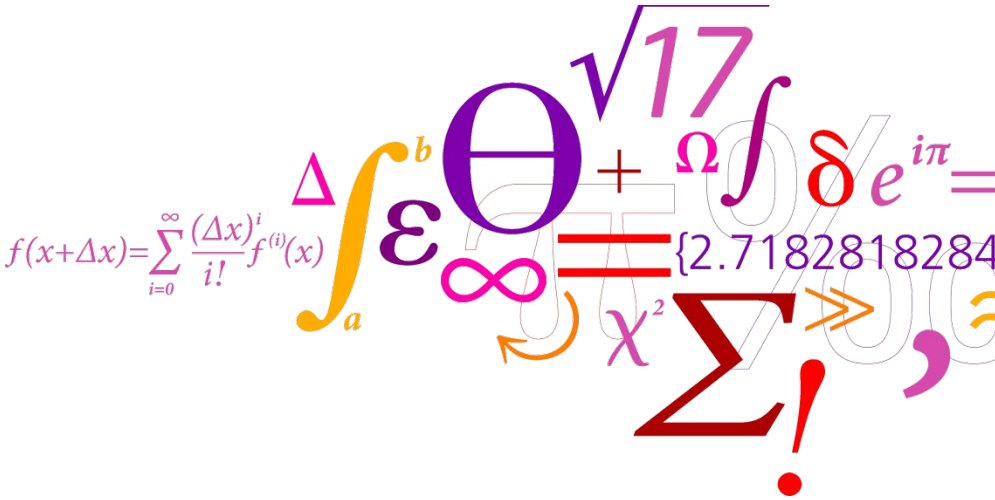
Operations Research at Copenhagen Airport

Anders Høeg Dohn



DTU Management Engineering
Department of Management Engineering

Copenhagen Airport

“An Operations Analyst in an Airport

is like a kid in a candy store”

Agenda

- Introduction to Copenhagen Airports A/S
- OR Optimization Methods in CPH
- Flow in the Airport
  - Passenger Flow in the Airport
    - Check-in Optimization
    - Manning Security
    - Manning the passport control
    - Baggage handling
    - Customs
  - Aircraft Flow in the Airport
    - Air Traffic Controllers
    - Ground Handling
    - Stands and Gate Optimization

Introduction to Copenhagen Airports A/S

- Copenhagen Airports A/S
  - Owns and operates the airports at Kastrup (CPH) and Roskilde (RKE)
  - Approximately 1900 employees
  - Makes its infrastructure, buildings and service facilities available to the many companies that have business operations at the airport.
- Mission
  - “Connect passengers and airlines — and bring Scandinavia and the world together”
- Vision
  - “Be the best airport in the world for passengers and airlines”
- Goals
  - Satisfaction: Top 3 in Europe by 2010
  - Growth: 30 million passengers in 2015
  - Competitiveness: Total operating costs for airlines: “Best in class”, 2012

Introduction to Copenhagen Airports A/S

- Facts
  - Founded in 1925
    - One of the first civil airports in the world
  - 39.2 % of the share capital held by the Danish State
  - 53.7% of the share capital held by Macquarie Airports Copenhagen ApS
  - **2 groups of customers: airlines and passengers**
  - Main airport / hub of Scandinavia
  - Main airport / hub of SAS
  - Scandinavian hub for DHL
  - Largest workplace in Denmark – approximately 22.000
  - Direct connections to a total of 140 destinations (July 2010) worldwide
  - **Number of operations in 2009 (take-offs and landings):** 236,172
  - **Number of passengers in 2009:** 19,7 million
  - **Cargo volumes in 2009:** 312,179 tonnes

OR Optimization Methods in CPH

- CPH is in operation 24/7/365
  - Primary focus is on ensuring a reliable and well driven airport
  - The operation has first priority no matter what (!)
- Historically CPH has had sufficient capacity in all areas
  - Motivation for optimization not present
- Airport = An OR candy store…BUT
  - OR optimization methods are still only applied to a small fraction of its potential areas.
  - If OR optimization methods are used, it is within externally delivered software products, i.e. development is not conducted/decided upon by CPH.
  - OR competences not present in-house (…)
- Next step
  - Is optimization needed?
  - What is optimization?
  - What defines an optimal solution?

OR Optimization Methods in CPH

- Is optimization needed?
  - Can we accommodate todays traffic without optimization?
    - Check-in?
    - Stand and gates?
    - Baggage?
  - Can we go from 19,7 to 30 mio pax in 5 years without investing?
    - Buildings?
    - Employees?
    - Equipment?
  - Can we utilize our facilities better than we do today?

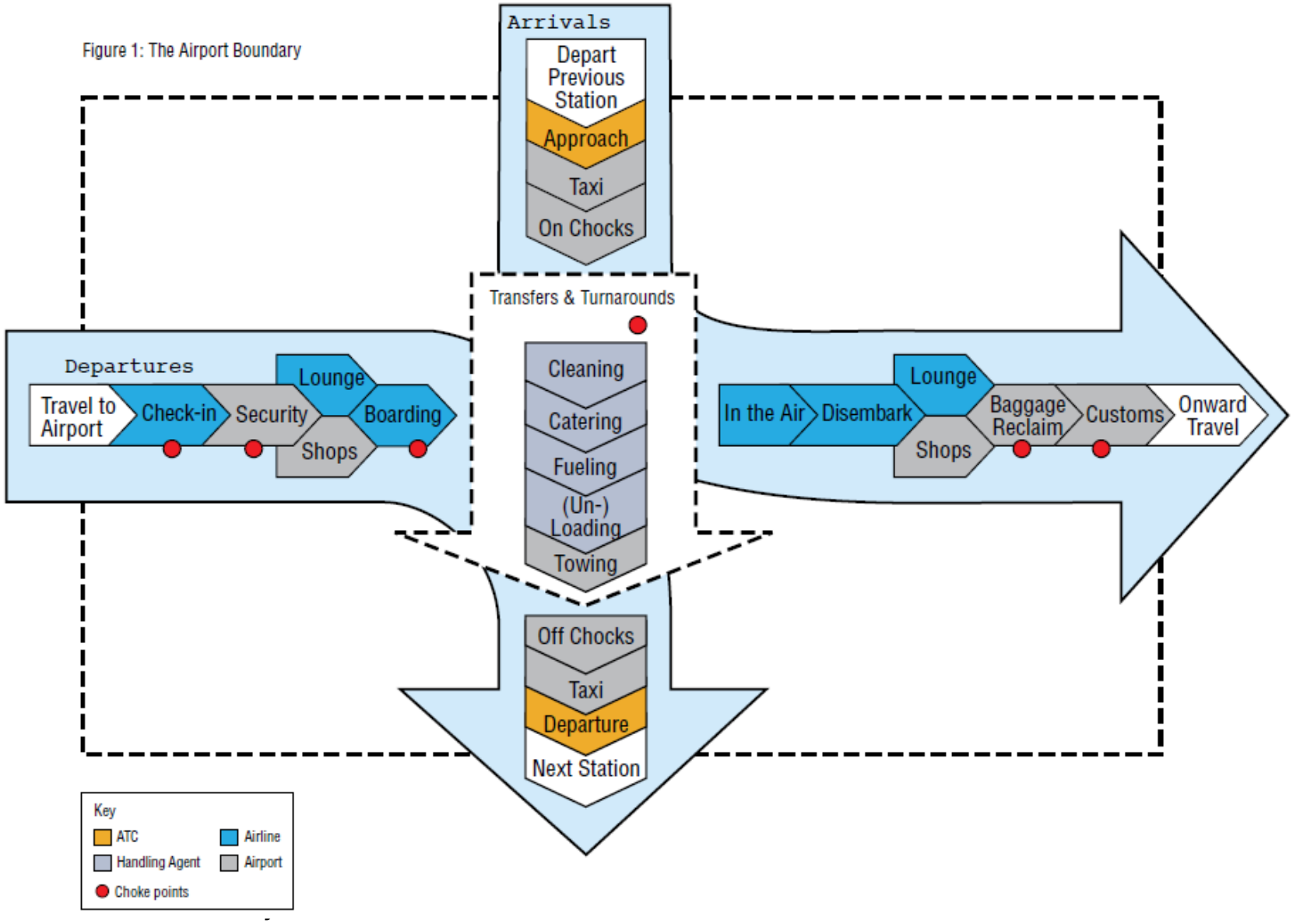
OR Optimization Methods in CPH

- What is optimization?
  - That you have made all of your calculations / planning in Excel?
  - That you are doing things in the same way as always?
  - That you find a feasible solution?
  - That you intelligently use statistical data and apply known OR optimization methods?
- Definition of “optimality” differs a lot within the company
  - Investors define optimality from a purely cost driven perspective.
  - For some departments optimality is when all tasks are covered, regardless of the number of people used.
  - For some departments optimality is when all employees have their wishes fulfilled.
  - For some departments optimality is when things are done in the way they have always been done.

