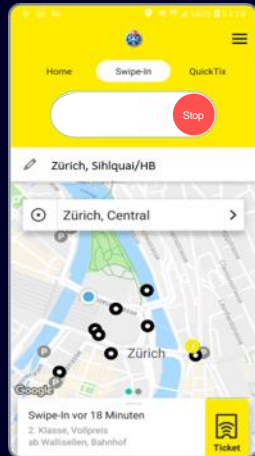
- no need to know the tariff system
- no need to buy a ticket in advance
- no need to know all trips in advance to get the best ticket → easy and flexible use of public transport

XIXO Next Generation Ticketing

April 2018, XIXO (BIBO, CICO, CIBO*) launched for the public in Switzerland.**

- **Commercial Swipe-In** (CheckIn-CheckOut) solution for public transport throughout Switzerland
- **First commercial Walk-In** (BeIn-BeOut) solution **worldwide** on trains and busses of SOB (Südostbahn Schweiz)

Partners: Siemens Mobility / Siemens HaCon, Siemens Technology, eos-Uptrade

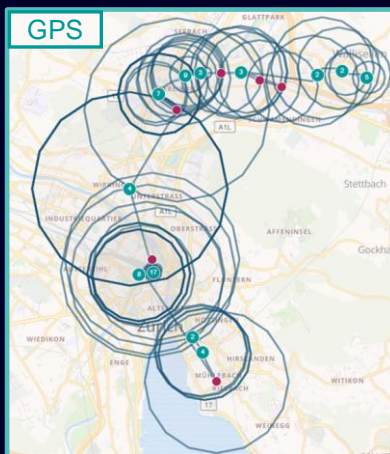
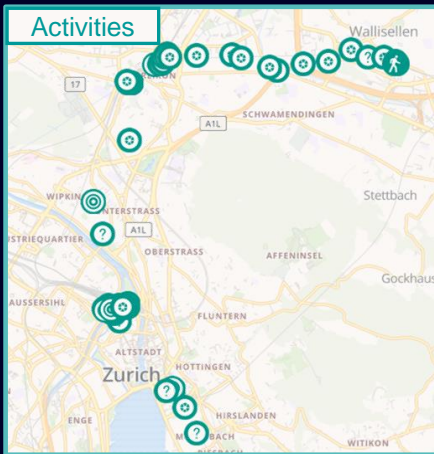
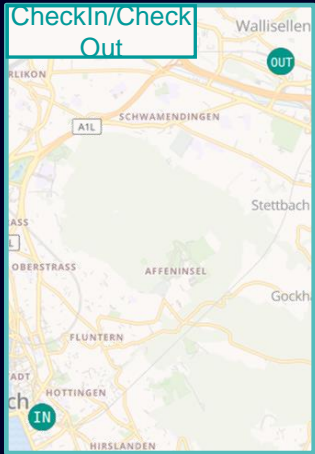


*C = “Check”, B = “Be”, I = “In”, O = “Out”

**commercial pilot till 2020, launch in Osnabrück 2020 “YANIQ”

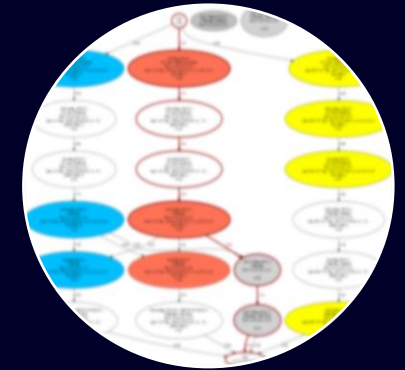
XIXO - Next Generation Ticketing - Check-In / Check-Out, GPS-based, basic setup

Trip Reconstruction by Mathematical Optimization



Discrete Optimization / graph algorithms for

- journey reconstruction
- best price calculation
- ...



Journey	
✓ Segment 3	09:00:15 Zürich Oerlikon - Wallisellen 09:03:29 (000011:18830:101) S 8
✓ Segment 2	08:50:47 Zürich HB - Zürich Oerlikon 08:59:12 (000011:18830:101) S 8
✓ Segment 1	08:45:24 Zürich Stadelhofen - Zürich HB 08:47:58 (000011:18730:101) S 7

