Synopsis of Capacity Management and Analysis in Air and Rail Traffic

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Virtual Institute „Airport Planning and Management“

- German Aerospace Centre (DLR)
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- RWTH Aachen University
  - Institute of Transport Science:
  - Department of Airport and Air Transportation Research
  - Chair of Railway Engineering and Transport Economics

Approved and supported by the Helmholtz Association of German Research Centres

Cooperation within a particular project for a given time

Staff: Natural/applied scientists, civil/traffic/aeronautical engineers, economists

Scope and Objective

Capacity analysis and modelling for air and rail traffic networks featuring limited capacity

Inclusion of performance criteria *and* quality criteria for air/rail traffic systems and facilities

➡ Level-of-Service policy

Interdisciplinary approach through consideration of different traffic systems with scheduled operations

➡ Use of synergy

Focus on operational aspects with regard to infrastructure and traffic companies

Motivation and content

Synoptical investigation as basis for the Virtual Institute's ongoing research activities

Description of capacity management and analysis including

- Relevant process levels from scheduling to operations
- Network infrastructure and vehicle/aircraft movements (trajectories)
- Allocation and utilisation of limited available capacity
- Capacity modelling and quality evaluation of traffic systems and facilities

Continuative research in the field of airport scheduling/slot allocation (preliminary results)

- Process levels and planning instruments
- Scheduling
- Operations

Initial position

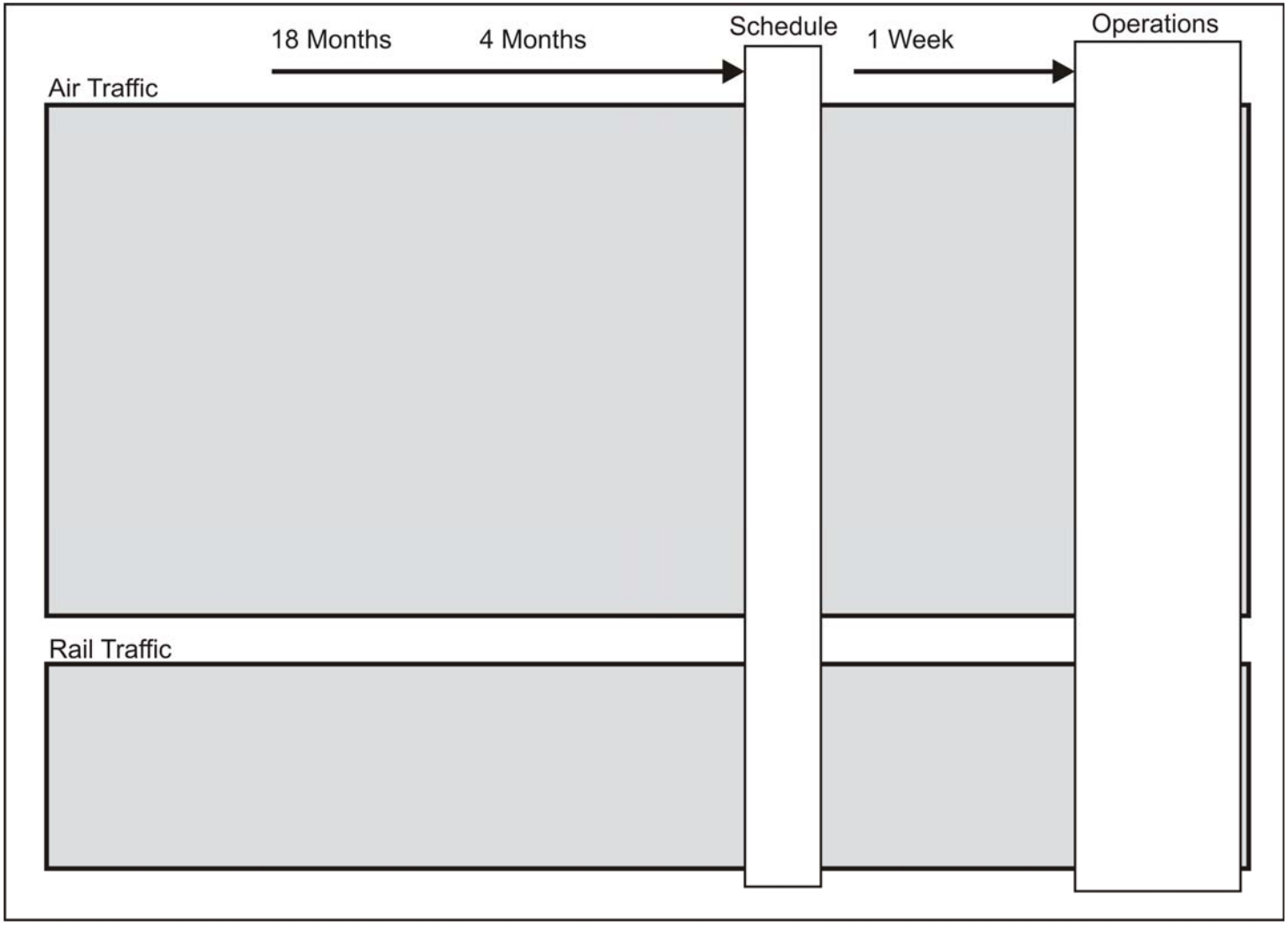
Air and rail traffic are transportation systems with scheduled operations

Two time horizons for both carriers: schedule and operations

- long-term until the fix point schedule
- short-term until the day of operations

Infrastructure and traffic companies are involved parties

Process Levels



Capacity Request

Traffic companies request for capacity provided by infrastructure companies

For quantifying the capacity utilisation, the instruments

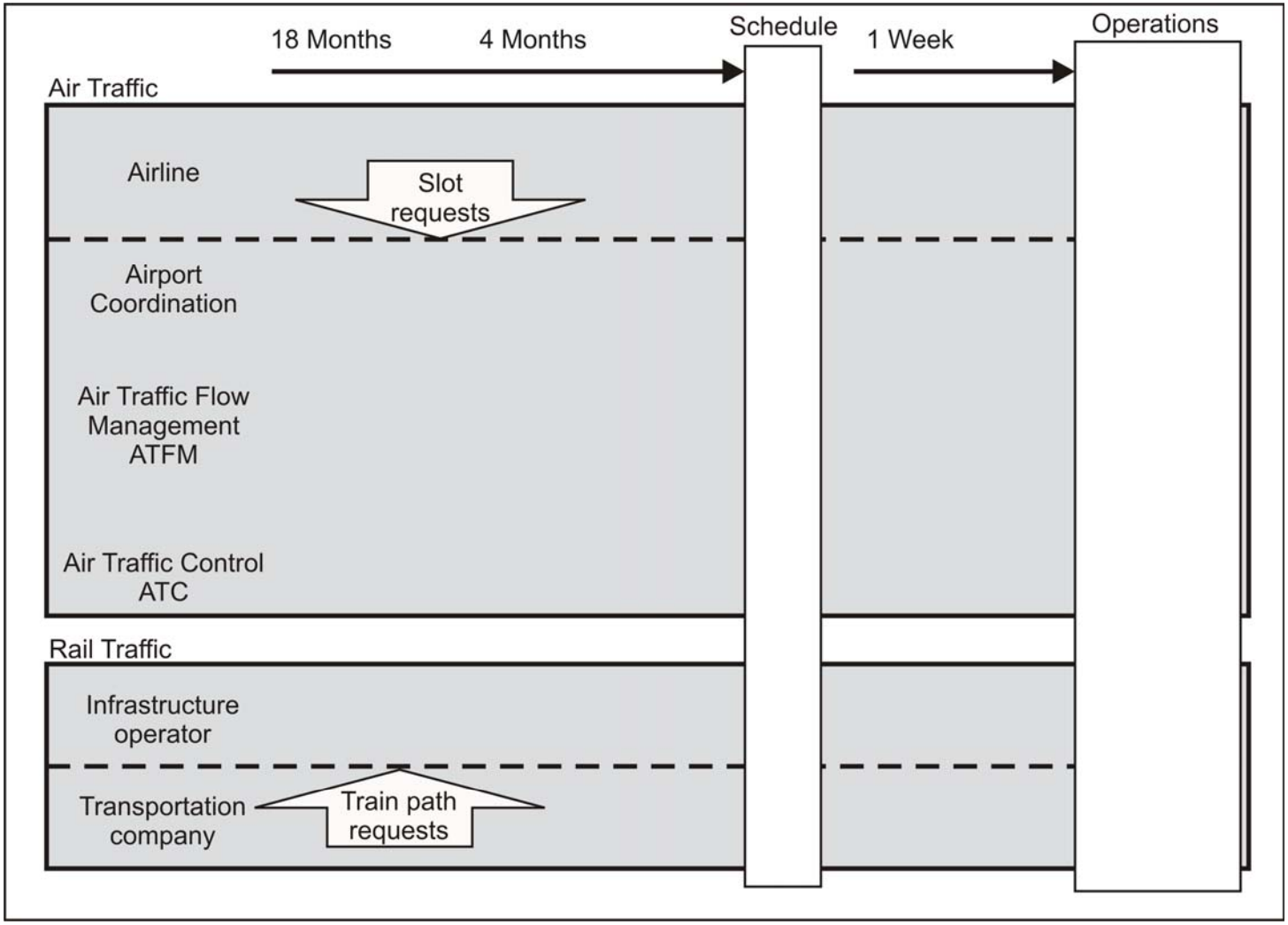
- slots

and

- train paths

are used.