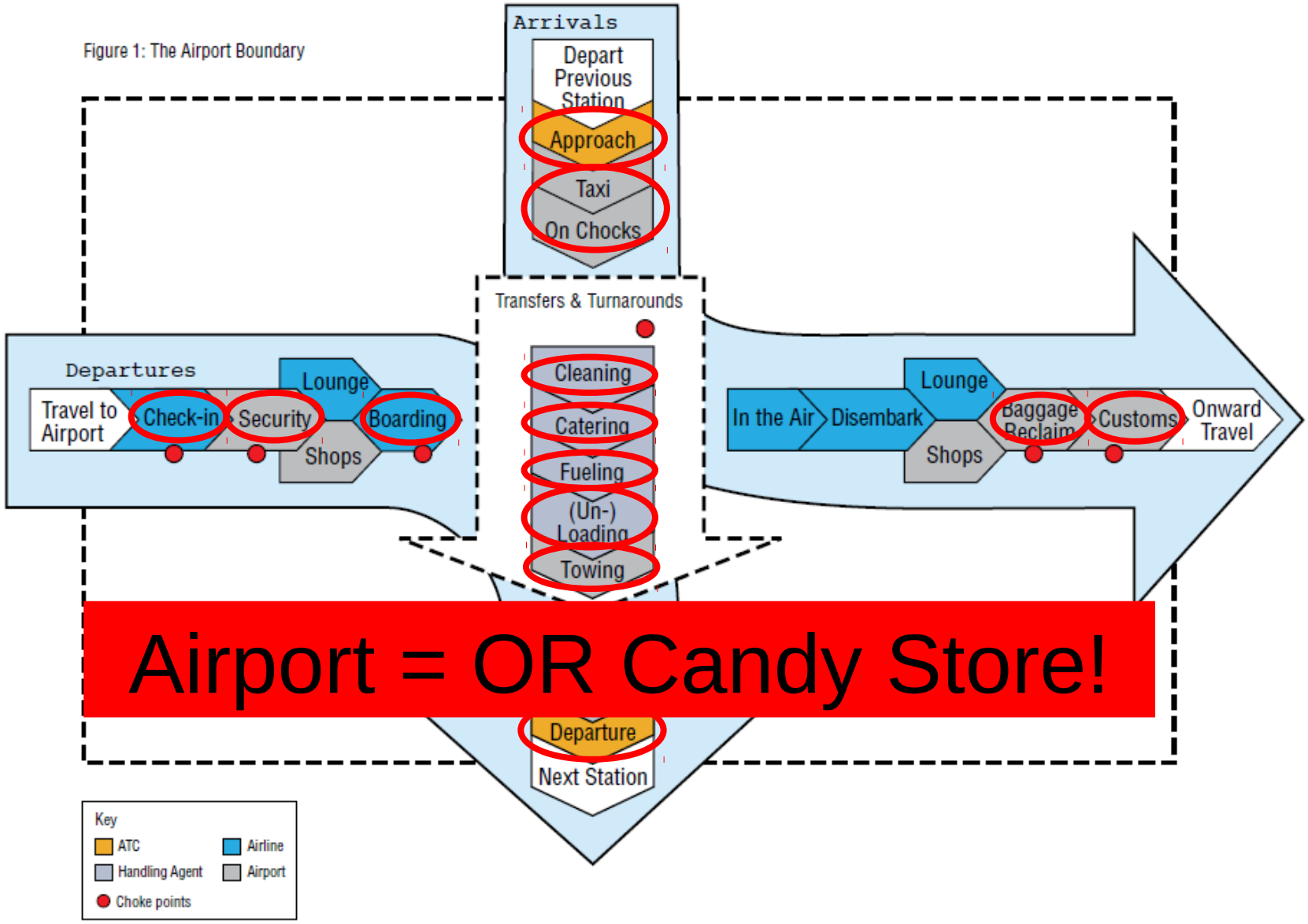
OR Optimization Methods in CPH

- So what are we doing?
  - Establishment of a centralized **Planning and Analysis** department (November 1st, 2010)
    - All analysts in the Operations Department (Passenger Service, Traffic Handling, Baggage Handling, Security, Environment, Quality, Roskilde Airport and Lean) gathered in one place.
    - All analyses relating to the Operations Department.
  - Projects:
    - Check-in optimization
    - Security / Police manning
    - Stand and Gate optimization
    - Baggage Sorting
    - Baggage Racetrack Allocation
    - Capacity Analyses of all of the above
    - “One Set of Numbers”
    - ?

Passenger / Aircraft Flow in the Airport

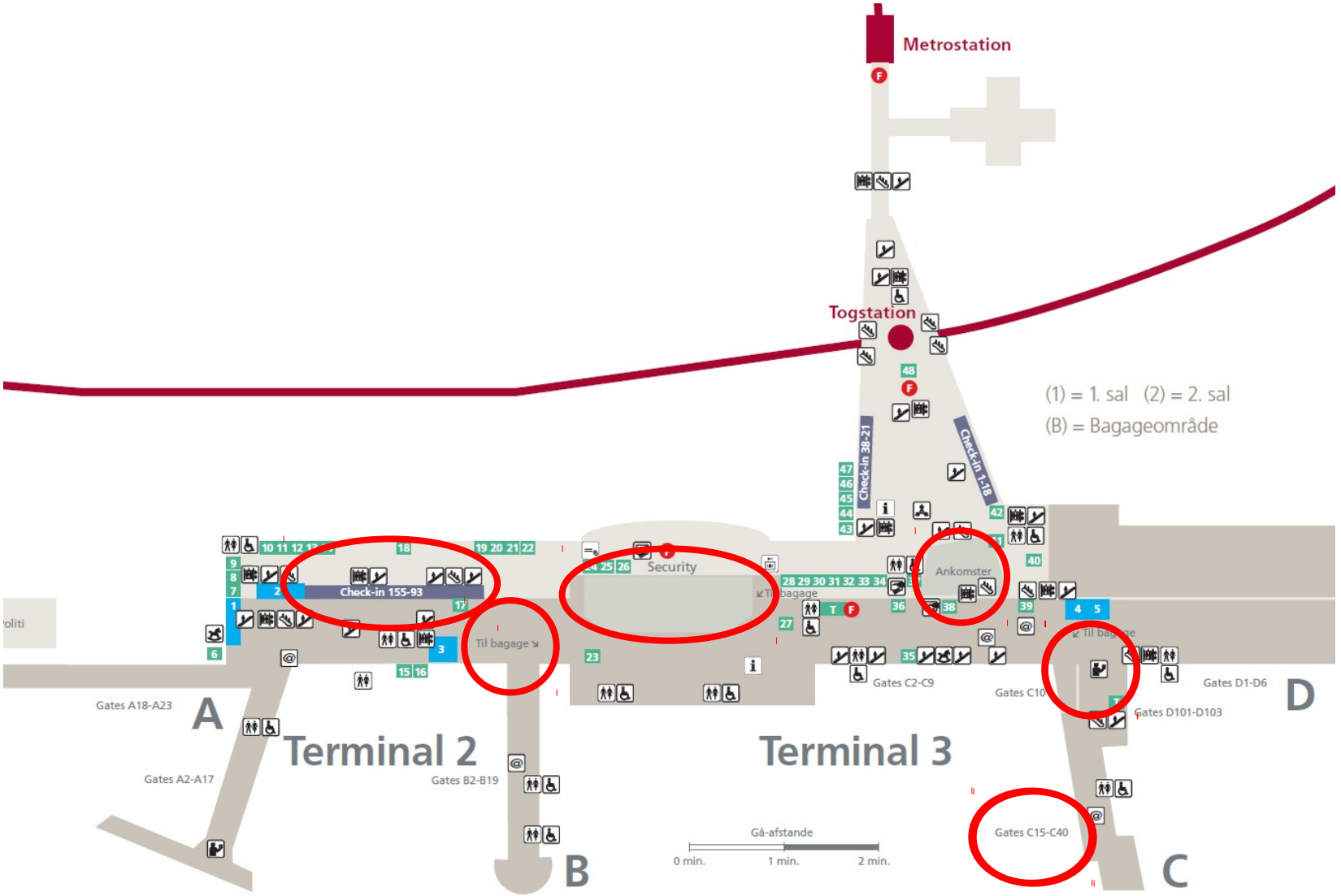


Passenger / Aircraft Flow in the Airport



Airport = OR Candy Store!

Passenger Flow in the Airport



Passenger Flow in the Airport

- All passengers are on an inbound or outbound flight.
- We know about all flights in advance.
  - Hence, we have a pretty good idea about passenger appearance.

Table

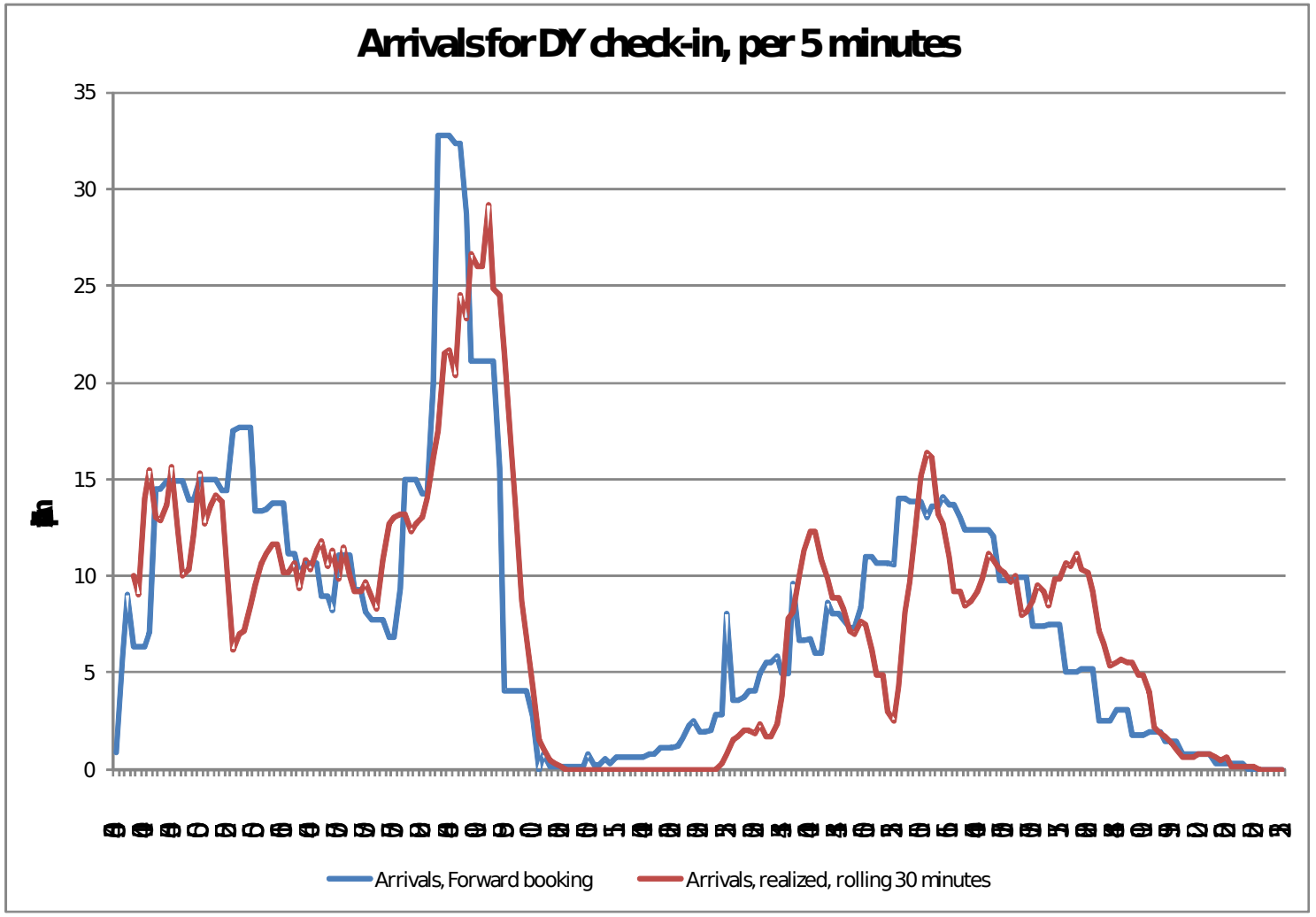
ATO - (CET) Timestamp	Operation type	Flight category	Operator		Destination 1		Plane type	Routenumber	Counter	Seat Capacity
2010/11/27 01:35:00	D	J	PC	PEGASUS HAVA TASIMACILIGI	SAW	Sabiha Gocken (Istanbul)	738	000834	1	189
2010/11/27 05:50:00	D	J	LH	LUFTHANSA	FRA	Frankfurt	733	000833	1	122
2010/11/27 06:00:00	D	J	DY	NORWEGIAN AIR SHUTTLE	RAK	Marrakesh	73H	003406	1	186
2010/11/27 06:05:00	D	C	PF	PRIMERA AIR SCANDINAVIA	LPA	Las Palmas	738	000533	1	189
2010/11/27 06:10:00	D	C	BLX	TUIFLY NORDIC	LPA	Las Palmas	73H	000295	1	189
2010/11/27 06:25:00	D	J	DY	NORWEGIAN AIR SHUTTLE	FAO	Faro	73H	003620	1	186
2010/11/27 06:30:00	D	J	DY	NORWEGIAN AIR SHUTTLE	AGA	Agadir	73H	003400	1	186
2010/11/27 06:30:00	D	J	DY	NORWEGIAN AIR SHUTTLE	MLA	Malta	73H	003530	1	186
2010/11/27 06:35:00	D	J	KL	KLM ROYAL DUTCH AIRLINES	AMS	Schiphol	73J	001124	1	189
