AIRPORT GROUND STAFF SCHEDULING:

MAKING IMPACT WITH A HIGH-PERFORMANCE BUSINESS APPLICATION BASED ON INTEGER PROGRAMMING

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PROJECT AUTOROSTER

Joint development of **Swissport International Ltd.** and **Zurich University of Applied Sciences (ZHAW)**

- *Initially:* Swiss National Research Project (CTI), 2007 - 2009
- *Now:* Strategic R&D Cooperation Swissport – ZHAW
- *Aim:* Provide efficient and flexible **optimization software** for **complex large-scale rostering problems**
    - For Swissport
    - For other ground handlers and aviation related enterprises
    - For other industries with complex rostering problems

Show you care Do the right things Win as a team

PROJECT STAKEHOLDERS
SWISSPORT INTERNATIONAL LTD.

- Largest international ground handling company, 57'000 employees
- More than 290 airports in 45 countries, 850 customer airlines, 117 warehouses
- 186 million passengers, 3.3 million flights, 4.8 million tonnes cargo p.a.

PROJECT STAKEHOLDERS
AIRPORT GROUND HANDLING: BUSINESS AREAS

swissport
zh
aw

Passenger Services:

- Check-in
- Gate handling
- Transfer services
- Surface transports, special assistance, VIP lounges, ...

Ramp Services:

- Baggage handling
- Aircraft handling: push-back tractors, ground power units (GPU), stairs, ...
- Aircraft servicing and cleaning
- Unit load devices (ULD), control and management
- Aircraft maintenance
- Executive aviation handling, ...

PROJECT CONTEXT

OVERVIEW: STAFF SCHEDULING AT SWISSPORT

swissport

zh aw

General Personnel Planning Functions:

Task Generation & Shift Construction

Translate demand from flight schedules into shifts

Rostering

Days-Off Planning
Shift Assignment

Real-Time Dispatching

Control of real-time situation

Software at Swissport:

Inform - GroundStar
GS Planning

Opportunity: AutoRoster

Inform - GroundStar
GS RealTime

PROJECT CONTEXT
ROSTERING

[SP-Expert, INTERFLEX, Stuttgart, Germany]

- Manual planning board
- No support for automated, optimized planning

BZPT 01.07.2010-31.07.2010 [BZPT-ACTUAL]

July 2010	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	3	NORM	PLAN	NORM
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AUTOROSTER: MOTIVATION
OPPORTUNITIES FOR AUTOMATIC ROSTERING

- **Manual Rostering** *(via SP-Expert) with 15 – 20 planners in ZRH*
  special education, long-term experience
- **230+ days per month** planning effort
- **High importance of employee preferences**
- Various informal planning aspects:
  planners implicitly know preferences of their employees
- Different individual planning policies of planners
- Different opinions on fairness and quality

→ **Expensive, laborious, time consuming, subjective**

AUTOROSTER: REQUIREMENTS
MINIMAL REQUIREMENTS FOR NEW ROSTERING TOOL

- **Automatization** of rostering at Swissport
  - Complex, department specific, monthly planning

- **Employee preferences** of crucial importance («Shift Bidding»)
  - Employee satisfaction critical for success

- **Numerous** types of regulations, contracts and preferences
  - Labour law, unions, company regulations, personal wishes, operational needs, etc.

- **Complex informal framework** for individual preference handling
  - Preference fulfilment: about **95%** with manual planning

- **Large-scale** planning groups:
  - Total 2000+ employees in Zurich
  - Planning groups up to 1000 employees, hundreds of shifts

AUTOROSTER: REQUIREMENTS
MINIMAL REQUIREMENTS FOR NEW ROSTERING TOOL (CONT.)

- **Demand-driven** rostering, no repetitive shift patterns («wheels»)
  → Take into account dynamic variation of demand

- **Evaluated** commercial rostering tools were **inadequate** or produced **unsatisfactory results**:

  - Solutions only **partially feasible**, to be fixed manually
  - Variety of constraints and goals too complex or not representable
  - Problem dimensions too large
  - Computational «instability»:
    small input changes yield large output changes («planner's nightmare»)
  - No information about solution quality («optimality gap»)
  - Lack of bottleneck analysis, rapid rough-cut planning and decision support features

AUTOROSTER: METHODOLOGY
EXACT METHODS VS. HEURISTICS

- Most large-scale rostering tools mainly rely on **meta-heuristics** based on **stochastic search**:
  - Trajectory based: Hill Climbing, Tabu Search, Simulated Annealing, (Variable) Neighborhood Search, ...
  - Population based (evolutionary): Genetic Algorithms, Scatter Search, ...
- Typically (far) sub-optimal solutions
- No information about solution quality (distance from optimum)
- Inherent high degree of randomness
- Little exploitation of mathematical problem structure

AUTOROSTER: METHODOLOGY
EXACT METHODS VS. HEURISTICS (CONT.)