Capacity Request



The Council Regulation 95/93 defines a slot as

„the permission given by a coordinator in accordance with this Regulation to use the full range of airport infrastructure necessary to operate an air service at a coordinated airport on a specific date and time for the purpose of landing or take-off as allocated by a coordinator in accordance of this Regulation.“

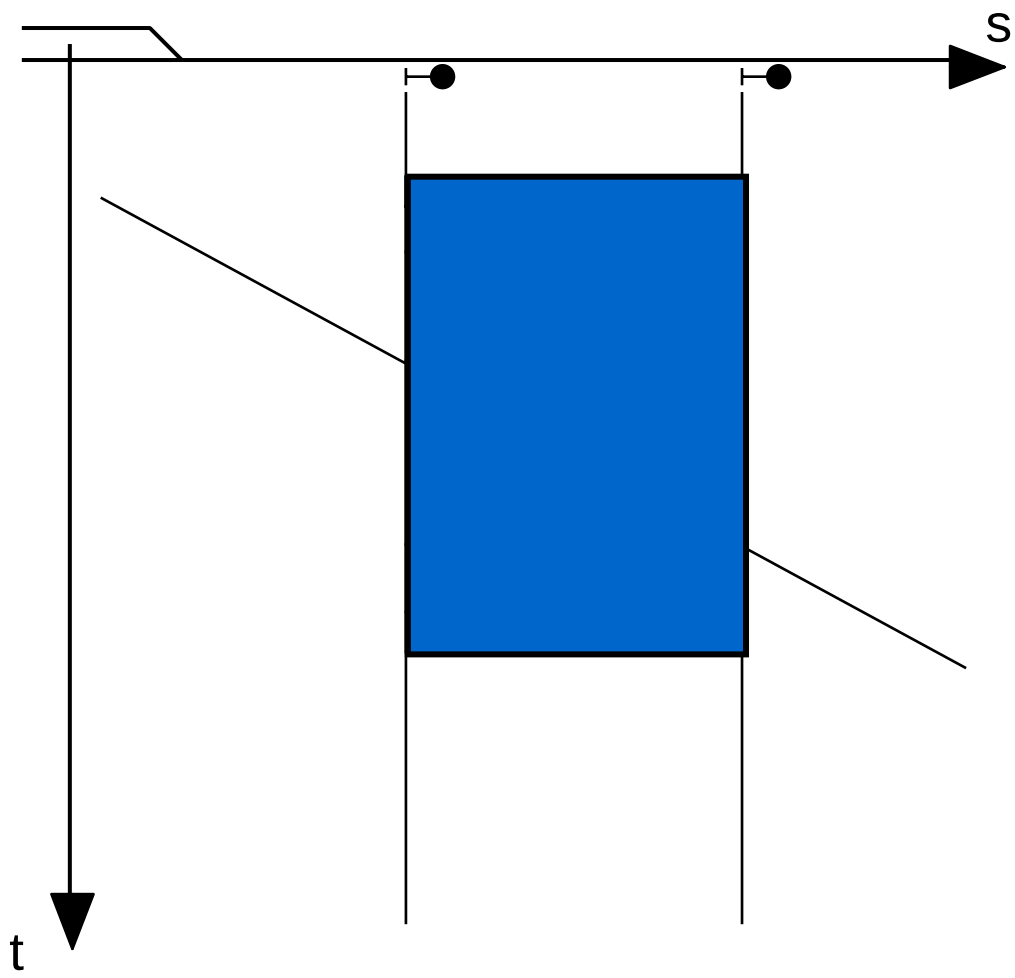
It is only one point planned locally and temporally at a node.

The Order of Railway Infrastructure Use (Eisenbahn-infrastruktur-Benutzungsverordnung) defines a train path as

„that part of the track capacity of an operator of the rail track system which is necessary so that a train can run at a particular time between two points“.

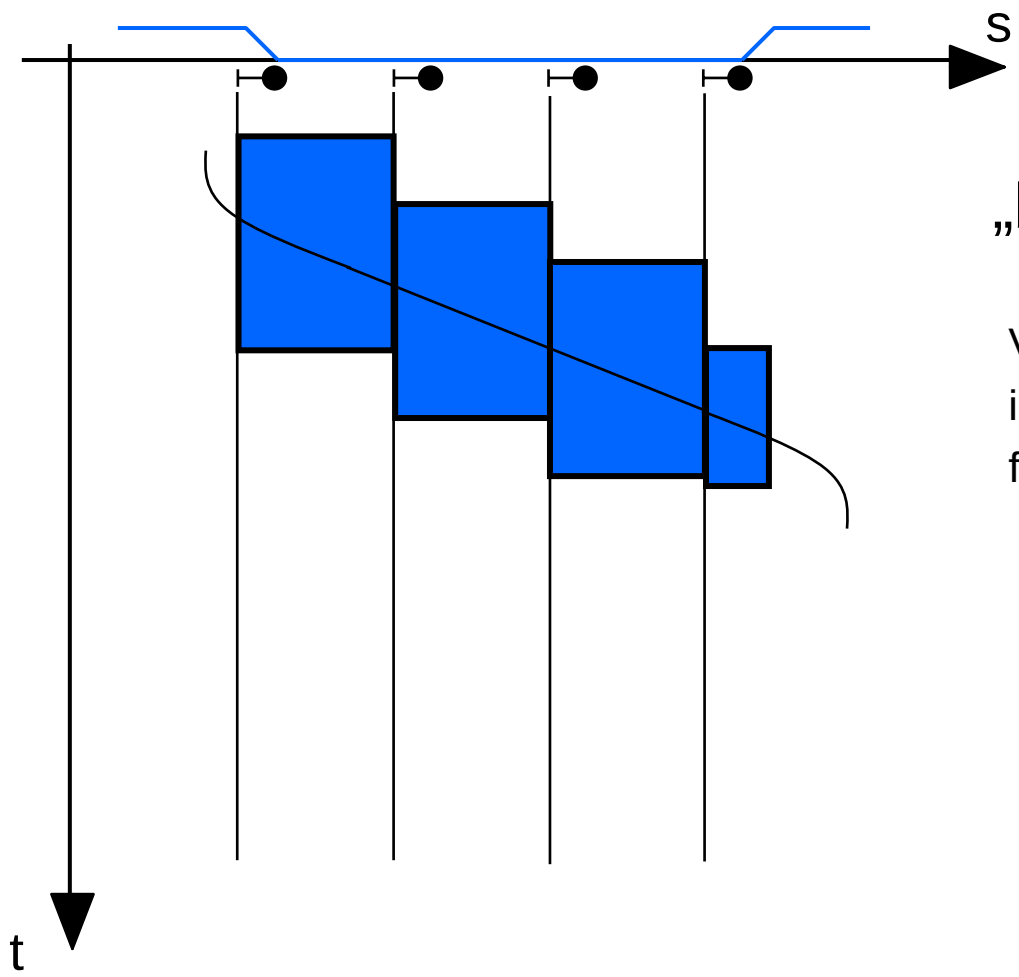
It is the planned local and temporal occupancy of infrastructure (nodes and links).