2010/11/27 06:35:00	D	J	SN	BRUSSELS AIRLINES	BRU	Bruxelles	AR1	002268	1	97
2010/11/27 06:50:00	D	J	AF	AIR FRANCE	CDG	Paris Charles De Gaulle	320	001351	1	165
2010/11/27 07:00:00	D	C	DK	THOMAS COOK AIRLINES SCANDINAVIA	LPA	Las Palmas	320	003733	1	177
2010/11/27 07:00:00	D	C	SK	SCANDINAVIAN AIRLINES	SSH	Sharm El Sheikh	321	007769	1	198
2010/11/27 07:05:00	D	C	SK	SCANDINAVIAN AIRLINES	AQJ	Aqaba	319	007787	1	141
2010/11/27 07:05:00	D	J	AB	AIR BERLIN	TXL	Berlin Tegel	319	008093	1	144
2010/11/27 07:05:00	D	J	OS	AUSTRIAN AIRLINES	VIE	Vienna	320	000308	1	159
2010/11/27 07:10:00	D	C	SK	SCANDINAVIAN AIRLINES	LPA	Las Palmas	321	007737	1	198
2010/11/27 07:10:00	D	J	JK	SPANAIR	BCN	Barcelona	321	000038	1	212
2010/11/27 07:15:00	D	J	BA	BRITISH AIRWAYS	LCY	London City	E70	008466	1	76
2010/11/27 07:15:00	D	J	SK	SCANDINAVIAN AIRLINES	FRA	Frankfurt	321	000639	1	198
2010/11/27 07:40:00	D	J	BT	AIR BALTIC	VNO	Vilnius	DH4	000162	1	76
2010/11/27 07:45:00	D	J	SK	SCANDINAVIAN AIRLINES	LHR	London Heathrow	321	000501	1	198
2010/11/27 07:55:00	D	C	SK	SCANDINAVIAN AIRLINES	TFS	Tenerife Sur Reina Sofia	321	007711	1	198
2010/11/27 07:55:00	D	J	BT	AIR BALTIC	RIX	Riga Splive	DH4	000132	1	76
2010/11/27 08:05:00	D	J	BA	BRITISH AIRWAYS	LHR	London Heathrow	321	000811	1	188
2010/11/27 08:10:00	D	J	KF	BLUE 1	HEL	Helsinki	AR8	000638	1	84
2010/11/27 08:10:00	D	J	SK	SCANDINAVIAN AIRLINES	BGO	Bergen	M81	002862	1	150
2010/11/27 08:10:00	D	J	SK	SCANDINAVIAN AIRLINES	SVG	Stavanger	CR9	001870	1	88
2010/11/27 08:15:00	D	J	SK	SCANDINAVIAN AIRLINES	AGP	Malaga	M81	000583	1	150
2010/11/27 08:15:00	D	J	SK	SCANDINAVIAN AIRLINES	AMS	Schiphol	M81	002551	1	150
2010/11/27 08:15:00	D	J	SK	SCANDINAVIAN AIRLINES	KRS	Kristiansand Kjevik	CR9	002880	1	88
2010/11/27 08:15:00	D	J	SK	SCANDINAVIAN AIRLINES	TXL	Berlin Tegel	CRJ	001673	1	50
2010/11/27 08:20:00	D	J	SK	SCANDINAVIAN AIRLINES	CDG	Paris Charles De Gaulle	321	000565	1	198
2010/11/27 08:20:00	D	J	SK	SCANDINAVIAN AIRLINES	DUB	Dublin	M81	000537	1	150

