Disruption Management for Outbound Baggage Handling with Work Group Pairings

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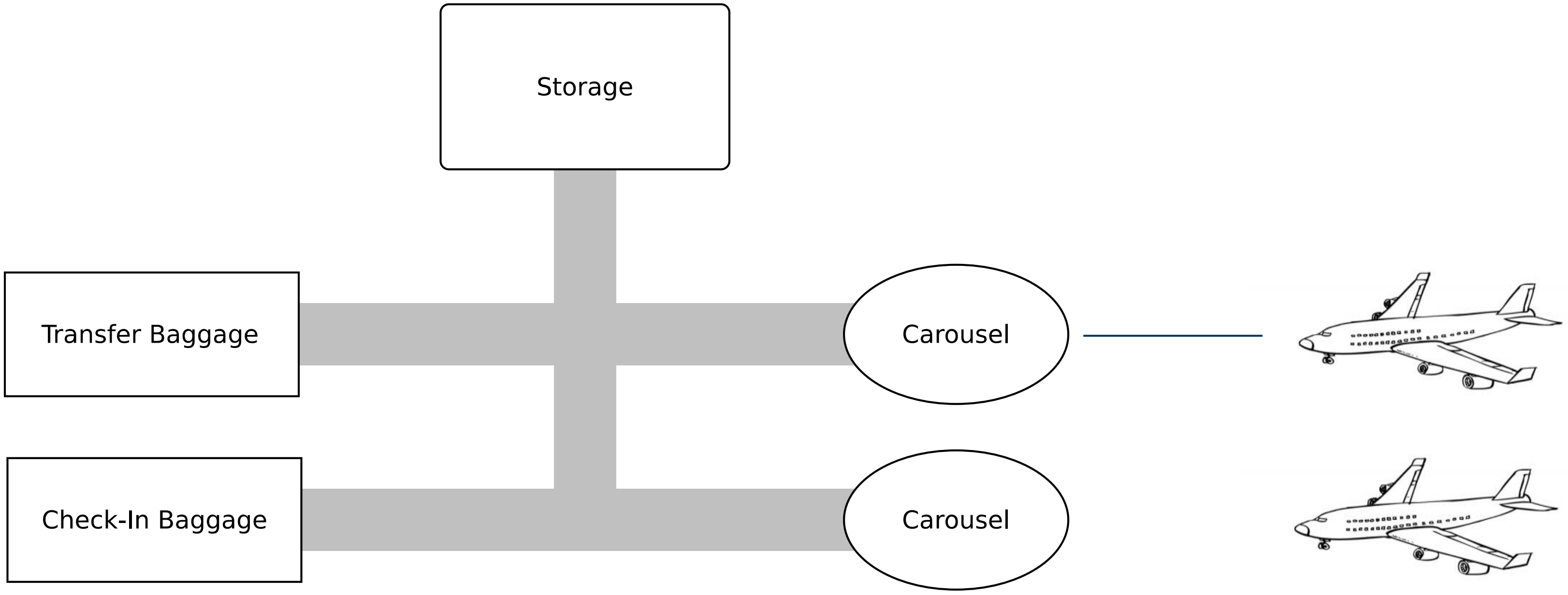
25. Workshop für quantitative Betriebswirtschaftslehre

Outline

- Problem Statement
- Literature Review
- Solution Methodology
- Computational Study
- Further Research
- Conclusion

Each flight is assigned to a carousel and a number of its working stations



Outbound Baggage Carousel

For each flight start of baggage handling and storage depletion needs to be scheduled

- Baggage handling has to be finished at S_i^{E}, about 10 – 15 minutes before take off
- Start of baggage handling s_i^{h} can be set in a time window
- Start of storage depletion s_i^{d} can be set between s_i^{h} and S_i^{E} such that all bags can be loaded

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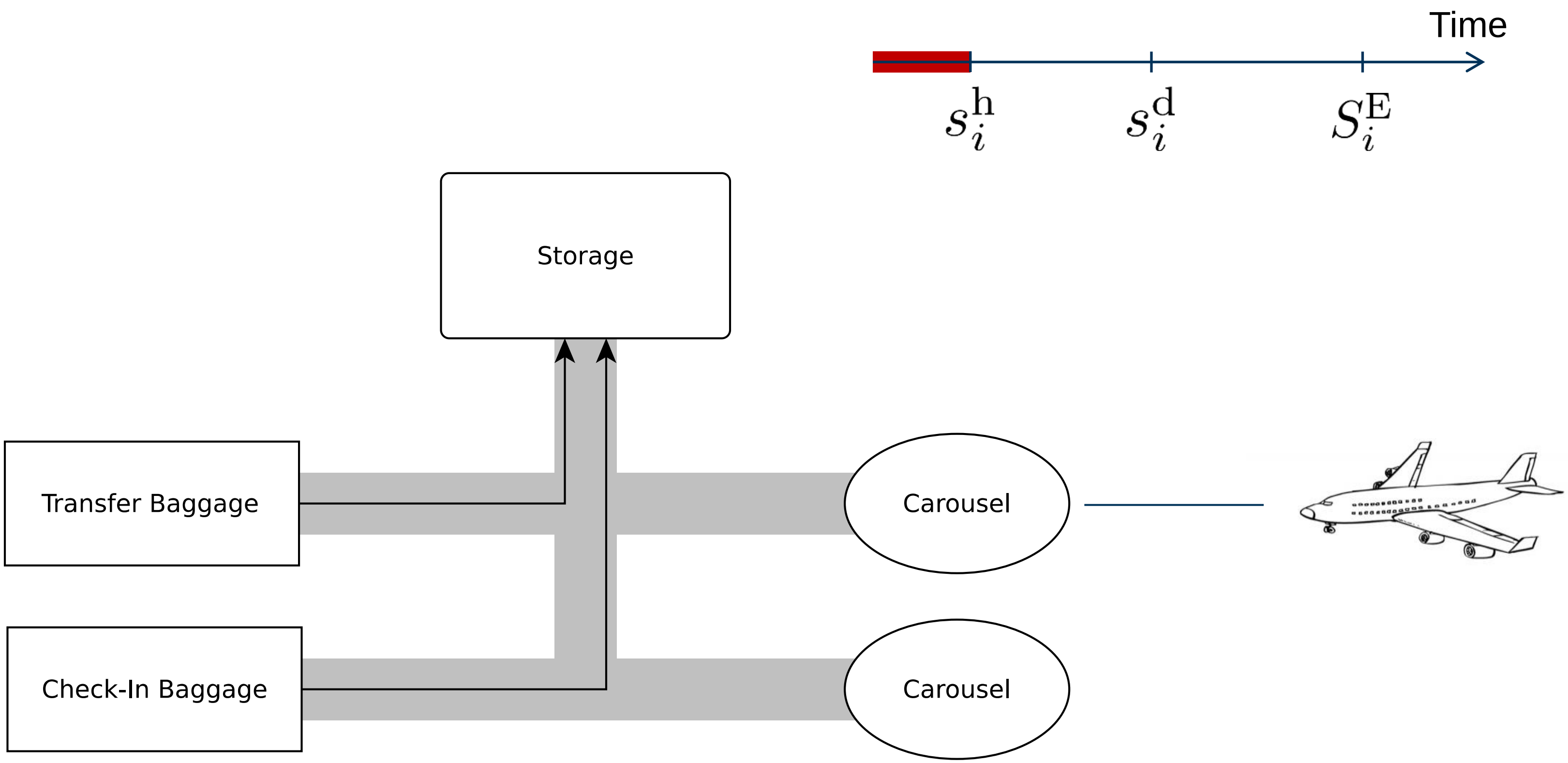