Blocking Time



running time
+ clearing time
+ approaching time
+ reaction time
+ switching times

= blocking time



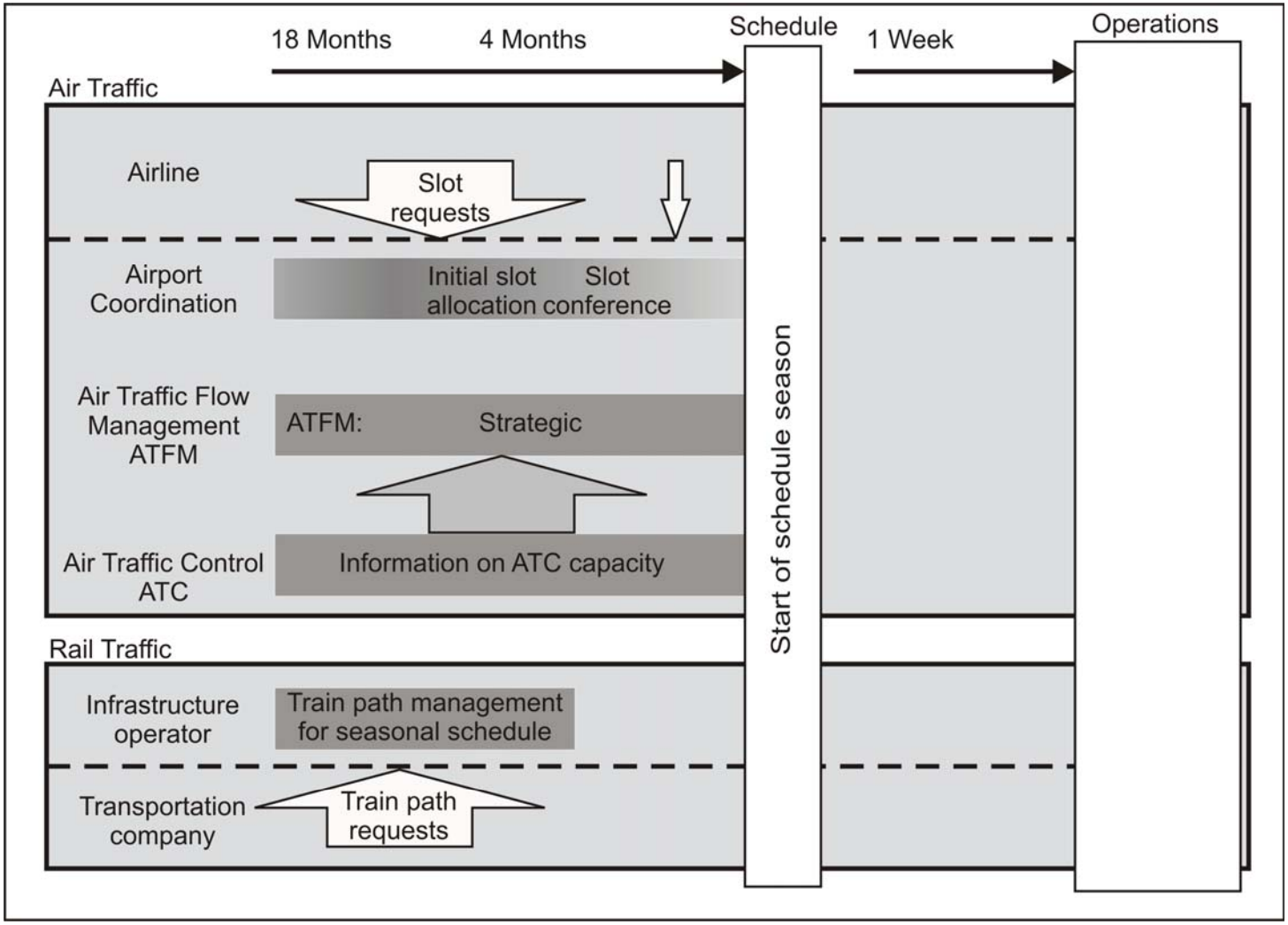
„blocking time graph“

Visualisation of
infrastructure occupation
for links and nodes.

Slot Allocation

- Fixed seasonal declared capacity as an input parameter
- Grandfather rights as most important priority regulation (“use-it-or-loose-it”)
- Airline internal matching of slot pairs for landing/take-off and take-off/landing
- Slots cover only the nodes as start or end points of a flight movement
- The network effects included in the airline internal planning only
- Imprecision by using only 10-min-slot-windows

Strategic Planning



Train Path Management

- Planning of line and station capacity
- Compulsory consideration of detailed parameters describing infrastructure configuration and driving dynamics of vehicles
- Infrastructure Manager constructs a conflict free schedule
- Minimum on-the-minute planning precision
- Priority regulations
- Framework agreement for a 5-year-period possible

Schedule

No network optimisation, but focus on traffic company and end customer requirements

Precise program for day-to-day operations

Railway traffic end customer is very sensitive to delays and reaches the railway station shortly before the scheduled time

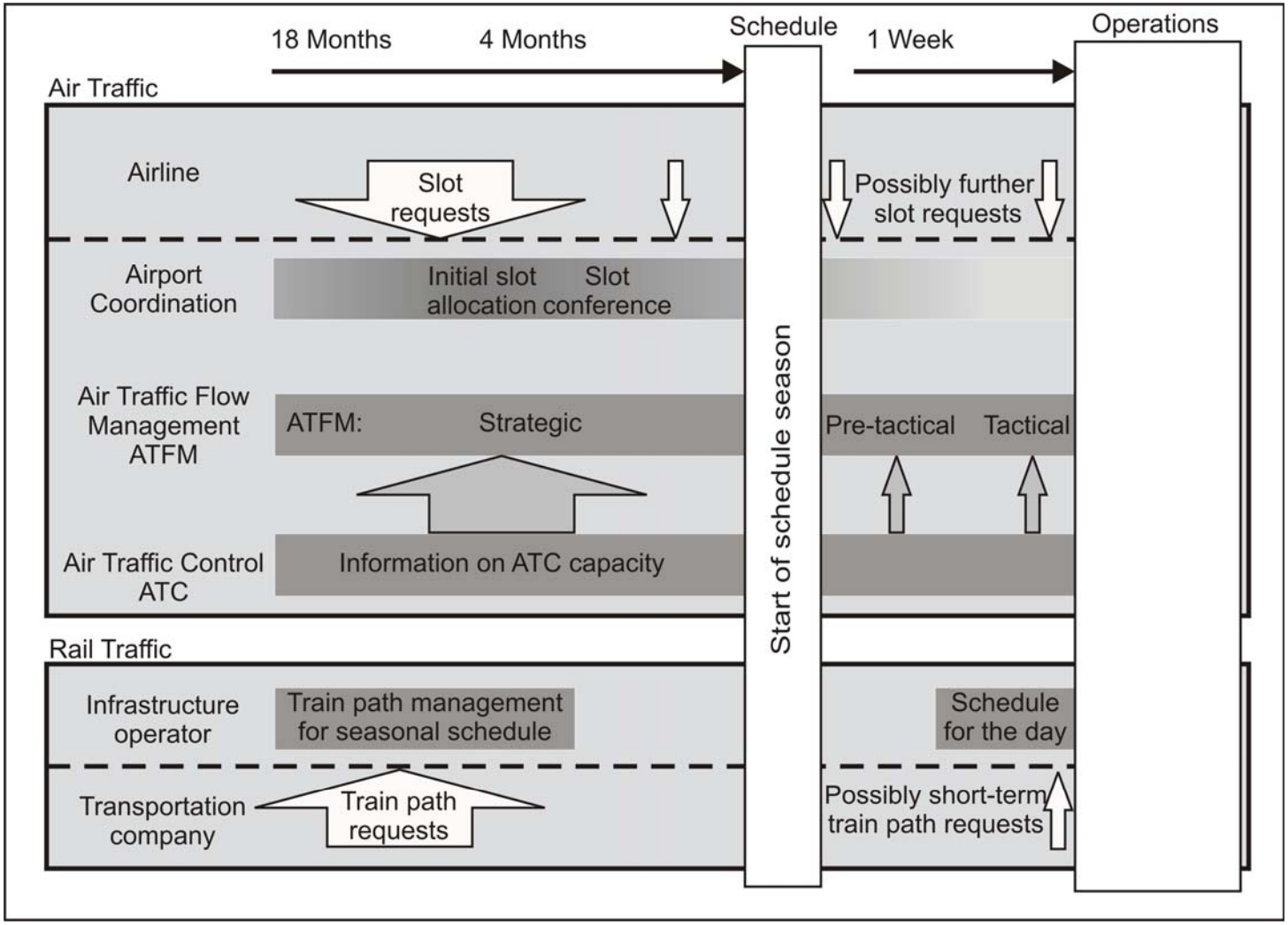
➡ Minimum on-the-minute planning precision necessary