Passenger Flow in the Airport

- For each flight, we have forecasts on:
  - Load factor
  - Appearance pattern
  - Bag factor
  - Passenger types (e.g. leisure / business)
- Forecast is based on historic data and differentiated on:
  - Airline
  - Destination
  - Aircraft type
  - Seat capacity
  - Flight type
  - Time of day
  - Handler

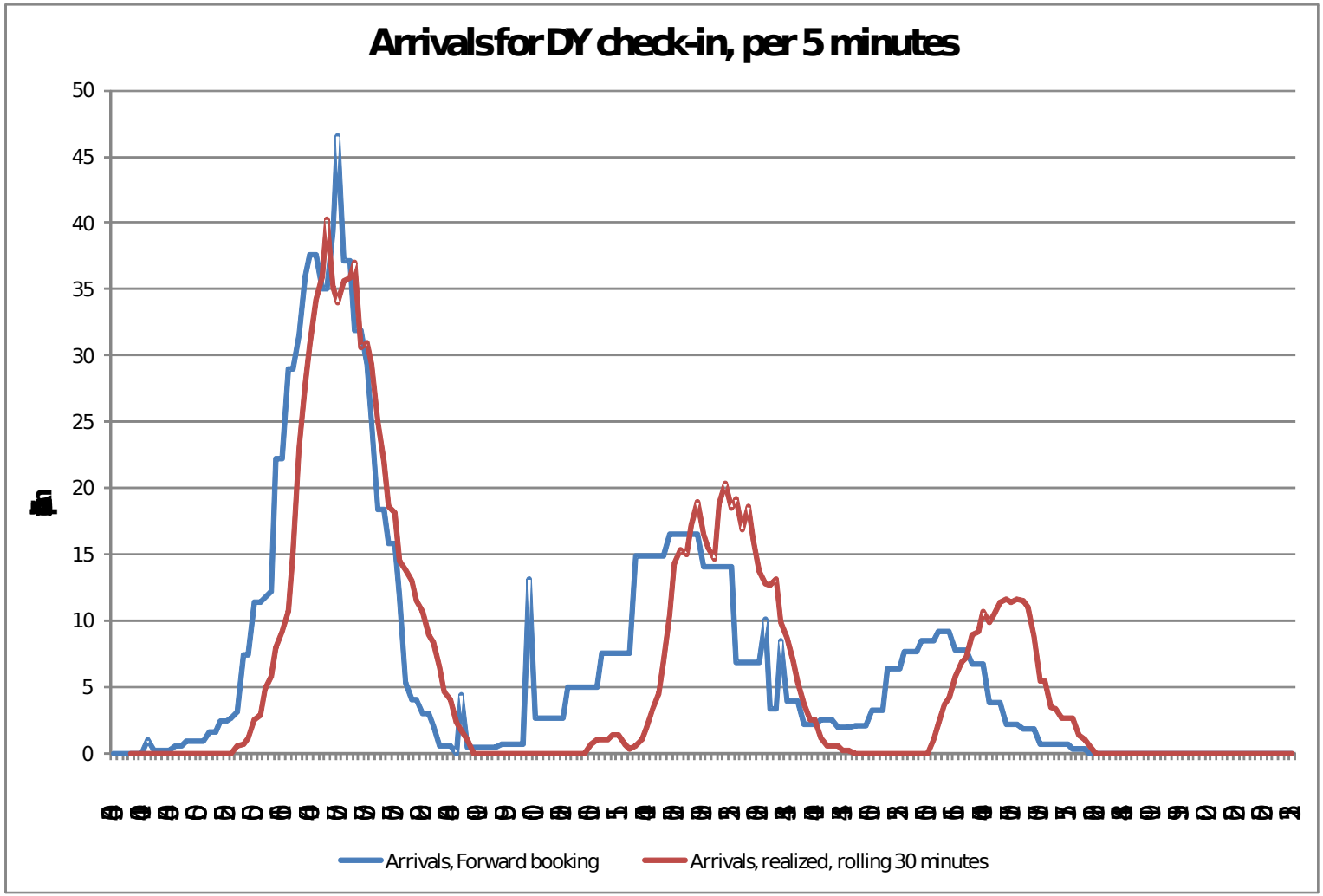
Appearance at Check-in

Arrivals, forecasted vs. realized - Tuesday September 1



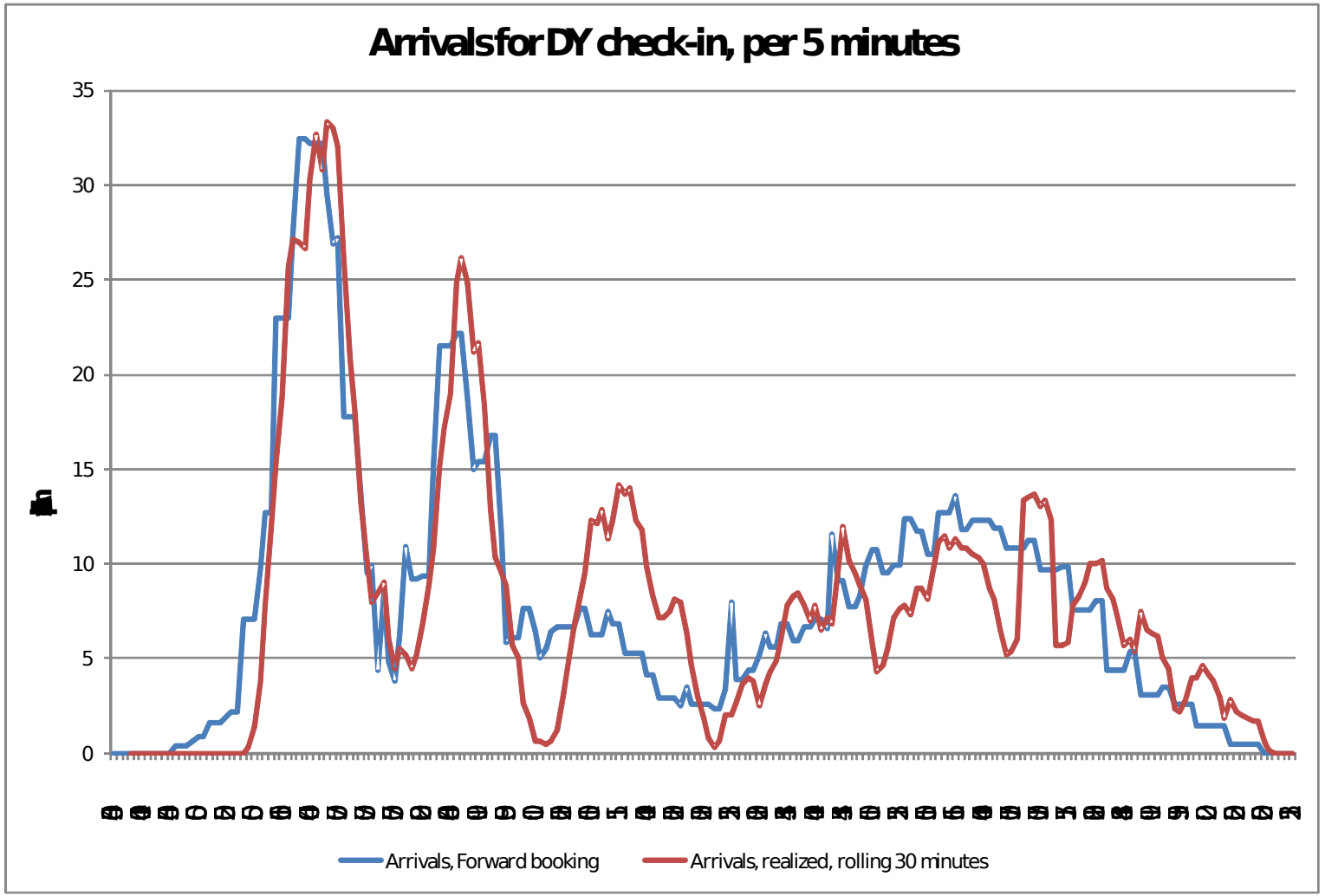
Appearance at Check-in

Arrivals, forecasted vs. realized - Saturday September



Appearance at Check-in

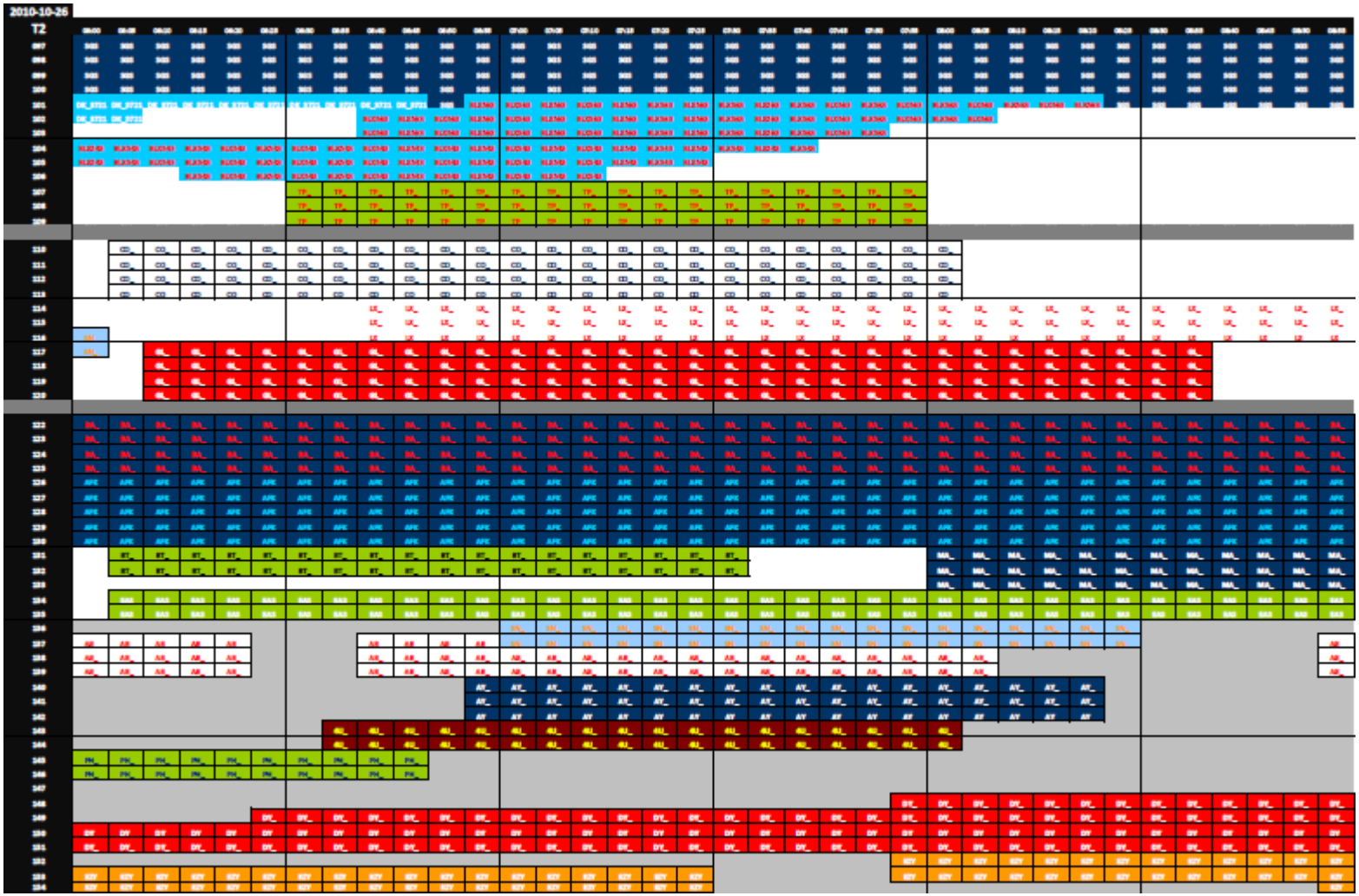
Arrivals, forecasted vs. realized - Sunday September 6



Check-in Optimization

- What is the problem?
  - Opening patterns not optimized to match appearance patterns
    - Driven strictly by SLAs between airlines and handlers
    - CPH: “Only open counters when there are passengers”
  - Allocation of check-in areas
    - Previously handled entirely by the handlers
    - CPH: “Allocation of check-in areas should take baggage belt direction, baggage belt take-away capacity, queue lenghts, CUSS kiosk demand and flow into consideration”
- What have we done?
  - Observation of appearance patterns
  - Dialog with airlines and handlers about opening patterns with CPH suggesting new and optimized opening patterns
  - As of May 3, 2010, CPH controls allocation of check-in areas to counters
    - **Mathematical Modeling and Optimization**

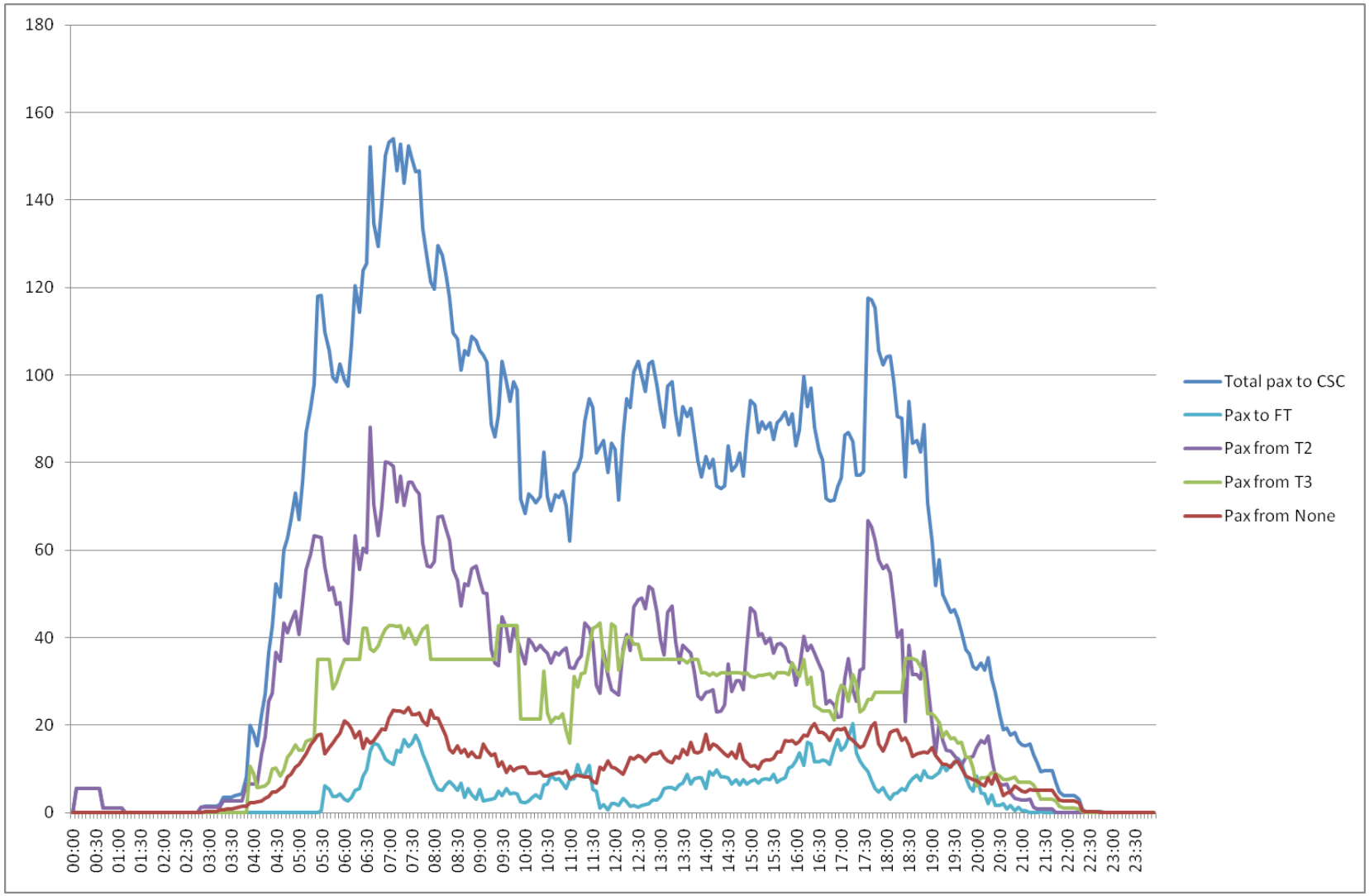
Check-in Optimization



Manning security

- Aggregate passenger appearance for all flights.
  - Incorporate the waiting time and processing time for check-in.
- Remove passengers that go through SAS Fast Track.
  - All other international passengers go through CSC.
- We assume that all passengers are identical.
  - However, we differentiate between summer / winter.
    - More clothes means longer processing time.