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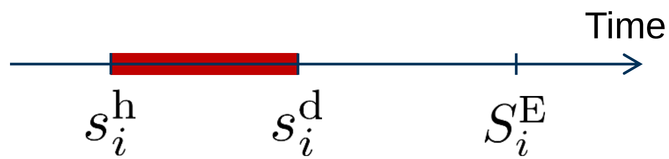

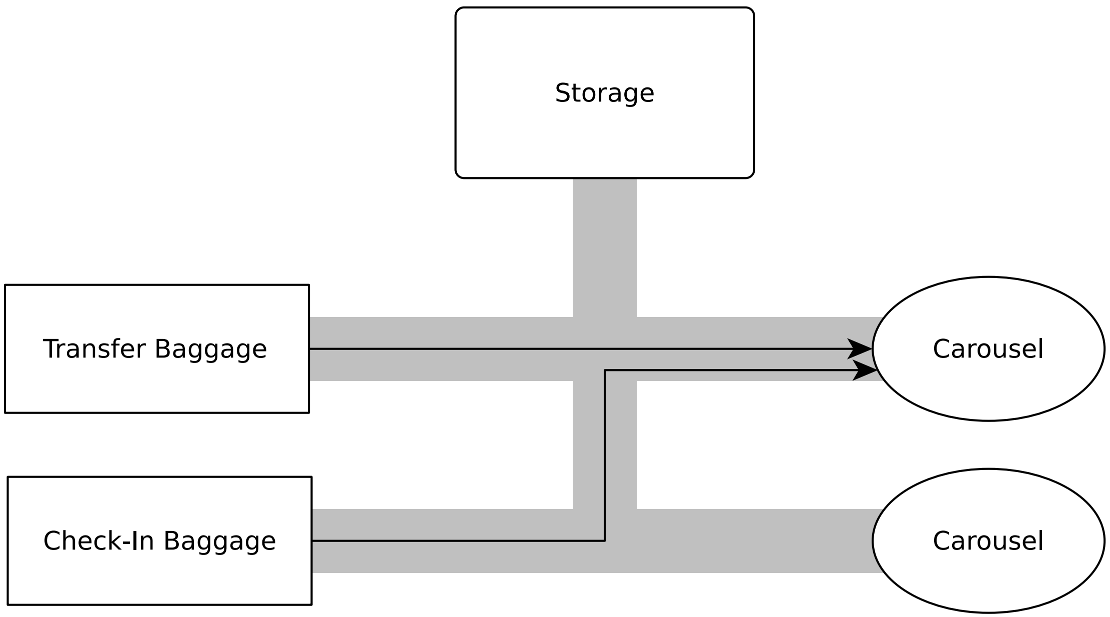

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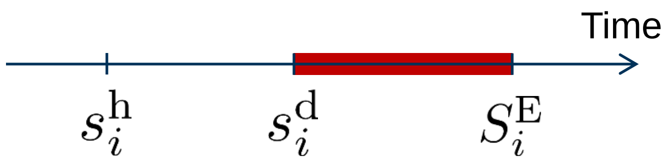