Approximate coordination of traffic demand, limited meaning for operational activities

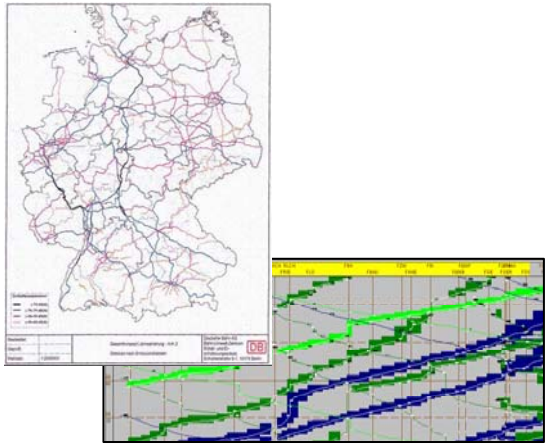
Air traffic end customer is less sensitive to delays and reaches the airport with sufficient time buffer before the scheduled time

➡ 10-minute-slot-windows are sufficient

Pre-tactical and Tactical Planning



Dispatcher



Only in case of operations being out of schedule:

- Disposition from the control centre
- Revision, modification and adaptation of previous planning/schedule of operations

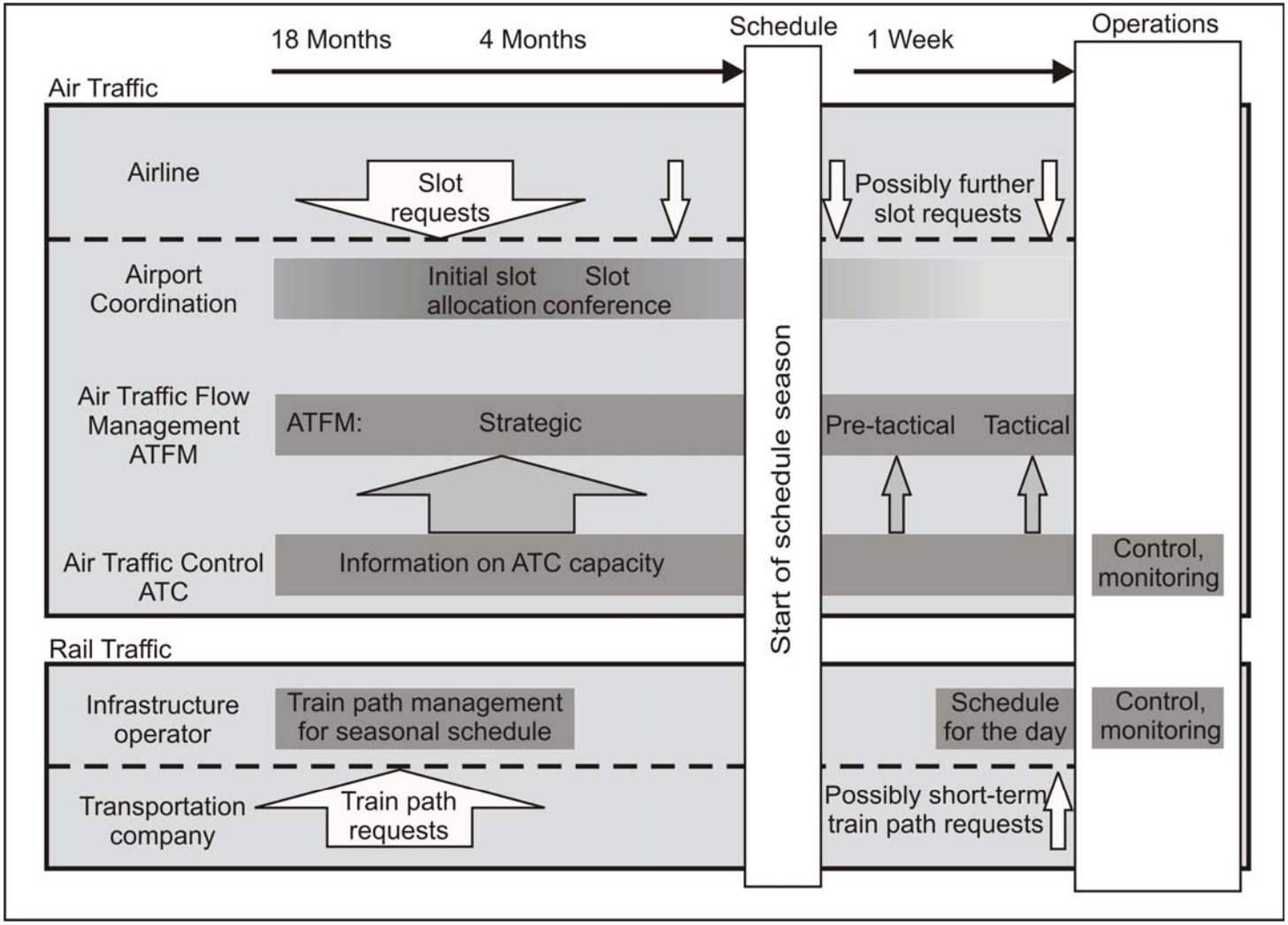
Disposition uses priority-regulation-strategy to return to scheduled operations as quickly as possible

Controller

Previous planning requires short-term specification and precision by controller's ad-hoc-decisions

Controllers use „First-come-first-served“-strategy

Operations


18 Months
4 Months
Schedule
1 Week
Operations
Air Traffic
Airline
Slot requests
Possibly further slot requests
Airport Coordination
Initial slot allocation conference
Slot conference
Air Traffic Flow Management ATFM
ATFM:
Strategic
Pre-tactical
Tactical
Air Traffic Control ATC
Information on ATC capacity
Control, monitoring
Start of schedule season
Rail Traffic
Infrastructure operator
Train path management for seasonal schedule
Schedule for the day
Control, monitoring
Transportation company
Train path requests
Possibly short-term train path requests

- Performance/ quality parameters
- Capacity, capacity function
- Level-of-Service

Performance parameters

- Flight movements/train runs per unit of time, e.g. Mvts/h
  (Possible also but less common: Per unit of area/space)

Quality parameters

- Various criteria: E.g. safety, environmental impact, cost effectiveness, speed, punctuality etc.

- With regard to capacity analysis for air/rail traffic:

Waiting Times (Delays)

Waiting Times (Delays): Deviation of a train/flight at a specific location from its planned time => Difference between reference/actual time

Rail Traffic

- **Scheduled Waiting Times:** Occurrence during schedule creation/train path management
- Adjustment/retiming of requested train paths
- **Non-scheduled (reactionary/ secondary) Waiting Times:** Train run‘s operational deviation from its planned/scheduled trajectory
- Do not occur when operations 100 % according to schedule (no exterior/ interior influences on operations)

Waiting Times (Delays)

Air Traffic

.....??

- **Delays:** Quality criterion for air traffic operations which is classified according to flight phase and delay cause
- Limited suitability of delay measurement based on scheduled block times only

Capacity: Processing capability of a service facility over some period and in compliance with a desired quality of service

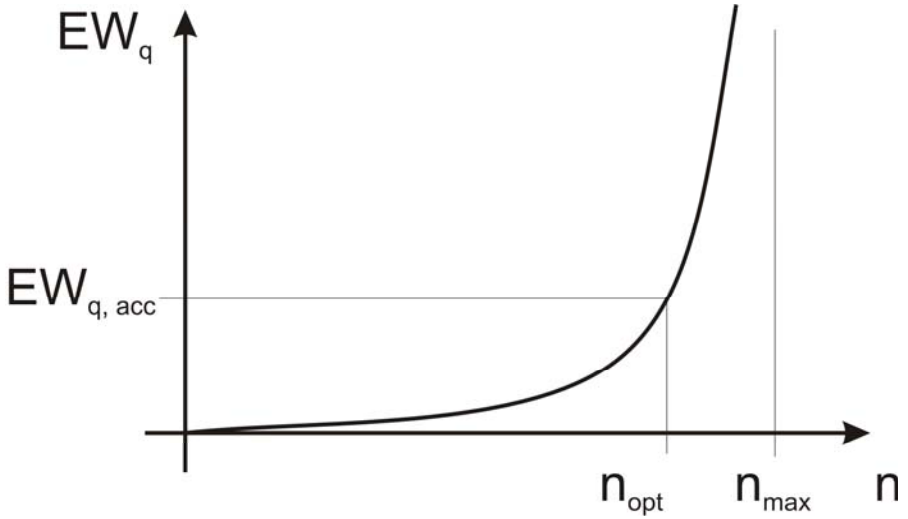
➡ Different measures of capacity: Sustained, declared, saturation, practical etc.