Manning security



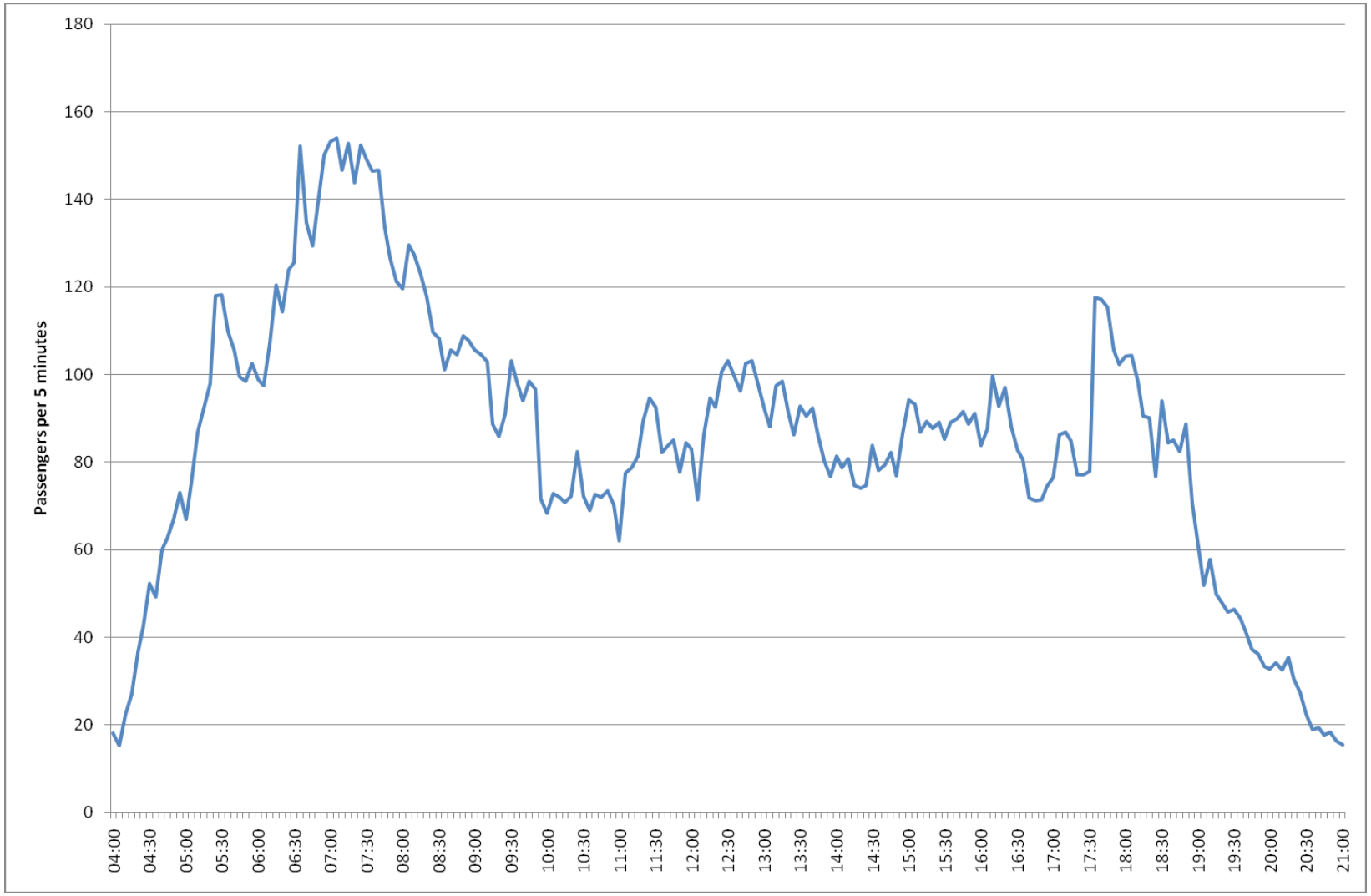
Manning security

- Converting a passenger forecast to a plan:
  - SLA’s (Service Level Agreements) define constraints for the acceptable quality level.
  - Robustness considerations add to the demands.
  - Optimization objectives:
    - Minimize manpower allocation (minimize cost).
    - Maximize employee satisfaction.

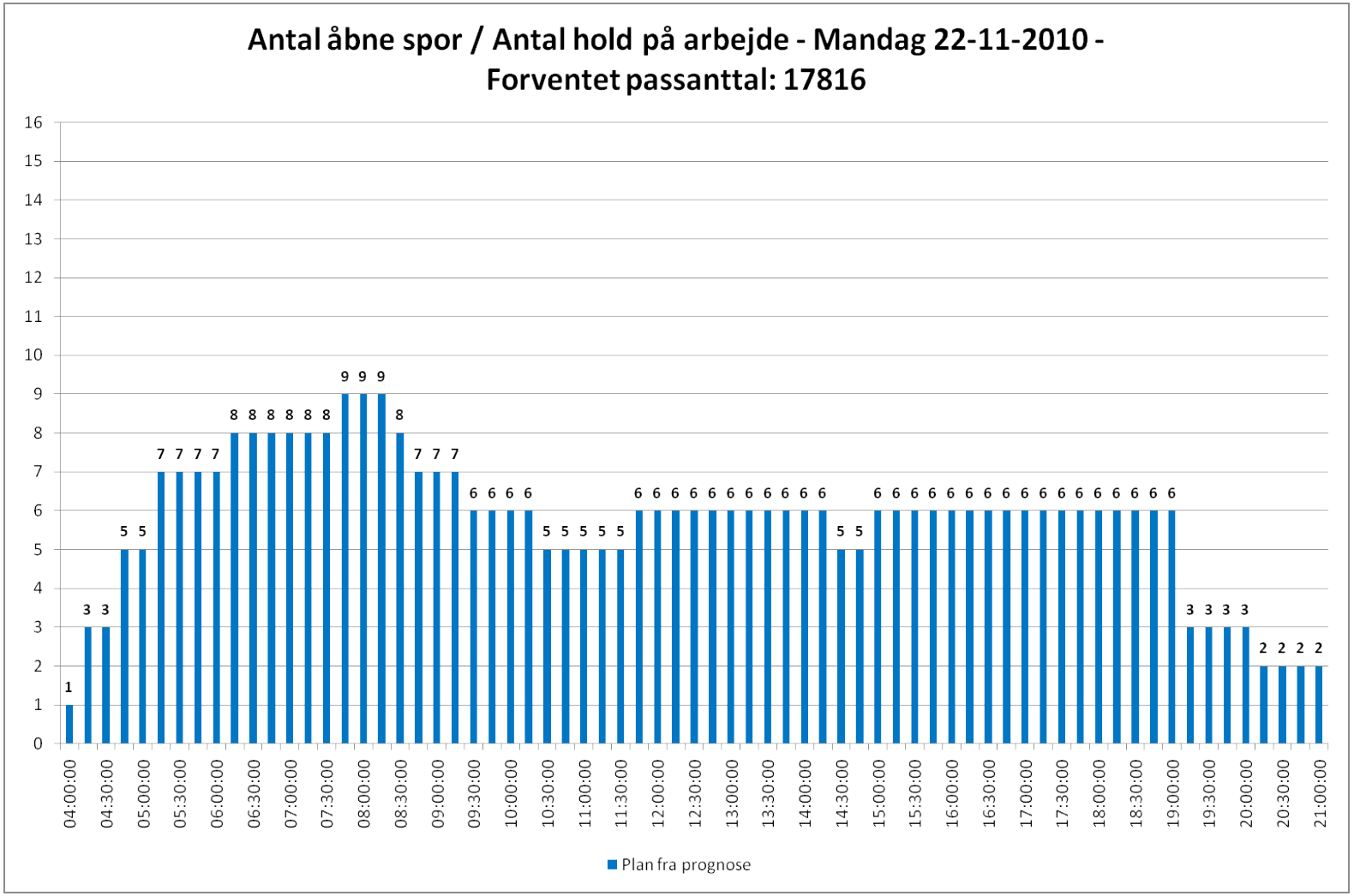
Manning security

- Currently, we use a greedy heuristic:
  - Initialize cover with large values.
    - All demand is covered. Solution is very expensive.
  - Lower cover as much as possible, while respecting SLA's.
    - Solution value drops to an acceptable level.
    - The quality of the service is still acceptable.
- Next step, enhance algorithm:
  - The problem is an optimization problem with:
    - A "nice" structure
    - "Simple" rules
    - Well defined objectives.
  - Solving the problem to optimality using mathematical programming should be possible.
    - Could make the basis of Master's Thesis!

Manning security: Forecasting and Planning



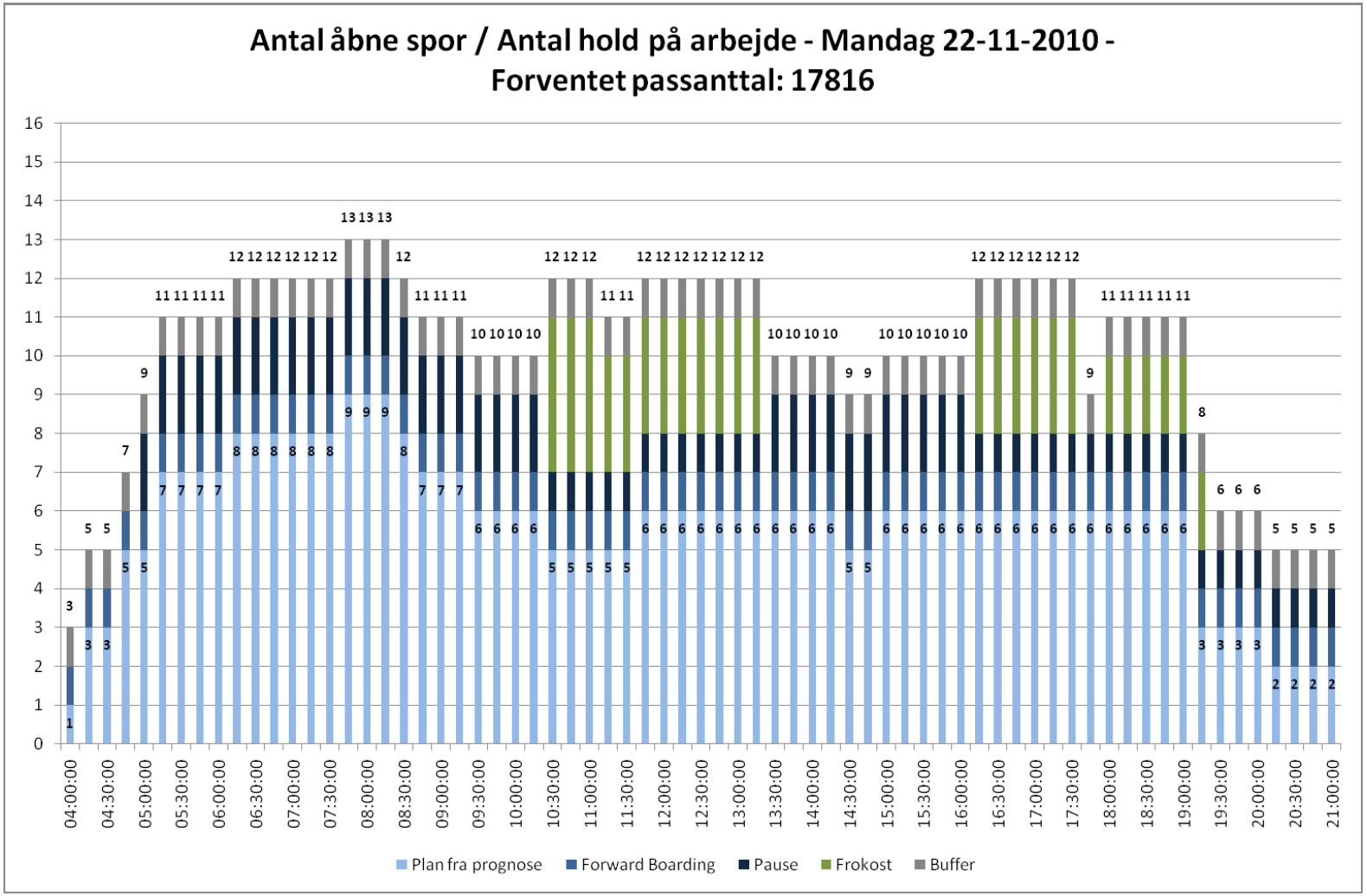
Manning security: Forecasting and Planning



Manning security: Forecasting and Planning

- We need more employees than that.
  - Breaks
  - Lunch breaks
  - Special tasks
  - Buffer

Manning security: Forecasting and Planning



Manning security: Forecasting and Planning

- With a demand per time interval, the demand must be covered by employees on shifts.
- From a “demand per time interval” the “demand per shift” is found.
- The employee shift plans are created to cover the “demand per shift”.