Station geographies,
planned timetables

user trip reconstruction using field data, timetables, station geography

Price optimal: 28.70 CHF sum: 41.20 CHF

Best Price

- ✓ Price optimal: 28.70 CHF sum: 41.20 CHF
- Journey 3 Price: 17.20 CHF SECOND.KI CalcTime: 2019-12-17 21:40:50
- Device: forwarded_user-19047:7fe33b83-1f2d-412a-9908-513d557baf15
- ✓ Trip 1 TRAIN S 2 Price: 17.20 CHF
 - ✓ 21:28:52 Stettbach - Zürich Stadelhofen 21:39:40
 - ✓ 21:23:58 Winterthur - Hettbach 21:27:53
 - ✓ 21:15:54 Hettlingen - Winterthur 21:19:04
 - ✓ 21:10:22 Henggart - Hettlingen 21:15:54
 - ✓ 21:06:40 Andelfingen - Henggart 21:09:54
 - ✓ 21:01:12 Marthalen - Andelfingen 21:05:42
 - ✓ 20:56:15 Dachsen - Marthalen 21:00:06
- Journey 2 Price: 17.20 CHF SECOND.KI CalcTime: 2019-12-17 21:40:50
- Device: forwarded_user-19047:7fe33b83-1f2d-412a-9908-513d557baf15
- ✓ Trip 2 TRAIN S Price: 13.00 CHF
 - ✓ 17:47:28 Marthalen - Dachsen 17:51:18
 - ✓ 17:41:35 Andelfingen - Marthalen 17:46:03
 - ✓ 17:30:01 Winterthur - Andelfingen 17:39:07
- ✓ Trip 1 TRAIN S 8 Price: 8.80 CHF
 - ✓ 17:12:25 Effretikon - Winterthur 17:18:48
 - ✓ 17:08:01 Dietlikon - Effretikon 17:12:25
 - ✓ 17:04:57 Wallisellen - Dietlikon 17:08:01
- Journey 1 Price: 6.80 CHF SECOND.KI CalcTime: 2019-12-17 21:40:50
- Device: forwarded_user-19047:7fe33b83-1f2d-412a-9908-513d557baf15
- ✓ Trip 2 TRAIN S 8 Price: 6.80 CHF
 - ✓ 09:00:15 Zürich Oerlikon - Wallisellen 09:03:29
 - ✓ 08:50:47 Zürich HB - Zürich Oerlikon 08:59:12
- ✓ Trip 1 TRAIN S 7 Price: 2.70 CHF
 - ✓ 08:45:24 Zürich Stadelhofen - Zürich HB 08:47:58
- ✓ OpenStreetMap

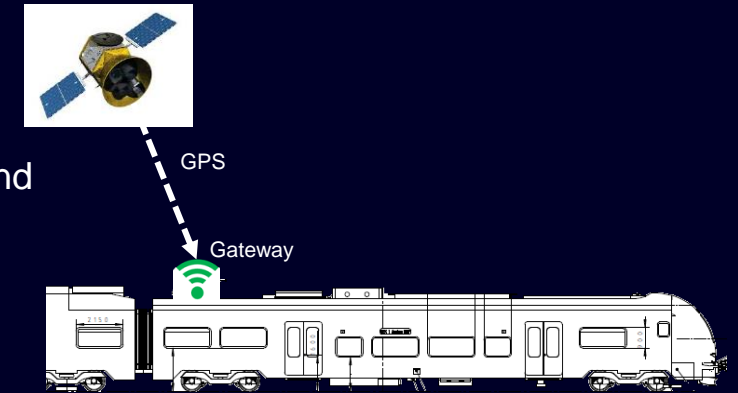
sum of single ticket prices

best price: day ticket

XIXO: Next Generation Ticketing: Variants

Be-In / Be-Out:

- vehicles are equipped with **gateways** that send positions
- vehicles are equipped with **Bluetooth beacons** whose signals are received by the user phones
- vehicle route reconstruction by mathematical algorithms using positions sent by the gateways and information about routes that are served
- user trip reconstruction from beacon signals and reconstructed vehicle routes



Check-In / Be-Out:

- user does not have to check-out
- **check-out is automatically detected** from information collected by the phone (activities, gps position, ...)
- (we cannot automatically detect check-in because we would have to track the user without her/his explicit consent whenever the app is running, user gives consent by checking-in)

Check-In / Be-Out or Check-In / Check-Out using subway lines:

- **beacons** are installed at entrances / exits of **subway stations**
- user trip reconstruction is done by mathematical algorithms considering received beacon signals and gps coordinates.

Project Examples: Photovoltaic Power Plant Layout

SUNNY: Photovoltaic Powerplant Layout and Design

Goal: automatically find a layout such that e.g.

- **peak power is maximized**
- **investment costs are minimized** for given target power
- **efficiency** of the plant is maximized ...

where **design rules** and **technical requirements** are fulfilled.

Subproblems to solve:

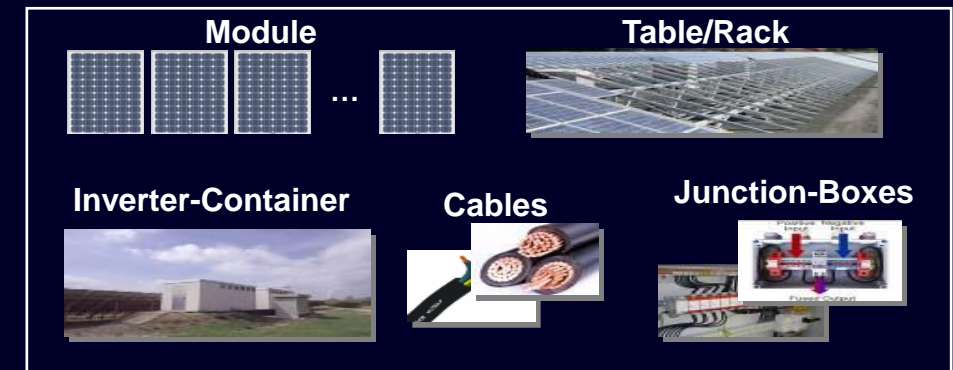
- location of pathways
- location of tables
- selection of inverters, assignment of tables to inverters, inverter positions
- positioning of junction boxes
- electrical wiring (cable cross sections, cable routing)