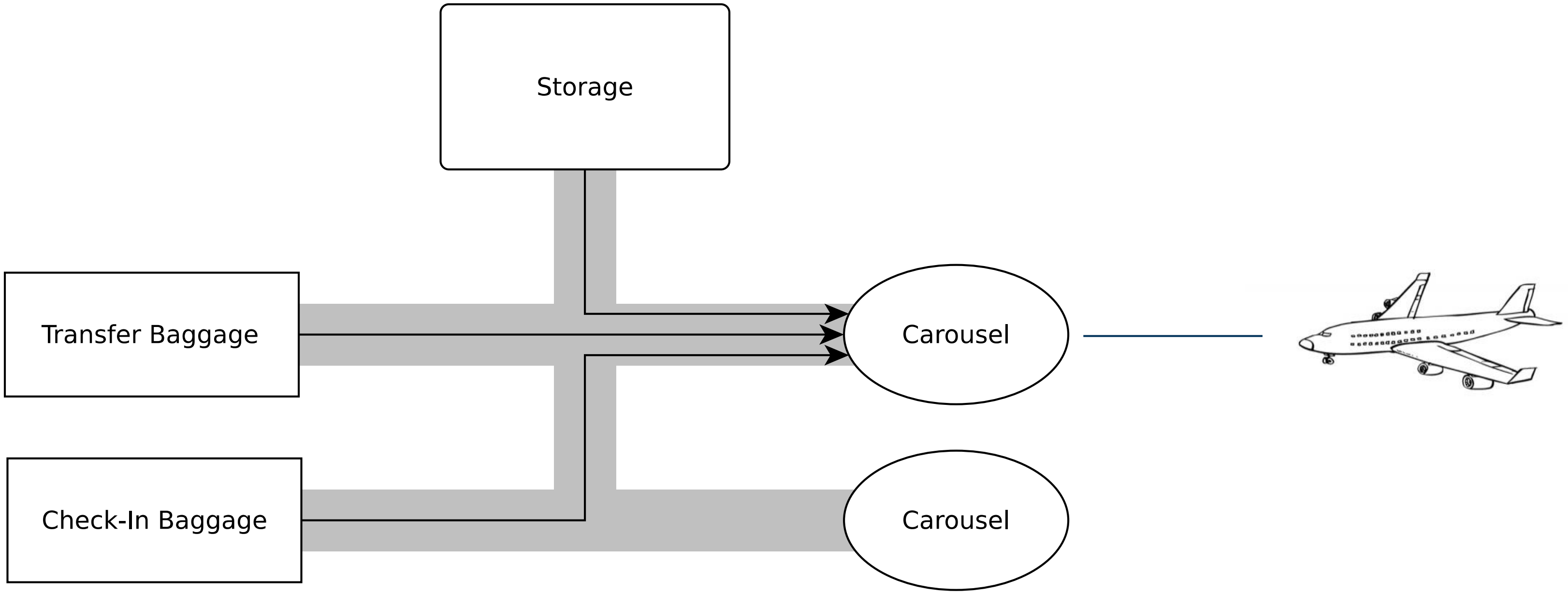

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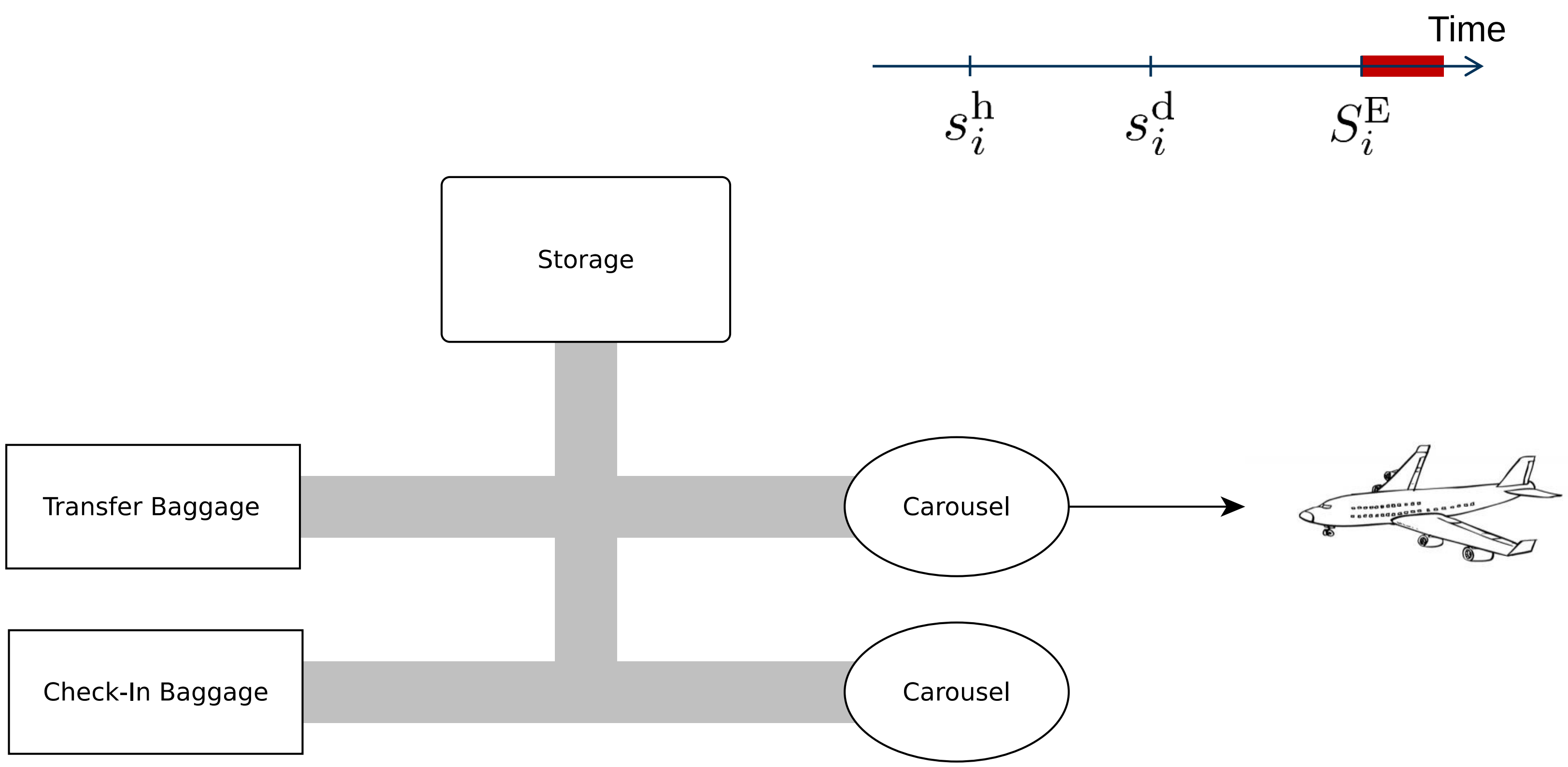
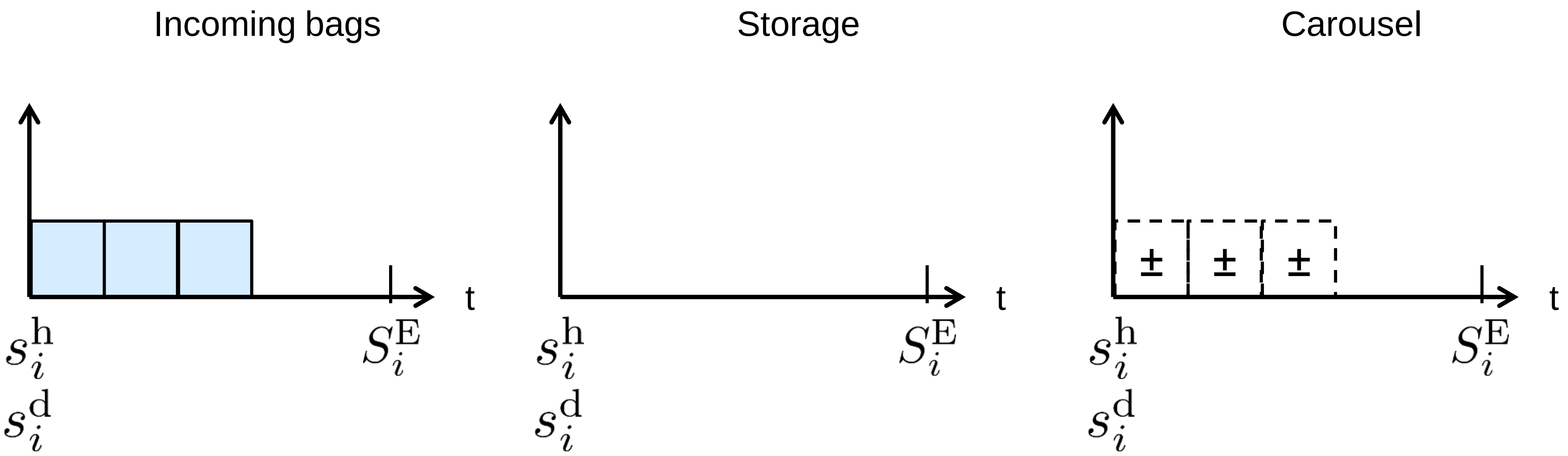