Shift Name	Time
A0	04:00-14:00
A1	05:00-14:00
C	06:00-18:00
D	10:00-20:00
F0	13:00-21:00
F1	14:00-23:00
H3	20:30-06:30
H4	18:00-04:00
K2	08:00-16:00

Manning security: Forecasting and Planning

ST 05	S 005	MANDAG	TIRSDAG	ONSDAG	TORSDAG	FREDAG	LØRDAG	SØNDAG	16	
Tj.nr:	Nøgle:								TIMER	
	1	Vfri	Kfri	C	C	Vfri	Lfri	Lfri	24,00	ulige
	2	A1	A1	Vfri	Kfri	C	C	C	54,00	lige
	3	Lfri	Lfri	A1	A1	Vfri	Lfri	Lfri	18,00	ulige
	4	C	C	Lfri	Lfri	A1	A1	A1	51,00	lige
	5	Vfri	Kfri	C	C	Vfri	Lfri	Lfri	24,00	ulige
	6	A1	A1	Vfri	Kfri	C	C	C	54,00	lige
	7	Lfri	Lfri	A1	A1	Vfri	Lfri	Lfri	18,00	ulige
	8	C	C	Lfri	Lfri	A1	A1	A1	51,00	lige
	9	Vfri	Kfri	C	C	Vfri	Lfri	Lfri	24,00	ulige
	10	A1	A1	Vfri	Kfri	C	C	C	54,00	lige
	11	Lfri	Lfri	A1	A1	Vfri	Lfri	Lfri	18,00	ulige
	12	C	C	Lfri	Lfri	A1	A1	A1	51,00	lige
	13	Vfri	Kfri	C	C	Vfri	Lfri	Lfri	24,00	ulige
	14	A1	A1	Vfri	Kfri	C	C	C	54,00	lige
	15	Lfri	Lfri	A1	A1	Vfri	Lfri	Lfri	18,00	ulige
	16	C	C	Lfri	Lfri	A1	A1	A1	51,00	lige
		4-4	*4-4*	*4-4*	*4-4*	*4-4*	*4-4*	*4-4*	588,00	

A1 = 5-14
C = 6-18

Norm:	592,00	Diff:	-4,00

Manning security: Forecasting and Planning

- Currently, most of this is a manual process.
  - We are currently in the process of buying a Resource Management System to optimize plans.
- Possible Master's Thesis projects:
  - Find optimal "demand per shift".
    - A (much) extended version of the assignment that I gave you at the previous lecture.
  - Generate optimal rosters.

Manning security: Evaluating

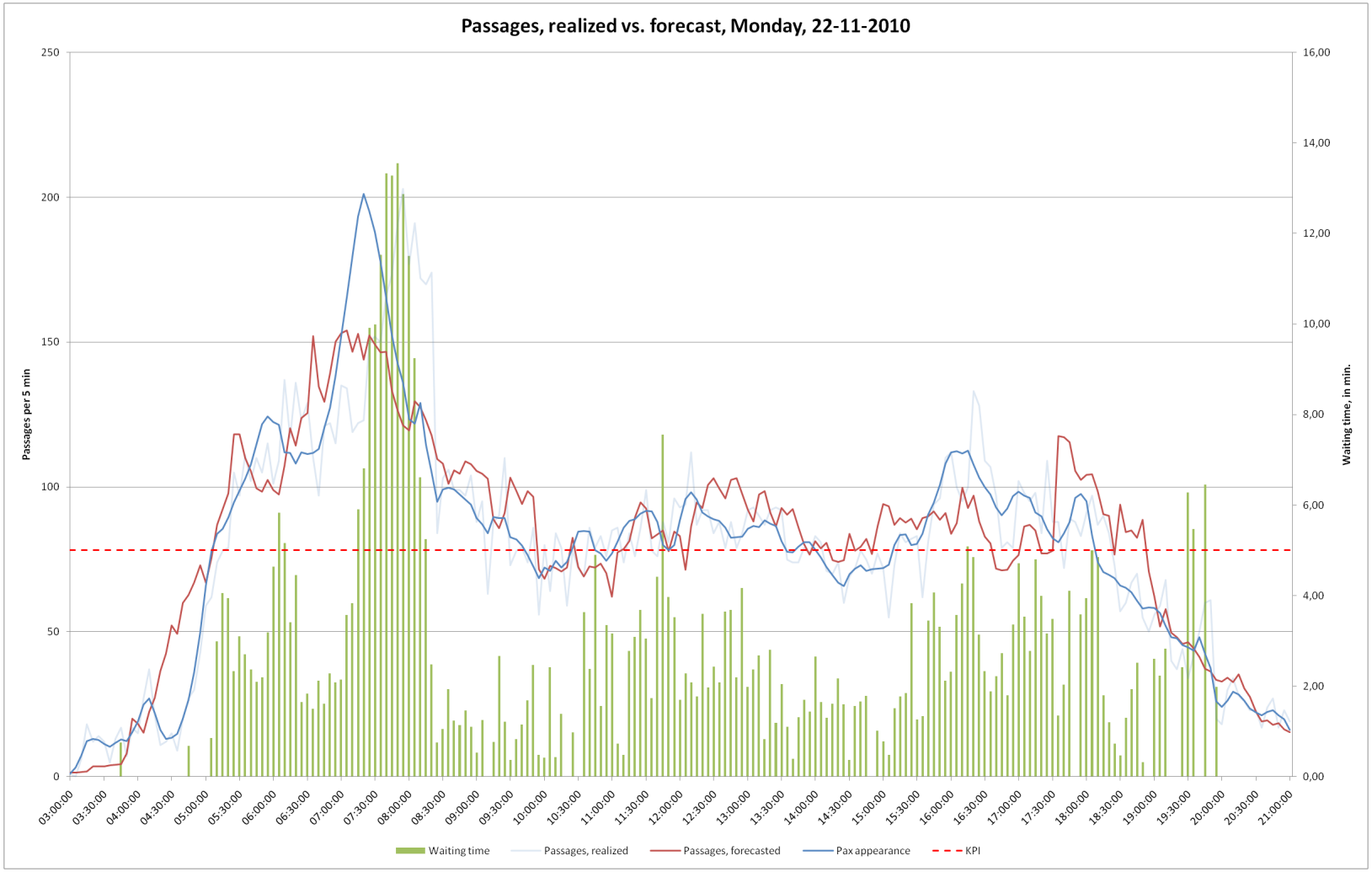
- Performance is evaluated.
  - Was performance acceptable?
  - If not, what are the causes.
    - The only way to improve is to find the origin of the causes.
- Passenger forecast is evaluated.
  - Even small variations can lead to queues.
    - Hence, the forecast must be very accurate.
    - We are constantly working to improve this.
- Plan is compared to realized opening of lanes.
  - If there are deviations, there should be a good reason.
- Productivity is compared to expected productivity.

Manning security: Evaluating

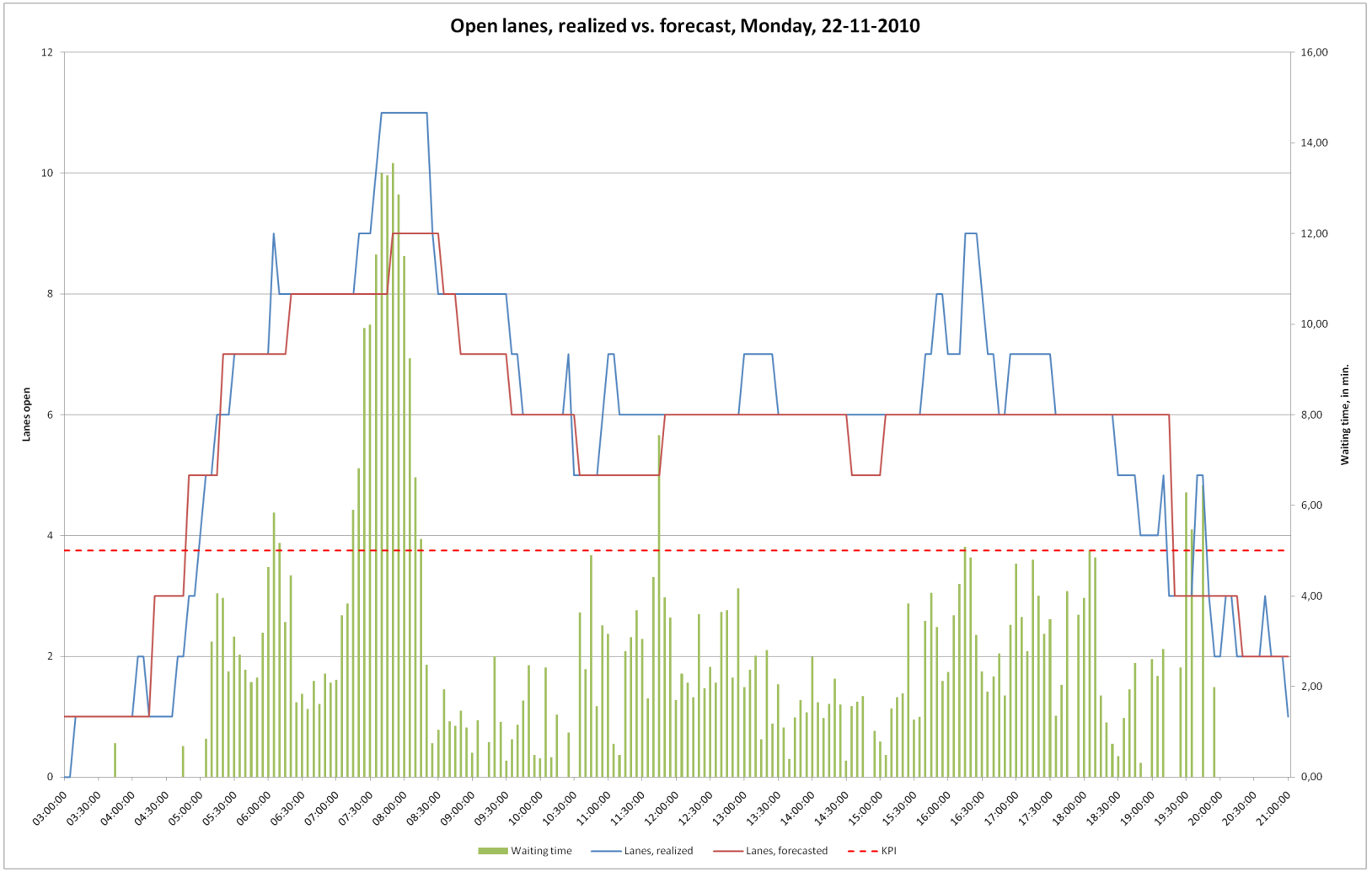
- Bad performance:
  - Find cause.
  - We know what the causes could be.
  - If we find consistencies over several days, the forecast and planning must be revised.