- AutoRoster substantially relies on **exact** methods, in particular on **Integer Linear Programming**
- **Explicit** mathematical description of solution space
  - Intensive exploitation of mathematical (polyhedral) **structure**
  - Elaboration of good polyhedral **formulations** (if possible)
- Solution by means of high-performance ILP solver: **Thank you, Gurobi!**
- Reduced computation time through **smart B&B truncation**
- **Combination** with various other large-scale optimization techniques:
  - decomposition
  - relaxation
  - pre- and post-processing
  - heuristic procedures

AUTOROSTER: METHODOLOGY
HANDLING OF HARD CONSTRAINTS

Intrinsic issue with **meta-heuristics** used in most rostering tools:

- Difficulty to explicitly handle hard constraints
- Common approach: constraint relaxation with penalty ("dualization")

High risk to produce **infeasible** (partially feasible) solutions:

- Not all hard constraints satisfied
- To be fixed manually by human planners

AutoRoster guarantees **strict feasibility** of solutions:

- Possible due to underlying MIP methodology
- If no feasible solution exists (mathematically proven): explanation and hints for recovery (crucial)

AUTOROSTER: METHODOLOGY
FEASIBILITY ISSUES

Tools based on **(meta-)heuristics** and constraint relaxation **always** produce **"solution"**

- "Solution" often has unsatisfied hard constraints, i.e. "infeasible solution"

In contrast: Tools based on **MIP** may produce **no solution** at all!

- Because of explicit formulation of hard constraints

For users, getting no solution is inacceptable

- Psychologically, users typically prefer "rubbish" over "nothing"

Best approach to handle infeasibilities:

- Provide **hints** about causes of infeasibilities, bottlenecks and recovery

Computing infeasibility hints is challenging

- With regard to both: methodology and computational complexity

AUTOROSTER: METHODOLOGY
FEASIBILITY ISSUES (CONT.)

Possible approaches for infeasibility hints:

- Search minimal inconsistent constraint subsystems
  - Supported by Gurobi, but computationally hard in general
  - Maybe no answer in time, or not interpretable
- Solve entire "brute force" relaxation and interpret slacks
  - Supported by Gurobi and LPL modelling language
  - Maybe not tractable, since no answer in time
  - Maybe tractable, but slacks not interpretable
- Heuristically devise **sophisticated partial relaxations/decompositions**
  - Then interpret slacks and/or partial solutions
  - In our project, most successful approach
  - But high effort for development and programming

Regarding overall time and financial budget of this project:

- Infeasibility handling consumed approx. **40%** of total budget
- Reason: Very tightly constrained problems, most instances initially infeasible

IMPLEMENTATION
COMPUTATIONAL RESULTS

MIP Model:

- Implemented in LPL (algebraic modelling language, virtual-optima.com)
- About 30'000 lines LPL MIP code

Java Framework (core data model, controllers, adapters, scripting, heuristics, etc.):

- About 30'000 lines of Java code

Largest MIP instances, e.g.:

- 450’000 rows, 947’000 columns, 21’000’000 non-zeros (before Gurobi pre-solve)
- 135’000 rows, 224’000 columns (binary), 2’243’000 non-zeros (after Gurobi pre-solve)

Computation time (until sufficient gap, typically << 0.01%):

- About 15 - 70 hours for most difficult instances

Computation time is permanent issue and challenge:

- results must be delivered within strict operational deadlines
- computation times at limit of deadlines
- fluctuation over instances of same group
- fluctuation for different computational random seeds

IMPLEMENTATION
CURRENT STATUS

- Currently **57 Departments** run per month in ZRH, GVA and BSL
- More than **40 Features** available: from **A**lternating to **W**orkingDays
- Very high fulfilment of slot and OFF wishes **(98 – 100%)**
- Shortened runtime thanks to better mathematical formulations and new Gurobi versions
- Development of Web Application almost finished
- Deployment and commercialization continues with other airports and customers

IMPLEMENTATION
SAVINGS AND BENEFITS

- Savings of planning workforce: **~ CHF 1 million p. a.** (for ca. 4500 employees)
- Shift Design optimization with AutoRoster regarding demand and contracts
- More operational needs considered due to later start of planning process
- New complex contracts possible (e.g. Shift Bidding: multiple wishes per day)
- Flexible and fast adjustments thanks to in-house development

CONCLUSION

- Complex large-scale rostering problems
- No satisfactory commercial software
- Approach based on MIP (instead of meta-heuristics)
- Advantages:
  - High quality results, lower computation times, complex instances solvable
  - Explicit handling of hard constraints, higher computational stability, …
- Significant savings
- Issues:
  - Computation times at limit of deadlines, unpredictable fluctuations
  - Sophisticated and expensive handling of infeasibility

THANK YOU
LET'S DISCUSS

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