The schedule influences how bags arrive at the assigned carousel

- Assume the storage depletion rate and loading rate are both 1 per time period



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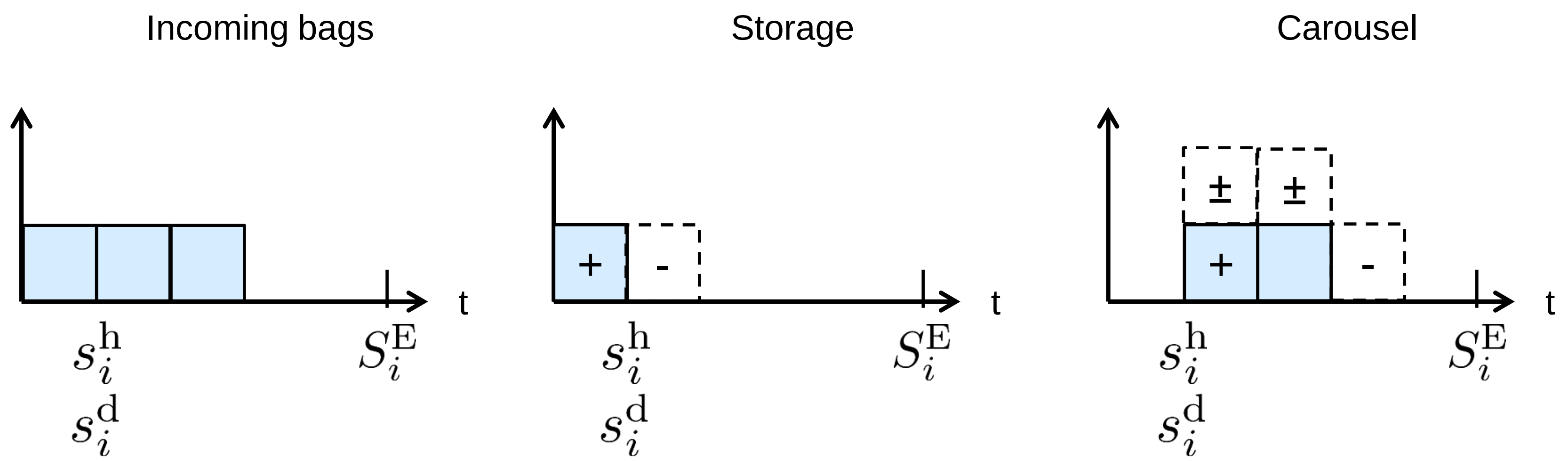
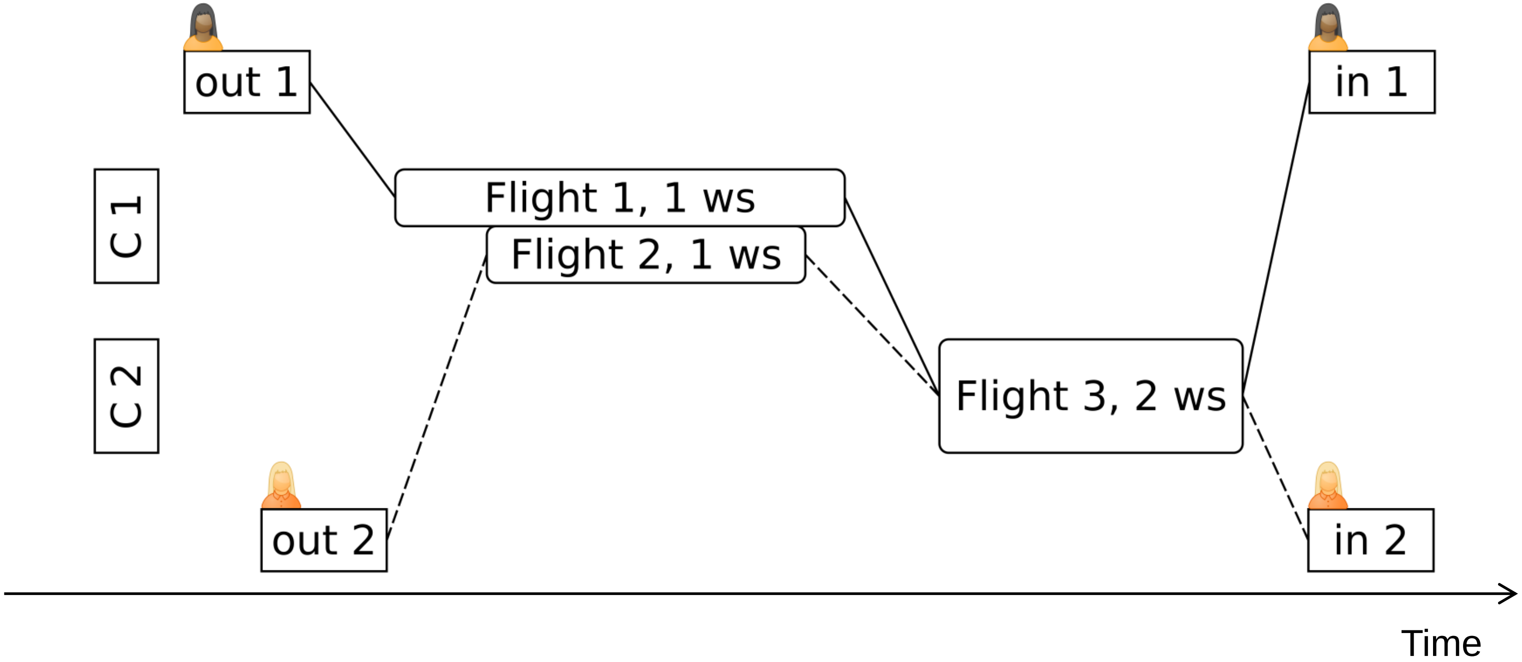
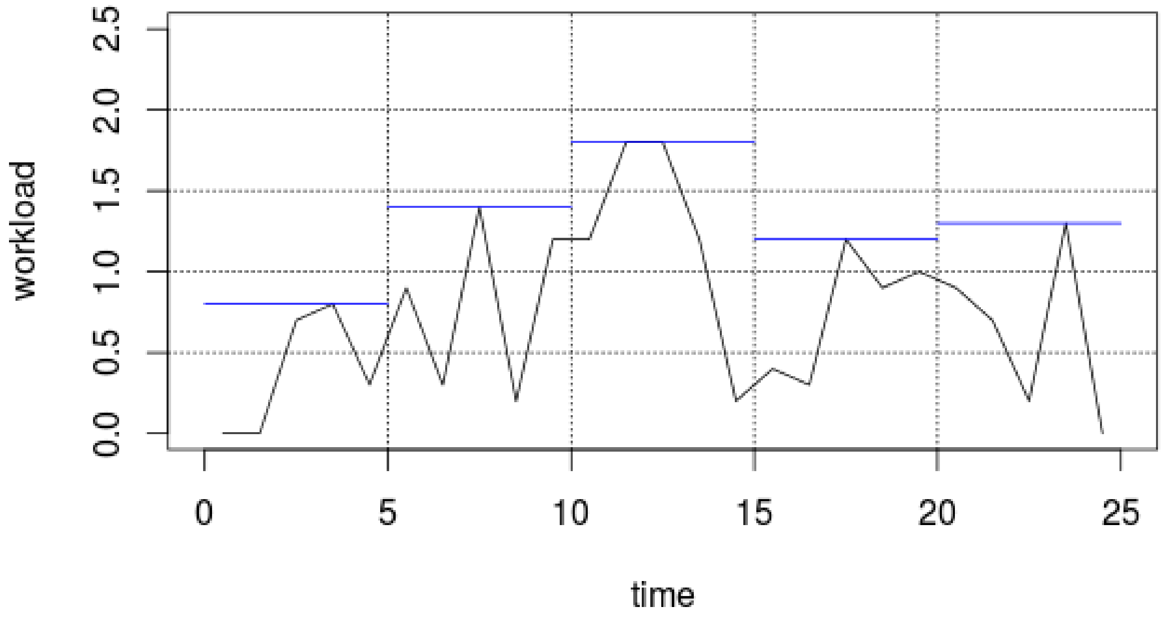


Each assigned working station must be staffed with workers



The goal is to smooth the workload and minimize left over bags

- The workload is defined as the number of bags on a carousel relative to its conveyor belt capacity
- In the objective we minimize the maximal workload for each carousel and in each time interval



- Faced with disruptions it is often not possible to find a solution where all bags can be delivered
- Therefore we allow infeasible schedules and assigning 0 working stations and apply penalty costs for each left bag

The problem characteristics lead to a large scale problem

About 400 flights departing from Munich Terminal 2 a day (~30000 bags)

- Each flight requires a decision regarding
  - When its baggage handling starts
  - When the storage depletion begins
  - How many working stations are used

21 handling facilities (carousels)

- Each facility has limited capacity regarding
  - Parking positions
  - Working stations
  - Conveyor belt

About 60 workers in 3 shifts

- Each worker
  - Starts and ends his shift at a defined time and location

Literature

Abdelghany et al. (2006) – Scheduling baggage-handling facilities in congested airport.
- Assignment of flights to handling facilities and scheduling the start of baggage handling for each flight
- Minimize used handling facilities

Clausen et al. (2010) - Disruption management in the airline industry - Concepts, models and methods.
- Overview on disruption management for aircraft routing and crew scheduling