	04:30	05:00	05:30	06:00	06:30	07:00	07:30	08:00	08:30	09:00	09:30	10:00	10:30	11:00
Passages, Diff	-79,5	-165,6	-58,7	78,7	-12,1	-95,2	223,9	103,8	-51,3	-58,6	-54,2	-76,3	12,7	56,5
Lanes, Diff	-0,7	-1,5	-0,2	0,0	0,7	0,0	0,5	2,3	1,2	0,5	1,0	0,3	0,0	0,5
Productivity	15,2	11,9	14,1	15,3	15,4	14,6	15,7	16,3	14,4	12,4	10,8	12,0	12,2	14,7
KPI exceeded	0	0	0	0	1	0	4	6	2	0	0	0	0	0

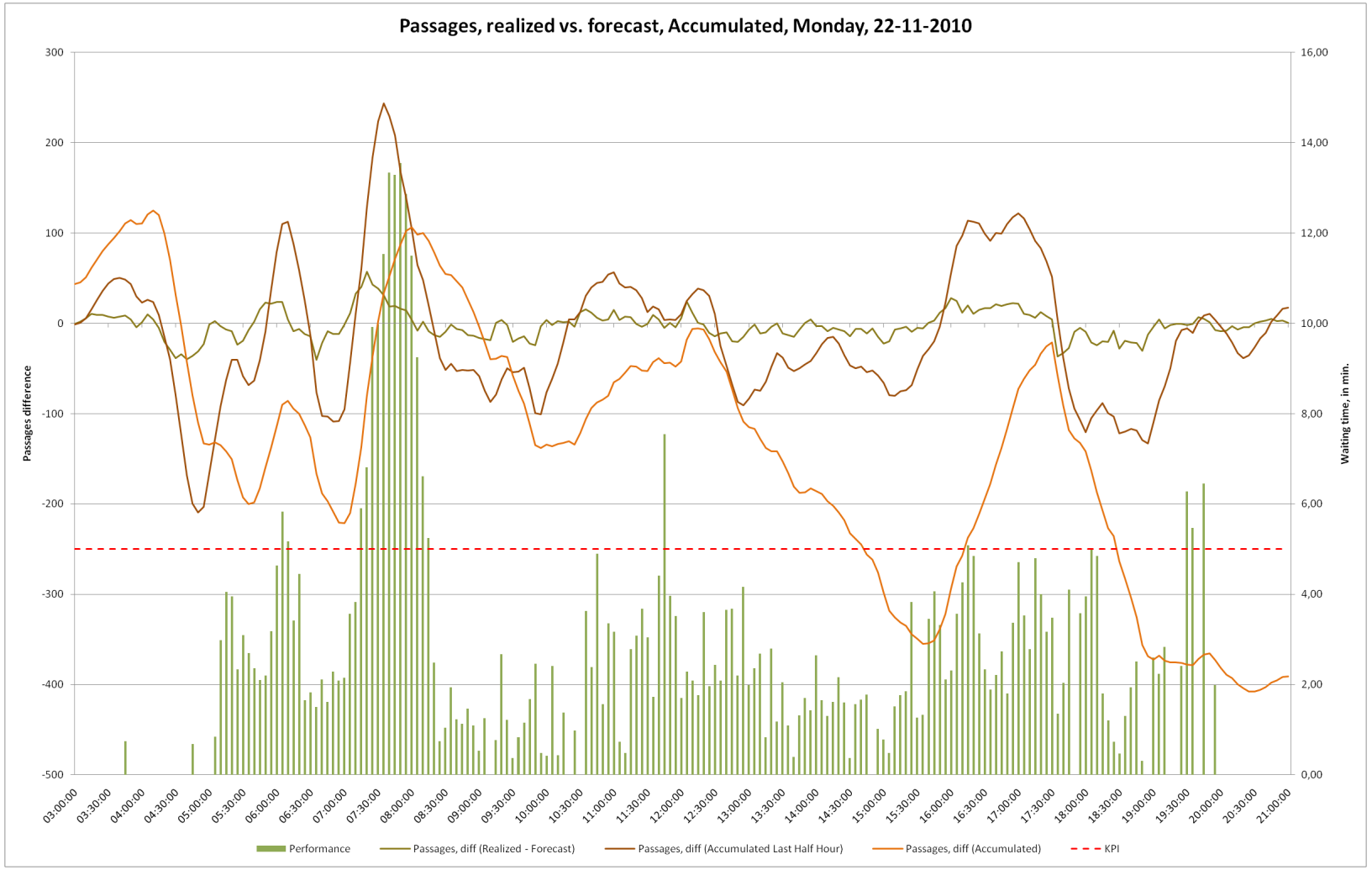
Manning security: Evaluating



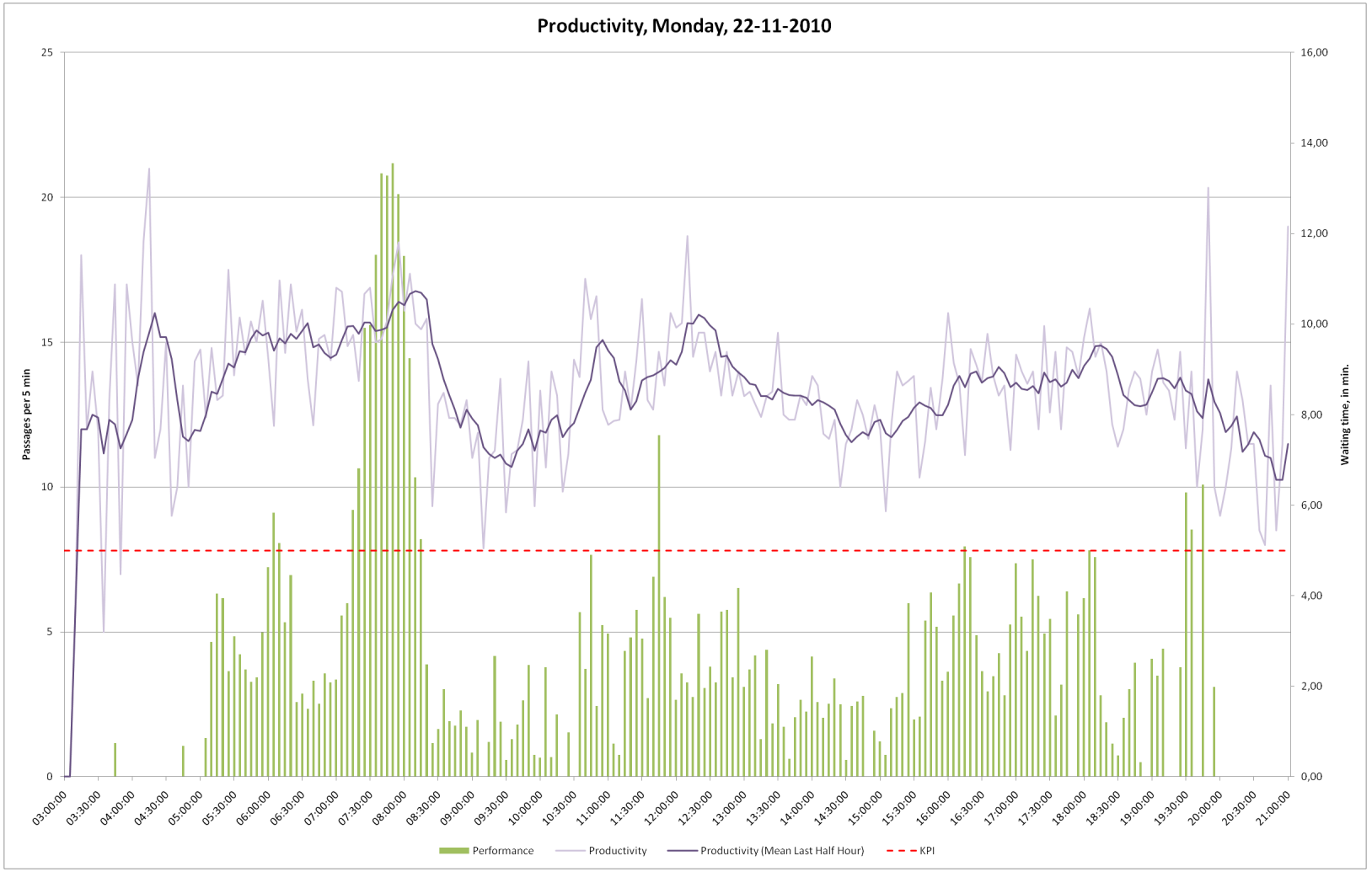
Manning security: Evaluating



Manning security: Evaluating



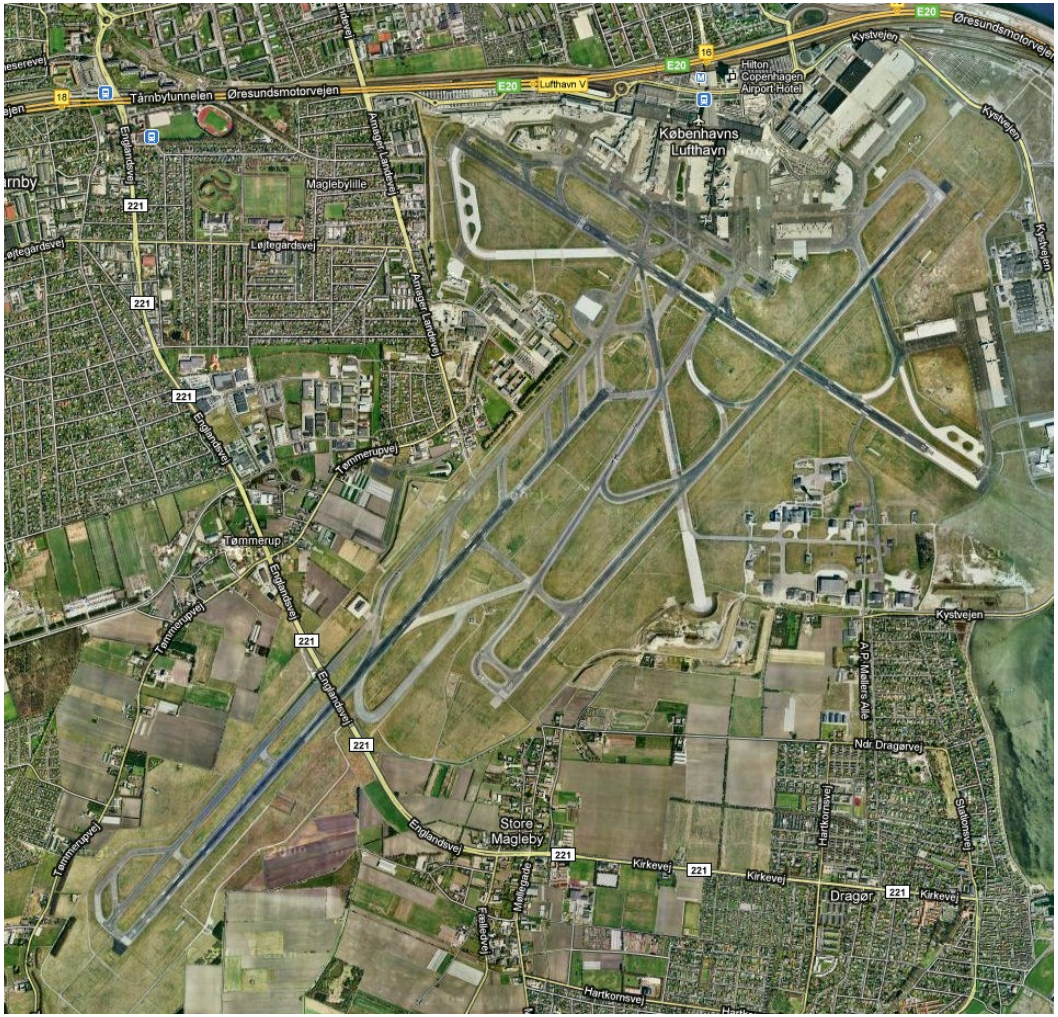
Manning security: Evaluating



Passenger Flow in the Airport

- Other planning problems:
  - Manning the passport control
    - We are cooperating with the Danish Police.
  - Baggage handling
    - We are currently developing models and planning tools in the Baggage Department.
  - Customs
    - We are not looking at this problem, at the moment.