Capacity determination:

➡ empiricism

➡ analytics

➡ simulation



EW_q	... Expected waiting time (total or average)
$EW_{q,acc}$	... Acceptable expected waiting time (total or average)
n	…Demand (No of flight movements, train runs)
n_{max}	…Saturation capacity
n_{opt}	…Practical capacity

Rail Traffic

Published LoS:

- A passenger train run is considered being punctual, if it arrives/departs within **5 min** from its scheduled time
- Early arrival/departure of no significance for passenger trains

→ Compulsory percentage buffer in scheduled times

For planning purpose:

- Acceptable queuing length during scheduling
  and
- Acceptable queuing length during operations
- Threshold depends on the proportion of passenger trains

Level of Service

Air Traffic

Published LoS:

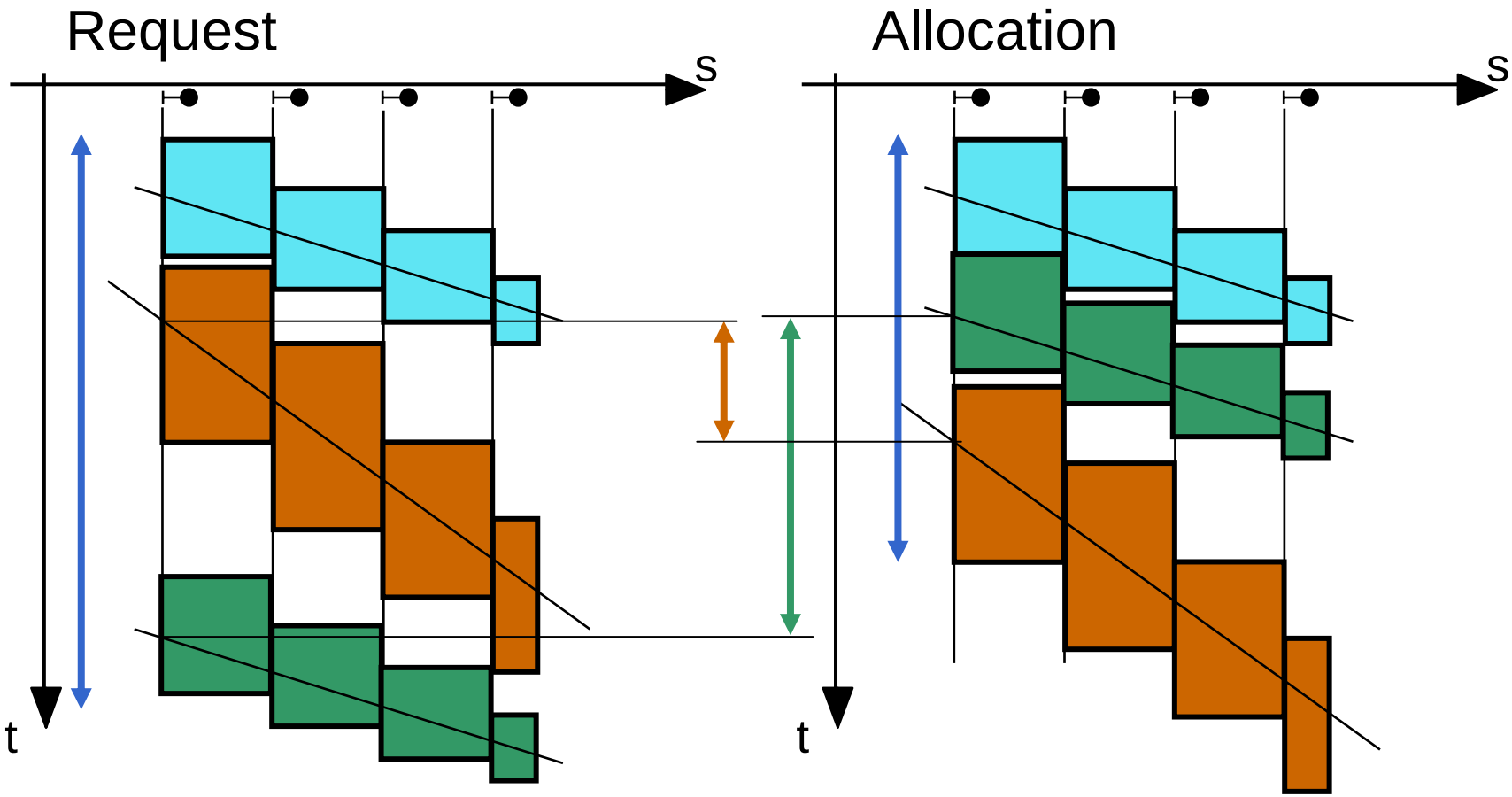
- A flight movement is considered being punctual, if it arrives/departs within **15 min** from its scheduled time
- No/very few early departures, but significant proportion of early arrivals

→ Possible buffer in scheduled times

For planning purpose:

- Acceptable average delay per flight movement during operations only
- Threshold varies from 2 to 10 min, 4 min used most commonly
- No consideration of strategic planning (scheduling phase)

LoS: Scheduled Waiting Time



Less infrastructure occupation

BUT

scheduled waiting times

- Continuative research – air traffic: planning/scheduling/slot allocation

Motivation and objective

Synopsis: Disregard of strategic planning phase (scheduling) in air traffic capacity models

Aviation community's increasing awareness of this phase‘s relevance with regard to capacity scarcity in air transportation network nodes (airports)

Within the Virtual Institute's research activities: Integration of the scheduling phase into capacity modelling being based on

- Precise analysis of the slot allocation process and its impact on the day-to-day operations
- Modelling of the slot allocation process
- Development and formulation of adequate performance/quality parameters to evaluate this phase