Petersen et al. (2010) – An Optimization Approach to Airline Integrated Recovery.
- Disruption management for flight schedule, aircraft routing, crew schedule, and passenger itineraries
- Minimize equipment costs, flight cancelation costs, crew costs, passenger delay and cancelation costs

Ascó et al. (2013) – An Analysis of Constructive Algorithms for Airport Baggage Sorting Station Assignment
- Assignment of flights to handling facilities and scheduling the start of baggage handling for each flight
- Maximize the number of flights assigned to baggage handling facilities
- Minimize distance between assigned baggage handling facility and stand
- Maximize buffer times between flights
- Smooth workload

Frey et al. (2014) – Column Generation For Outbound Baggage Handling (tbp).
- Assignment of flights to handling facilities and scheduling of baggage handling including storage depletion time
- Minimize/smooth workload on carousels

Basic model

- 2 main binary decision variables
  - $x_{j,c,w,\tau}$ = 1, iff flight i is assigned to carousel c
    with w working stations and start time tuple τ
  - $f_{m,i,j}$ = 1, iff worker m goes from flight i to flight j
- Objective

  Minimize workload

- Subject to

  Assign flights

  Storage capacity

  Carousel capacities

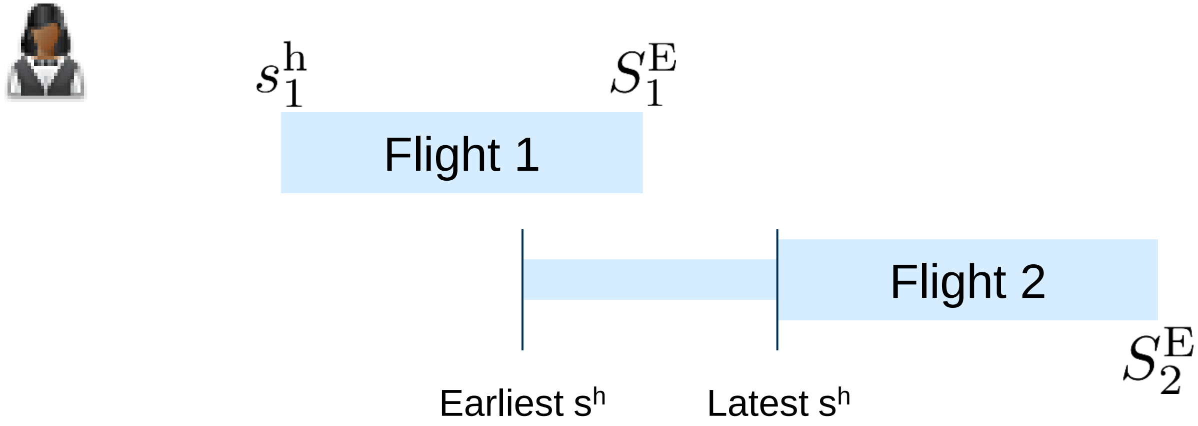
  Occupy working stations

  Worker tours

Example

Example:

- 2 flights, 1 working station each
- 1 worker



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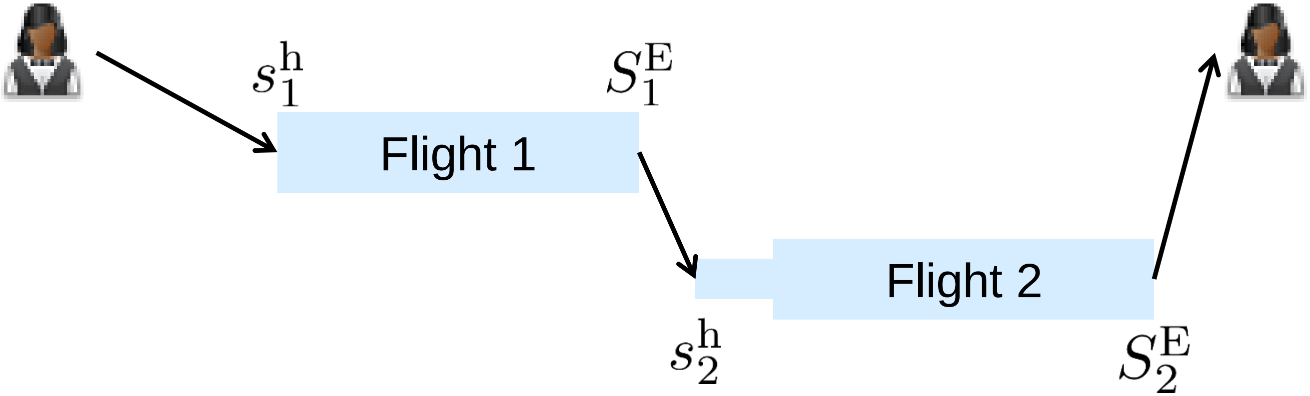
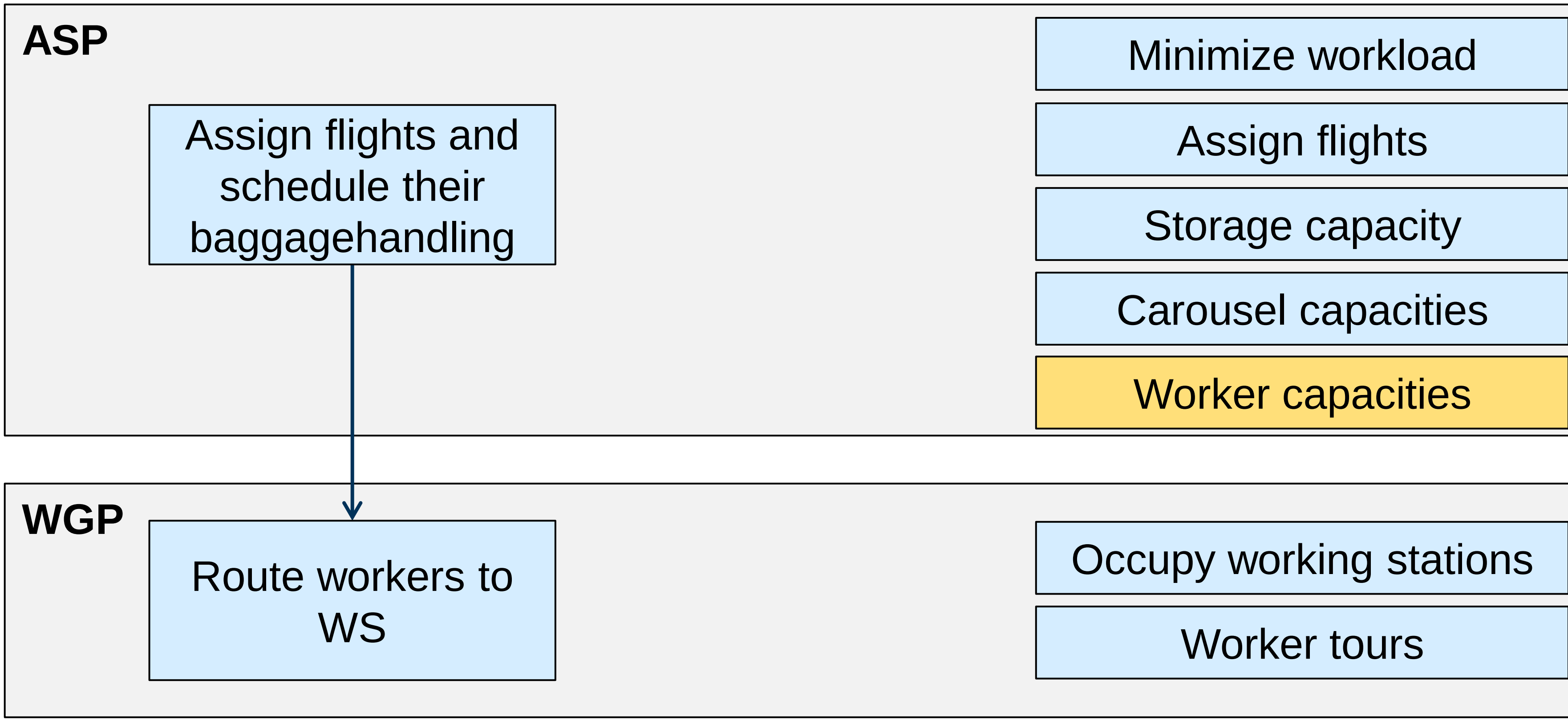