Deliverable:

Planning tool for automatized plant layout optimization supporting manual modification and reoptimization

Discrete Optimization algorithms applied:

- Mixed Integer Linear Programming
- Dynamic Programming
- combinatorial heuristics



SUNNY: Photovoltaic Powerplant Layout and Design

Siemens PV Layout and Design Tool - v1.6.2

Data maintenance | Optimizer parameters | Optimizer runs | Optimizer results

Equipment and area

Module types | Inverter types

Default values

Layout parameters | Cable cross-section rules

Import/Export

Central data location | Export data

Options

Auto save result list | Show warnings

Edit properties

Outline	Exclusions	Altitude
219,8	1205,8	0,0
291,4	1054,8	0,0
544,9	642,6	0,0
926,4	599,0	0,0
1325,8	850,0	0,0
1085,2	1346,7	0,0
570,5	1436,3	0,0
747,2	1190,5	5,0
834,2	921,6	5,0
1064,7	985,7	5,0
1026,3	1280,1	5,0
918,7	1113,7	8,0
701,1	768,0	3,0

Name: Test | Latitude: 48° 0' 0" | Longitude: 0° 0' 0"

Siemens PV Layout and Design Tool - v2.1.0

Data maintenance | Optimizer parameters | Optimizer runs | Optimizer results

Waiting optimizer jobs

Currently running

Finished optimizer jobs

Test 5 / 16 26,0° tilt 15,0° shad. 24,980 MWp

14:42:31 info Preparing parameters for the optimizer.
 14:42:32 info Starting optimizer.
 14:42:34 info Optimizer version: 2.1.0
 14:42:34 info Problem instance read.
 14:42:34 info Starting table optimizer.
 14:42:37 info Table optimizer successful.
 14:42:37 info Starting cable optimizer.
 14:42:37 info Optimizing inverter positions and areas.
 14:43:56 info Cable optimizer successful.

Table length: 31,6 m
 Table height: 5,0 m
 Table clearance: 0 mm
 Tilt angle: 26,0°
 Latitude: 48° 0' 0"
 Longitude: 0° 0' 0"
 Shadow angle: 15,0°
 Row distance: 12,7 m
 In. DC inputs: 16
 Inputs per GJB: 27
 Module temperature: -30,0 - 75,0°C
 Power per module: 260,00 W
 Modules per string: 16
 Rows per table: 5

Siemens PV Layout and Design Tool - v2.1.0

Data maintenance | Optimizer parameters | Optimizer runs | Optimizer results

Optimizer mode

Maximize plant power

Area information

Latitude: 48° 0' 0" | Est. number of tables: 1272
 Usable area: 54,315 ha | Shading angle at location: 18,6° | Estimated power: 26,458 MWp

Area information

Solar cell temperature: | Latitude: 48° 30' 0" | Est. number of tables: 1359
 Usable area: 56,723 ha | Shading angle at location: 18,1° | Estimated power: 32,616 MWp

Equipment

Module: Suntech STP260-24/Vb
 Inverter: Siemens Sinvert 1700 MS

Number of rows per table: | Number of modules per row: | Module distance horizontally: | Module distance vertically: 10,0 mm

Table design

Table depth 4,458 m | Table distance 6,652 m | Row distance 11,110 m

Siemens PV Layout and Design Tool - v2.1.0

Data maintenance | Optimizer parameters | Optimizer runs | Optimizer results

Test 5 / 16 26,0° tilt 15,0° shad. 24,980 MWp

14:44:00 Finished Shown 24,980 MWp

Report options

Show summary
 Show inverters
 Show GJBs no grouping
 Show AJBs no grouping
 Show Tables
 Print preview

Parameters

Area name	Test	Total area	54,31 ha	Latitude	48° 0' 0"	Fence length	2823,46 m	Avg. peak module power	260 W	Modules per string	16	Rows per table	5
Area name	Test	Total area	54,31 ha	Latitude	48° 0' 0"	Fence length	2823,46 m	Avg. peak module power	260 W	Modules per string	16	Rows per table	5

Equipment summary

Component	Name
Inverter	Siemens Sinvert 1700 MS
Module	Suntech STP260-24/Vb
GJB (5 inputs)	
AJB (5 inputs)	
AJB (6 inputs)	
Cable string <-> AJB	
Cable AJB <-> AJB	
Cable AJB <-> GJB	
Cable GJB <-> Inverter	
Tables	

Thank you for your attention!