Approach

Focus on airport scheduling (slot allocation) only

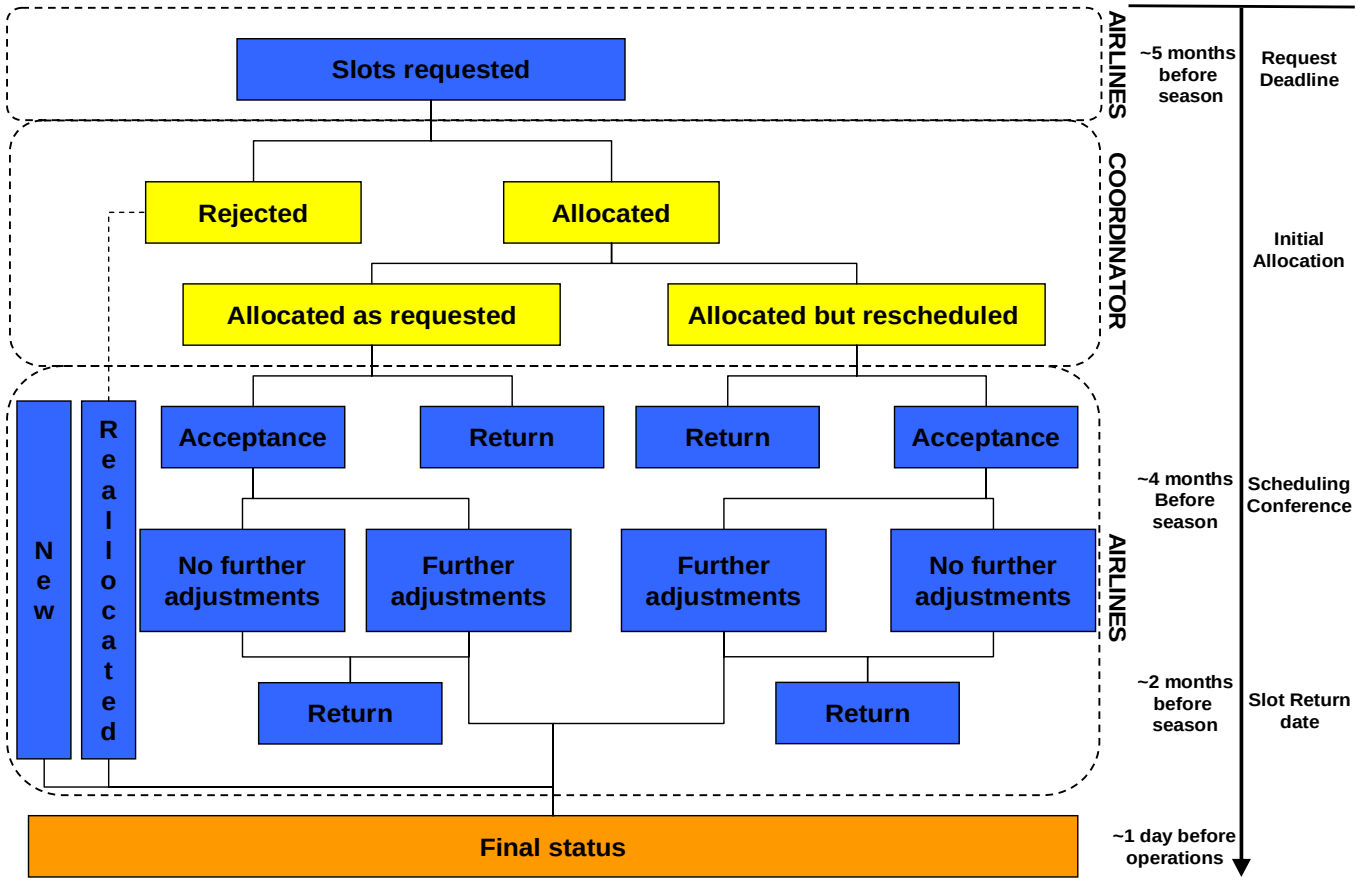
Summer 2005 scheduling season (217 days), data cooperation with German airport coordination office (FHKD), slot allocation status updated weekly

Current analysis addresses 3 main parts:

- Scheduling inefficiencies causing suboptimal utilisation of available capacity (not economic inefficiency, proportion of slots not usable)
  => preliminary results
- Predictability achievable during scheduling (traffic volume)
  => preliminary results
- Retiming/rejection and adjustment/ return of requested slots resulting in a certain kind of *? air traffic scheduled delays ?*

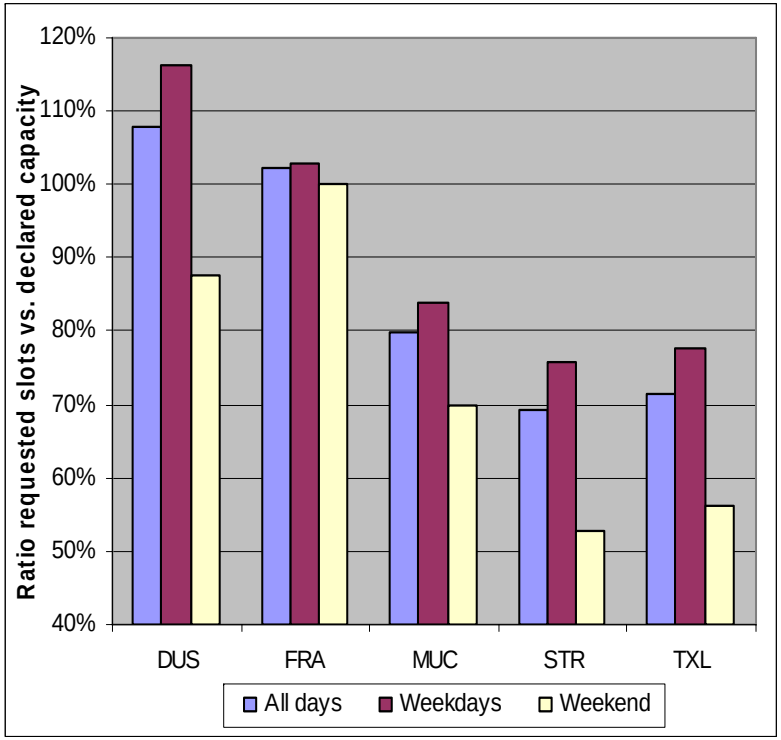
Relevant slot allocation key moments

- Input parameter: Declared airport capacity



Initial Request: Capacity utilisation

/source: FHKD/



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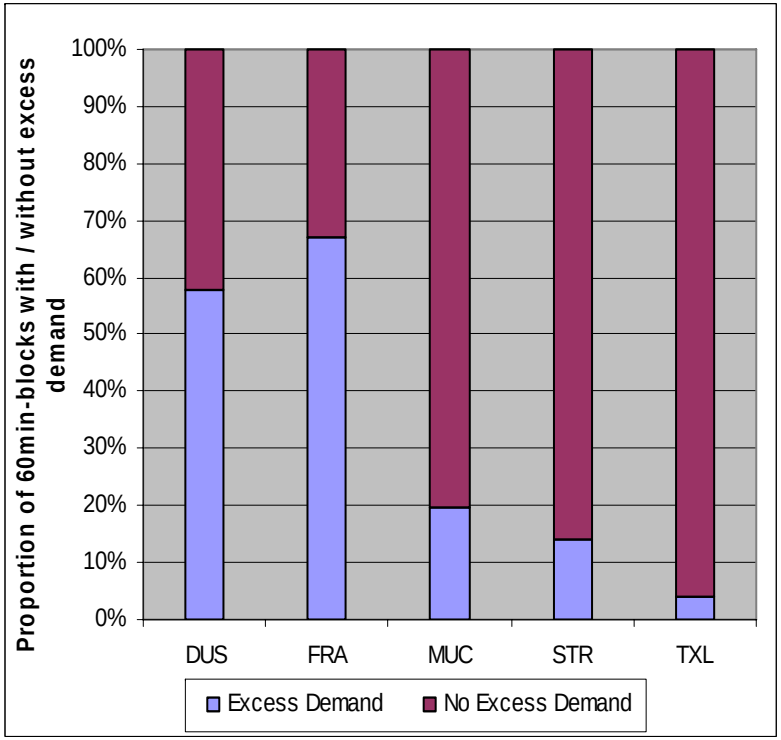
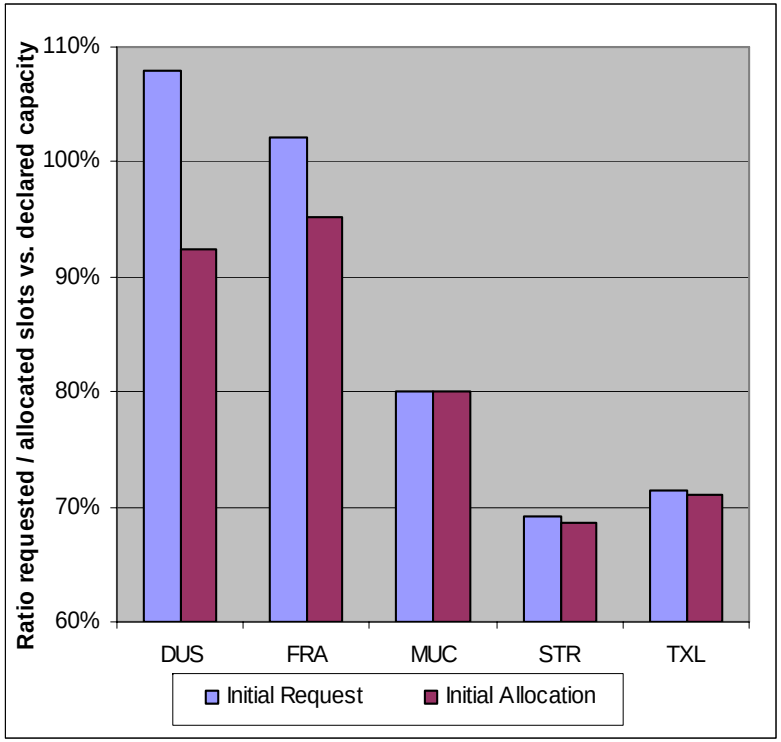