As the basic model is computationally intractable, it is decomposed sequentially



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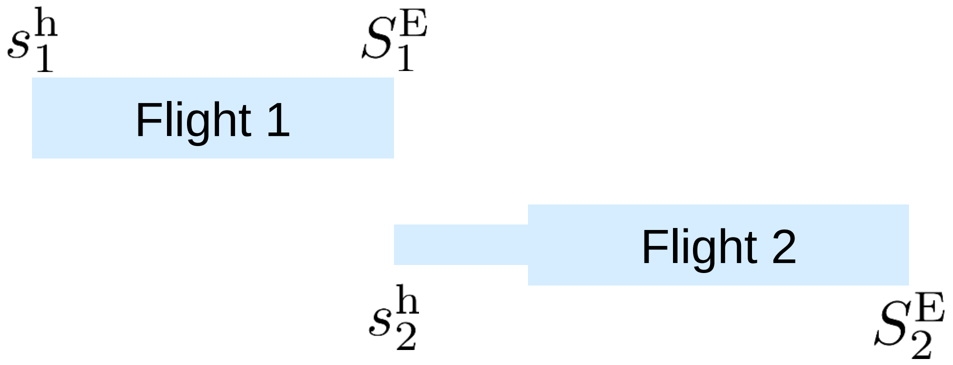

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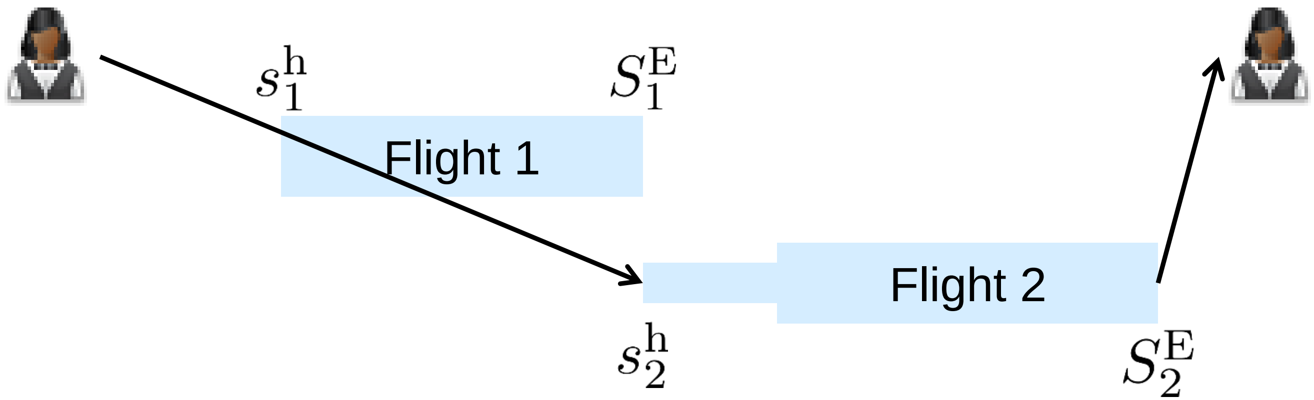

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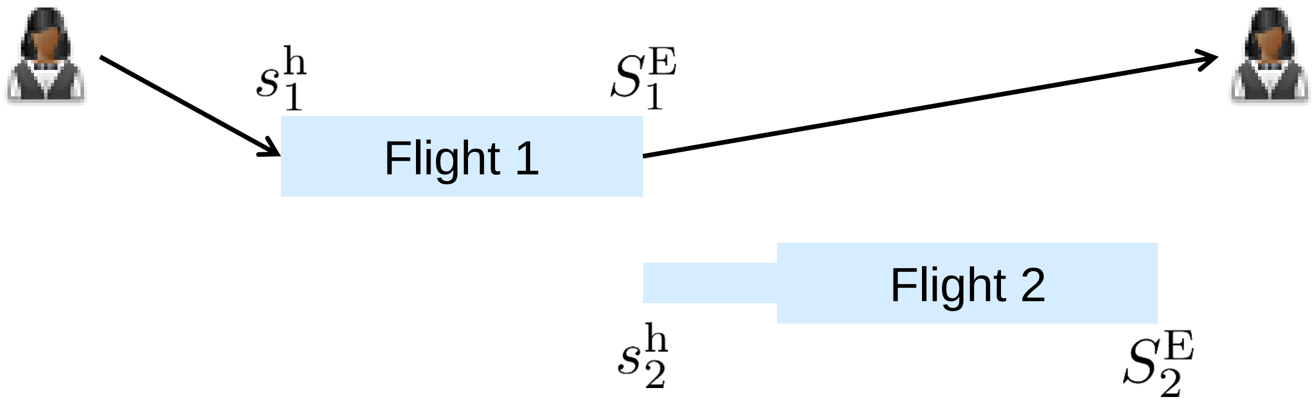


Dantzig-Wolfe Decomposition for ASP

- A duty is feasible assignment and schedule of flights to one carousel
- decision variables: z_d = 1, iff duty d is selected
- Objective

Minimize cost for selected duties

- Subject to

Assign flights

Storage capacity

Each carousel once

Worker capacity

C1

Cn

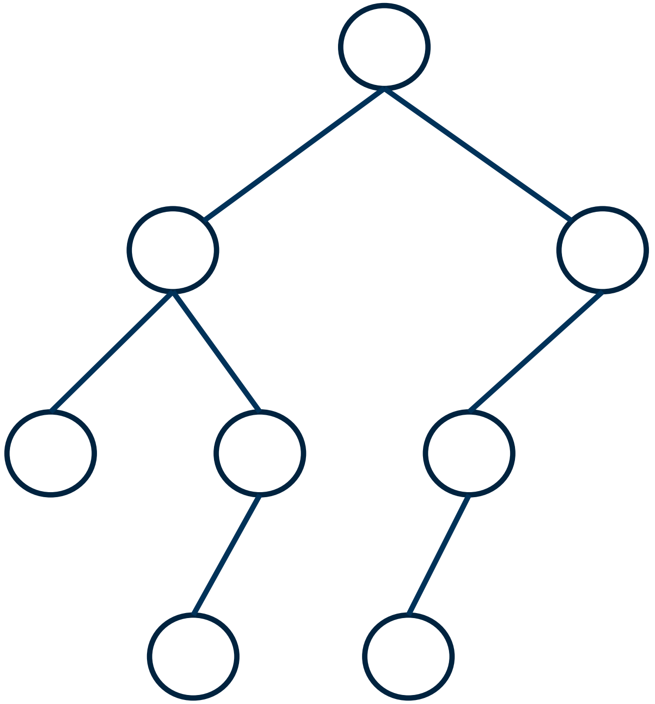
Master Problem

Subproblem for each carousel

Depth-first-search heuristic

- At each node:
  - Generate columns for a predefined number of iterations
  - Select a master variable to fix to 1 by rounding
  - Go to that node
- If no solution was found, start backtracking
- The number of deviations from the initial search path is limited to some k