Aircraft Flow in the Airport



Aircraft Flow in the Airport

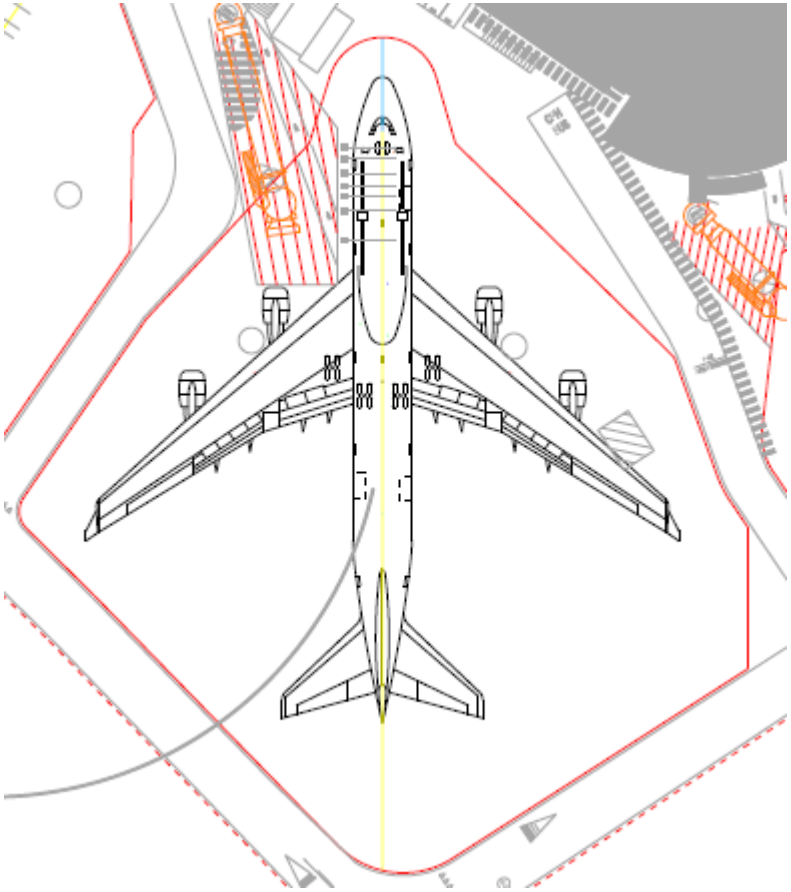
- The airlines are in control of their own schedules.
  - We have limited influence.
  - Usually, we consider them to be fixed.
- Optimization Tasks in the Aircraft Flow:
  - Air Traffic Controllers
    - Rostering
    - Task Scheduling
  - Ground Handling
    - Rostering
    - Task Scheduling
  - Stands and Gate Optimization

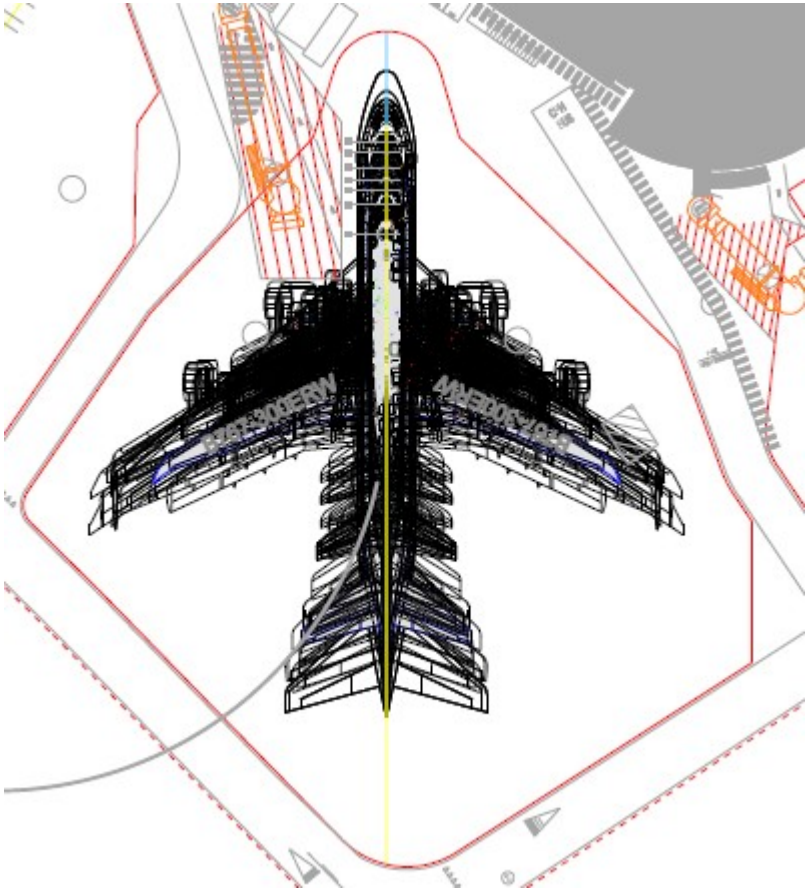
Stands and Gate Optimization

- A *stand* is an area on the apron where aircraft are parked
- A stand is (primarily) characterized by the following properties
  - Remote / gate
  - Size / physical conditions
    - What aircraft can / may at a given stand?
  - Passenger Status (Schengen, non-Schengen, non-EU, domestic)
    - Regulatory requirements
- CPH
  - 108 stands (including cargo and GA)
    - 9 domestic
    - 43 gate stands
    - 54 remote stands
    - 2 helicopter stands

Stands and Gate Optimization

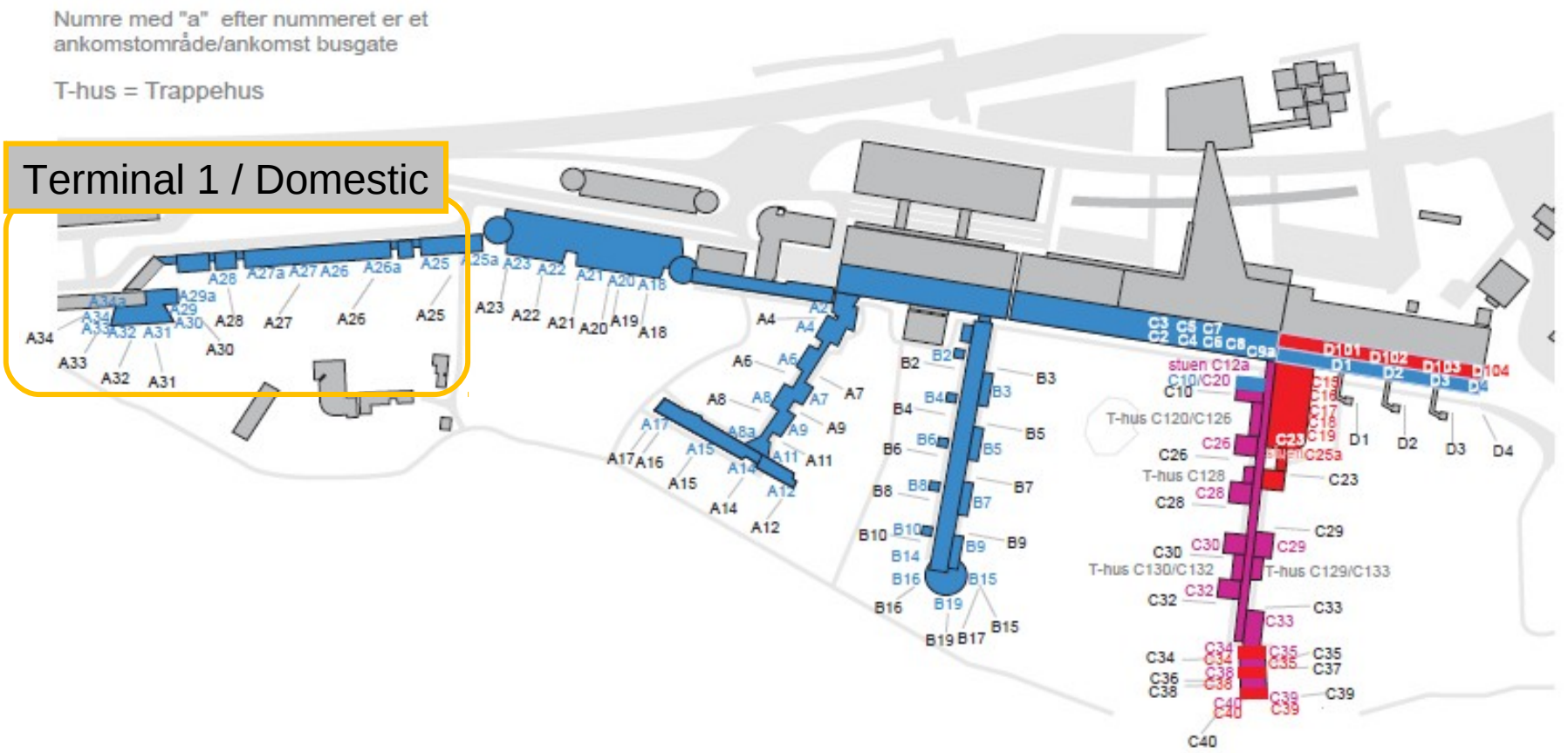
- Aircraft Types on B17





Stands and Gate Optimization

- Schengen
- Non-Schengen
- Schengen / Non-Schengen
- Non-Schengen / Non-EU inbound + outbound
- Schengen / Non-Schengen / Non-EU inbound + outbound
- Non-Schengen / Non-EU outbound



And then things don’t go as planned, anyway

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Merry Christmas!