- Total movements (ARR+DEP), 06:00 – 23:00 LT
- Significant excess demand in FRA and DUS

Initial Allocation: Capacity utilisation

/source: FHKD/



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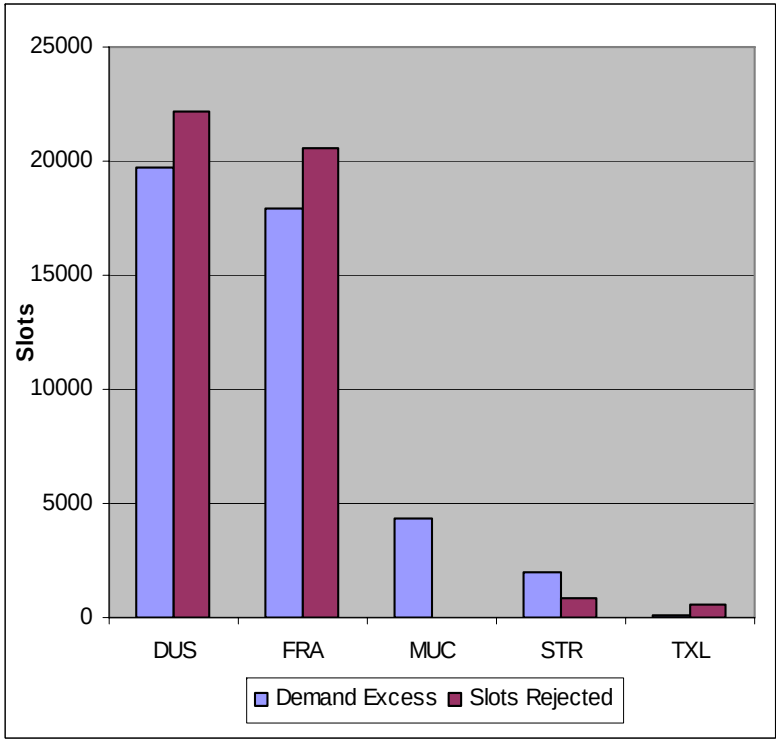
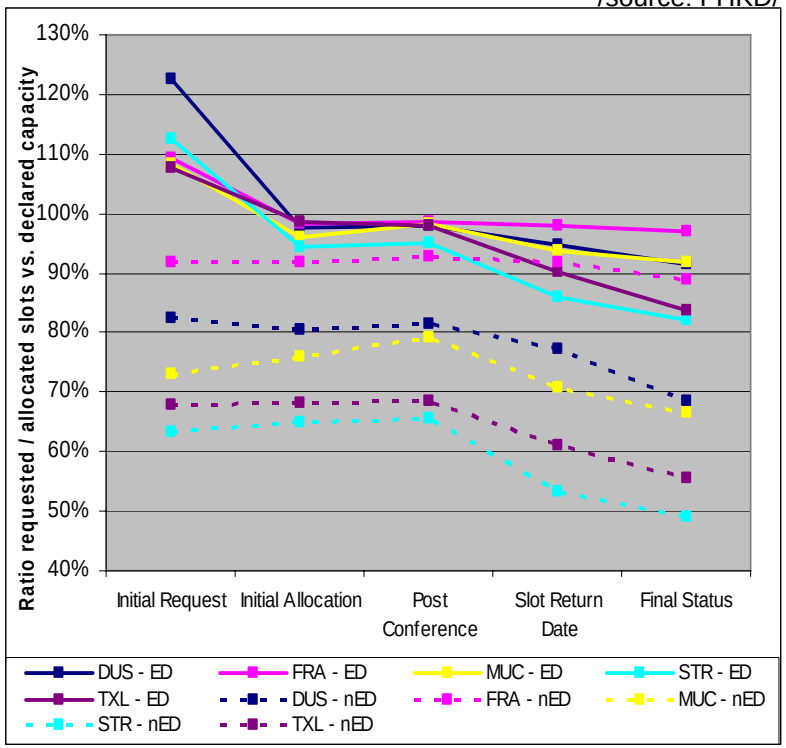


- Significant number of rejected slot requests in FRA/DUS
- Retiming instead of rejection in MUC/STR, gaps available

Slot allocation key moments: Capacity utilisation

/source: FHKD/



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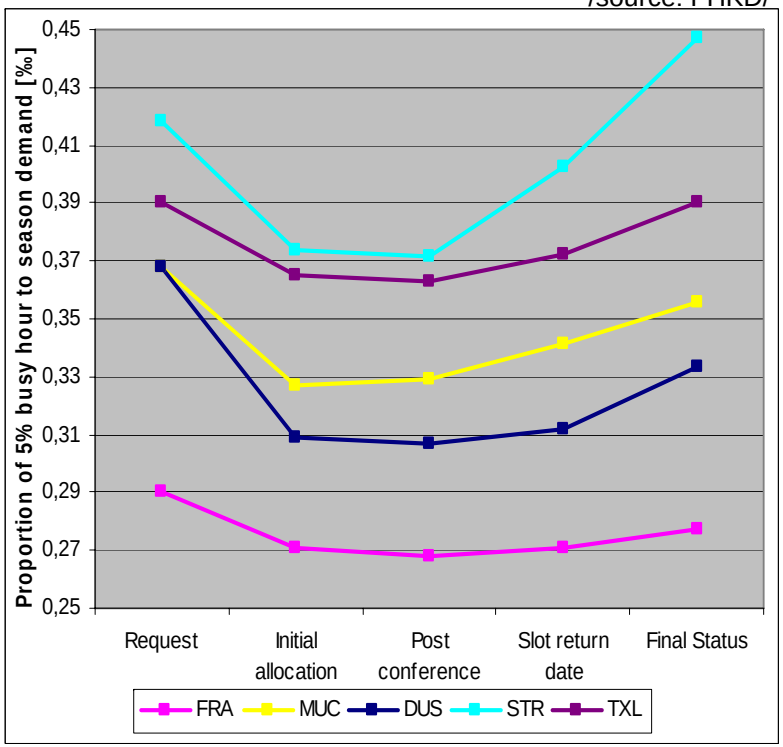
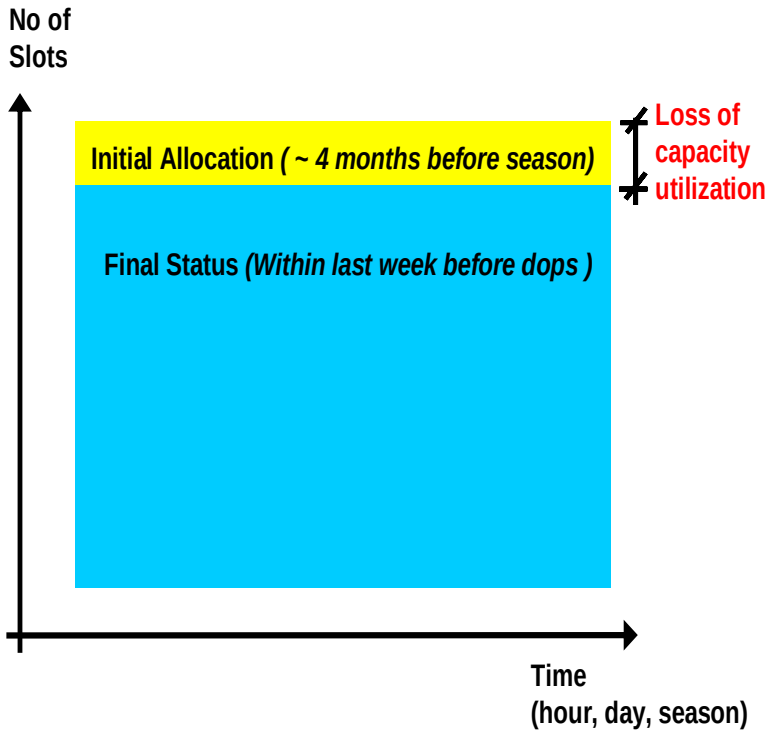