- Example for 3 carousels



Korf (1996) - Improved Limited Discrepancy Search
Jancour (2010) - Column Generation based Primal Heuristics

In WGP we penalize the lack of workers

- Decision variables:
  - $f_{m,j,i}$ = 1, iff worker m goes from flight i to j; 0 otherwise
  - r_i = number of missing workers for flight i

$$\min \quad \sum_{i \in \mathcal{F}} r_i$$

$$\text{subject to}$$

$$\vdots$$

$$\sum_{m \in \mathcal{M}} \sum_{j \in \mathcal{F}_m} f_{m,j,i} + r_i \geq \hat{w}_i \qquad \forall i \in \mathcal{F}$$

$$\vdots$$

Computational Study

- Carousel layout

Carousel type	No	Working stations	Parking positions	Conveyor belt capacity
1	8	2	8	20
2	8	4	12	25
3	1	8	20	40

- Shift plan

Shift	No	From	To
1	20	3:00	10:00
2	20	9:30	16:30
3	20	16:00	22:40

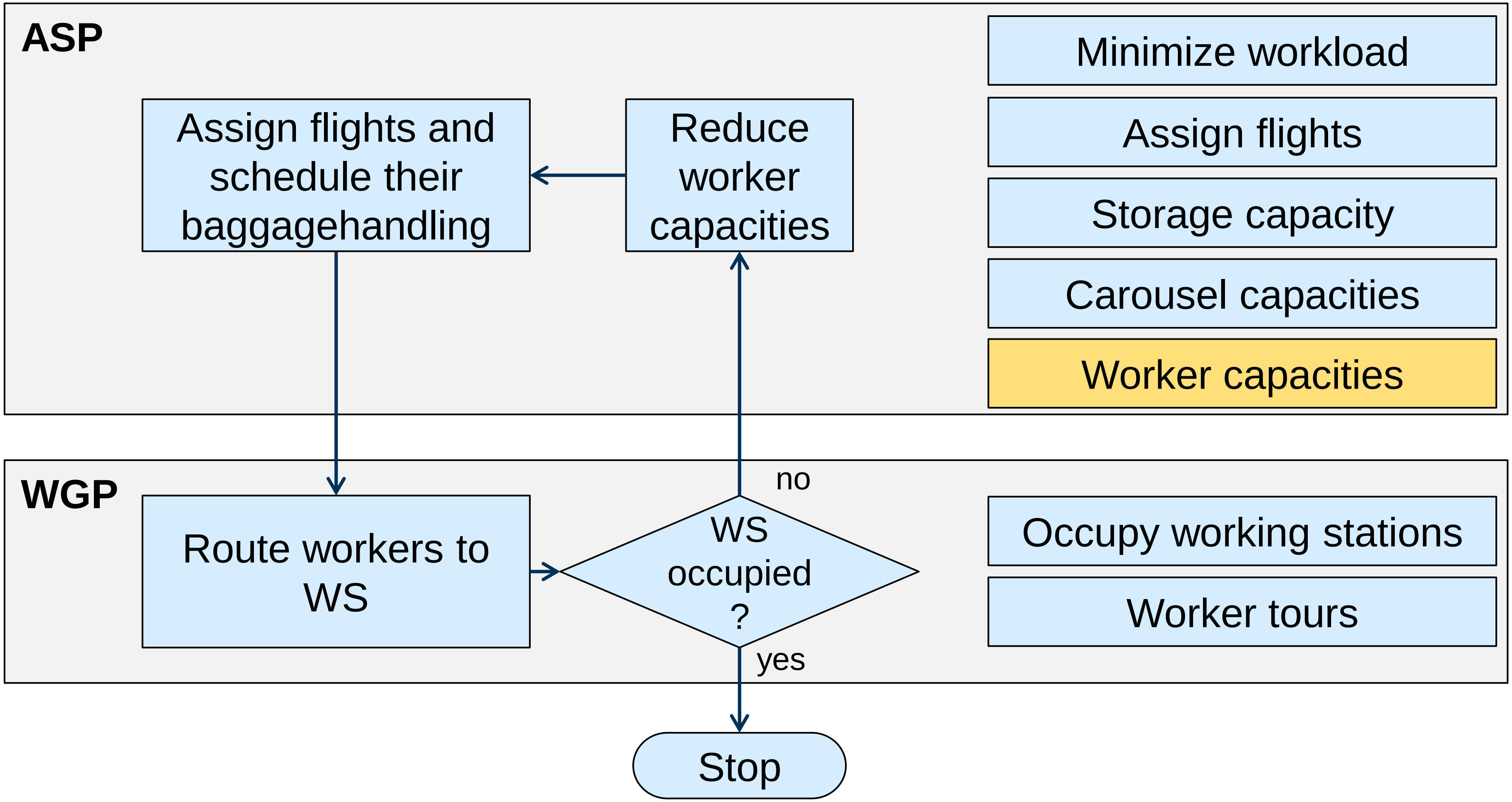
Computational Study

- Computational results in the absense of disruptions

Inst	From	To	F	RI	WI	u*	u	b*	b
I20.1	3:00	7:55	21	4.1	17	0.3	1.2	0	0
I20.2	3:00	9:20	43	5.4	22	1.6	1.2	6	11
I20.3	3:00	9:20	73	6.0	25	1.6	1.6	34	40

- Maximum Runtime = 10 minutes
- RI – Lower bound on min number of required carousels
- WI – Lower bound on min number of required workers
- u* workload peak in the optimization
- u workload peak in simulation
- b* left bags in optimization
- b left bags in simulation

Further research – iteratively reduce worker capacities



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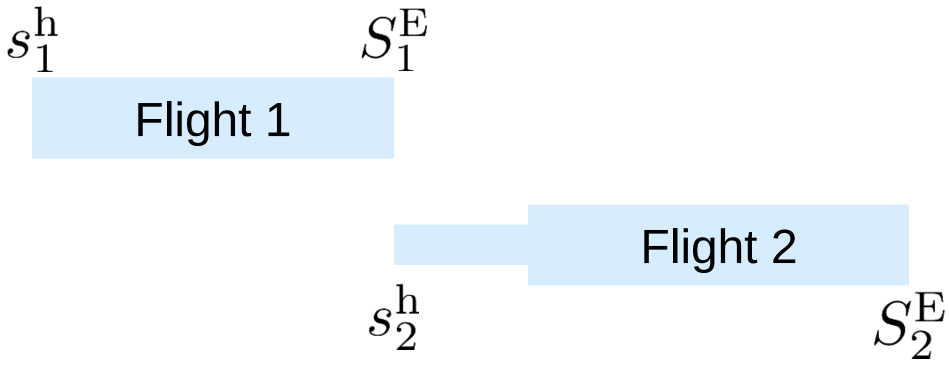