➡ Loss of capacity utilisation during slot allocation process

➡ “Re-peaking” of demand pattern

From allocation to final status: Loss of capacity utilisation



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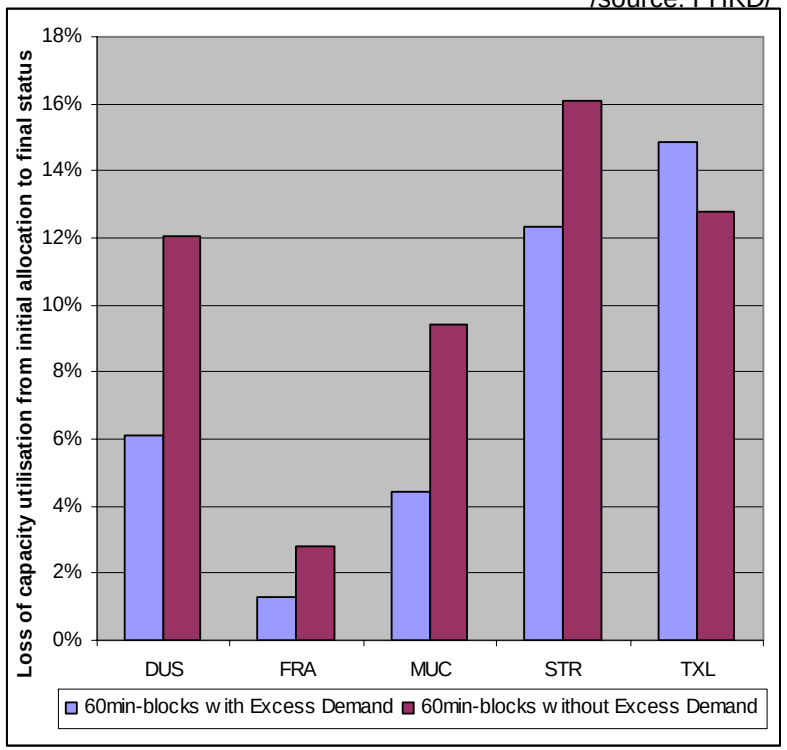


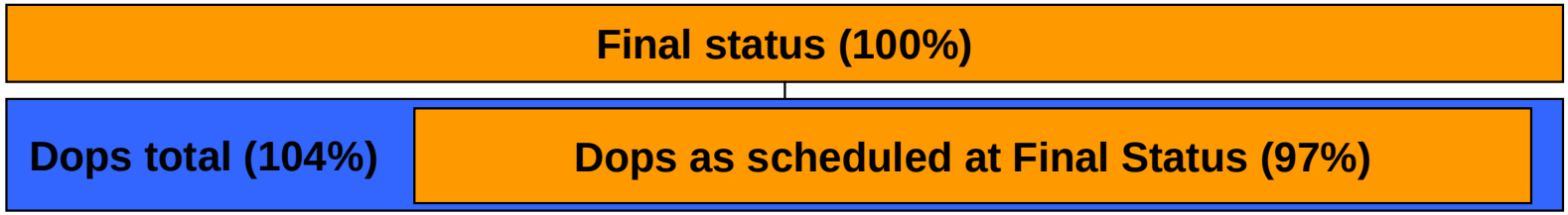
- To quantify scheduling inefficiency: Loss of capacity utilisation
- Major relevance: Time periods with initial excess demand

Loss of capacity utilisation: Possible reasons

- **Slot allocation regulations**
  (No severe penalties in case of non-compliance, generous 80/20 rule, scheduling of slot return date, re-allocation/retiming mechanisms, only few local guidelines)
- **Airline commercial reasons**
  (overbidding, late returns)
- ….

Scheduling predictability: Traffic volumes

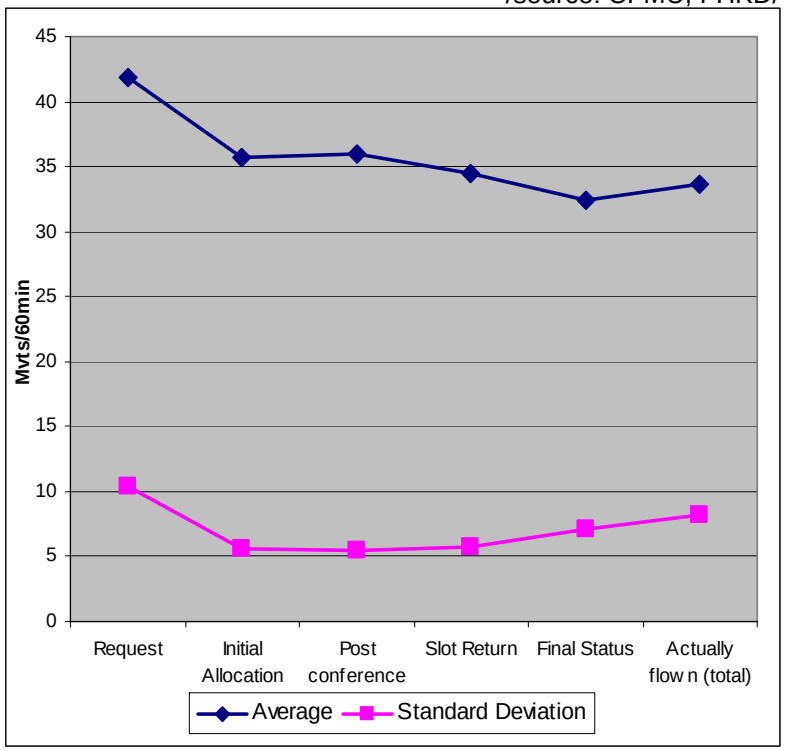
/source: CFMU, FHKD/



- DUS, summer 2005 scheduling season
- Dops (days of operations) total: Total number of IFR flights
- 3 % decrease of capacity utilisation as scheduled (no shows, short-term slot returns)
- 4 % increase of capacity utilisation compared to final coordination status (ac-hoc charter, taxi flights, General Aviation, etc.)

Scheduling predictability: Traffic volumes

/source: CFMU, FHKD/



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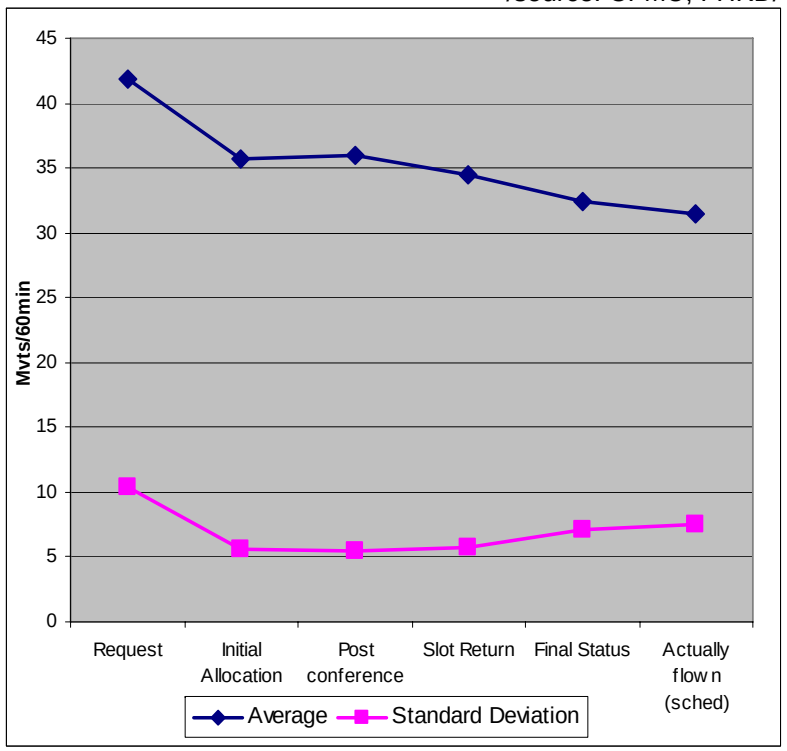

- DUS, rolling 60min blocks, whole season, ARR + DEP
- Approach to measure the level of predictability achievable during scheduling

Conclusions

- Significant similarities based on the identical classification as traffic systems with scheduled operations
- Virtual Institute‘s interdisciplinary approach confirmed – synopsis forms a basis for the reciprocal use of capacity theories/models, thus the use of synergy is enabled
- Continuative, but separate work in the fields of air and rail traffic capacity research is encouraged
- Slot allocation analysis’ preliminary results show the scheduling’s relevance with regard to capacity scarcity in air transportation network nodes
- Data analysis will be continued aiming at a precise modelling of scheduling processes