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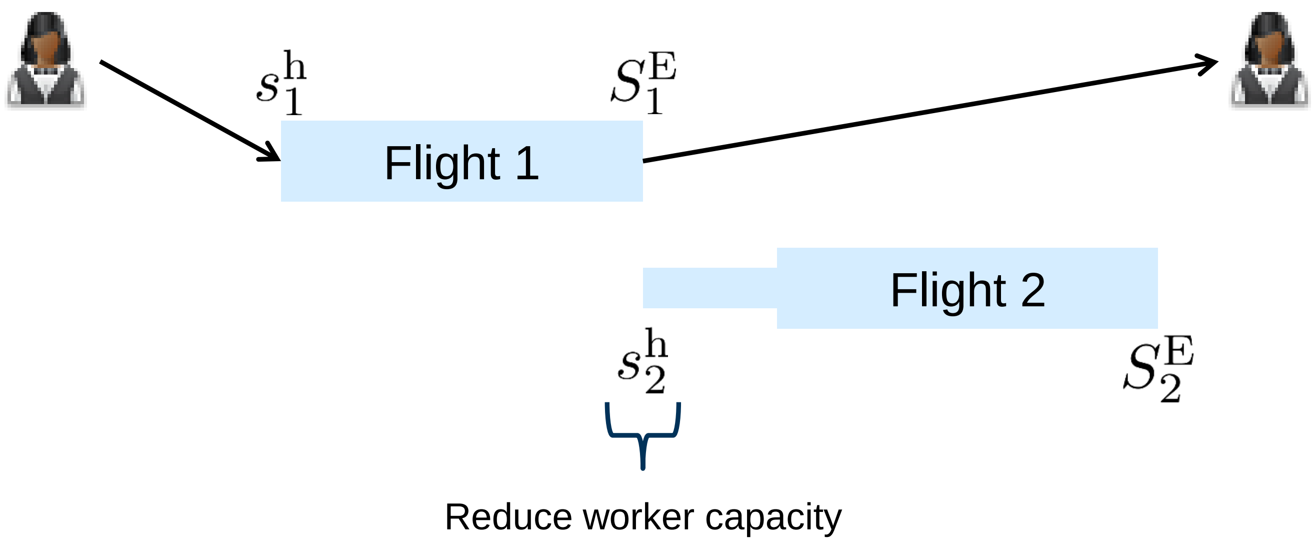

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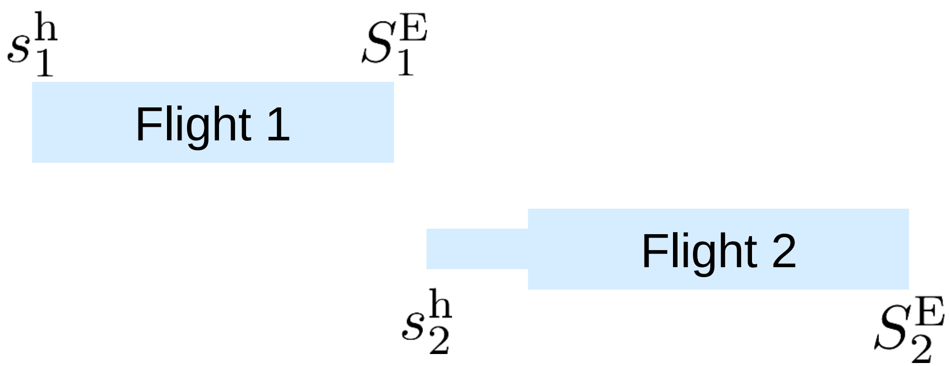

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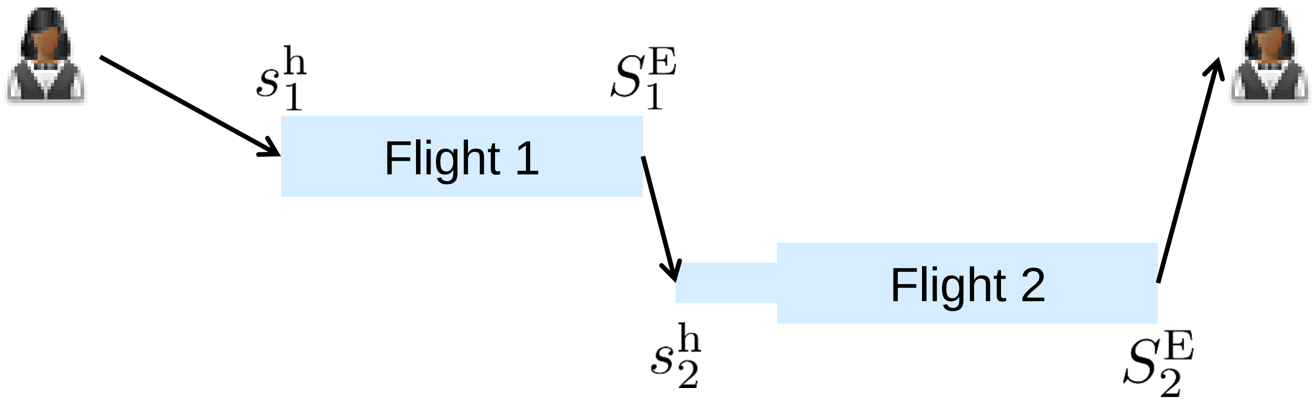

Conclusion

- The computational results show that the procedure generates solutions in the limited time in the absence of disruptions
- Preliminary computational result show that the procedure can cope with disruptions as well
- In an extensive simulation based study we hope to confirm that the procedure works well with real world data and stochastic disruptions
- Is there a way to obtain an optimal solution for the integrated problem or at least at tight lower bound?
- Contribution:
  - Outbound baggage handling problem extended to include the worker assignment
  - Rolling planning framework to update the planning based on new information about expected baggage arrival streams and disruptions

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Dantzig-Wolfe Decomposition for ASP

$$\min \quad \sum_{d \in \mathcal{D}'} C_d \cdot z_d$$

subject to

$$\sum_{d \in \mathcal{D}'} \Phi^{\text{ass}}_{d,i} \cdot z_d \geq 1 \qquad \forall\, i \in \mathcal{F}$$

$$\sum_{d \in \mathcal{D}'} \Phi^{\text{sto}}_{d,t} \cdot z_d \leq K^{\text{s}}_t \qquad \forall\, t \in \mathcal{T}$$

$$\sum_{d \in \mathcal{D}'} \Phi^{\text{wor}}_{d,l,t} \cdot z_d \leq K^{\text{wor}}_{l,t} \qquad \forall\, l \in \mathcal{L}, t \in \mathcal{T}$$

$$\sum_{d \in \mathcal{D}'_c} z_d \leq 1 \qquad \forall\, c \in \mathcal{C}$$

$$z_d \in \{0, 1\} \qquad \forall\, d \in \mathcal{D}'$$

$\Phi^{\text{ass}}_{d,i}$	1, iff flight i is assigned to duty d
$\Phi^{\text{sto}}_{d,t}$	required storage for duty d at time t
$\Phi^{\text{wor}}_{d,l,t}$	required workers for duty d of subset l at time t
C_d	costs for using duty d (workload penalty & left bags)
z_d	1, iff duty d is selected