PERSONNEL PLANNING AT THE REMOTE TOWER CENTER

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Co-financed by the Connecting Europe Facility of the European Union

Remote Tower Center in Sweden

- ✓ LiU works in a close collaboration with LFV

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Research questions

- ✓ How HR are **organized** at RTC?
- ✓ How the **total workload** from an number of airports is **distributed** over several controller working positions? (**KODIC I, II projects 2016-2017, funded by Trafikverket**)
- ✓ How the **workload** at the Remote Tower environment **differs** from the one at the traditional tower? (**CAPMOD project 2018-2021, funded by Trafikverket**)

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Methods

- ✓ Data analysis for scheduled and special traffic (LFV, Eurocontrol DDR2)
- ✓ Mathematical modeling (Integer Programming)
- ✓ Several objectives: min #modules, balancing, switches
- ✓ Avoidance of potential conflicts in airport schedules
- ✓ Constant reality checks with RTC specialists

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Problem description

GIVEN

1. Scheduled airport traffic for 5 airports
2. Specifications of special traffic for these airports (VFR, charters, schools, helicopters, military…)

GOALS

1. Propose **optimal** assignments of the airports to RTC modules for different traffic scenarios – ***KODIC I***
2. Construct optimized ATCO rosters – ***KODIC II***
3. Study impact of the remote control operations on human resources including workload – ***CAPMOD***

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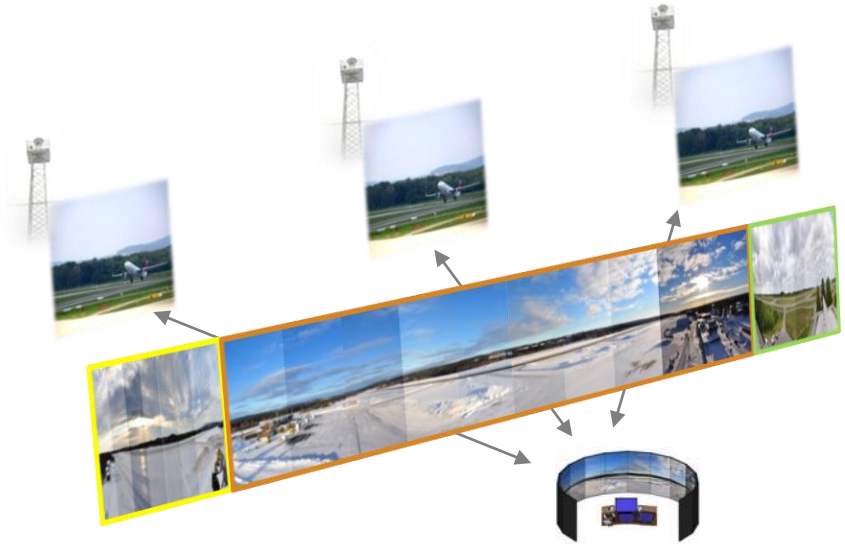
Problem 1: Assigning airports to RTMs

Main CONSTRAINTS

- ✓ Number of airports assigned to one module <= maxAP
- ✓ Total number of moves within a module <= maxMOV



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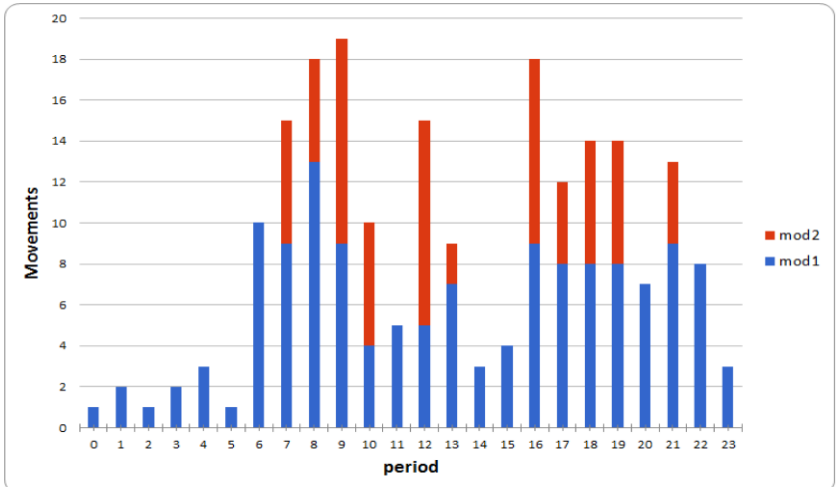
Minimizing the number of modules at RTC

Airports\Hours	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AP1	0	0	0	0	0	0	1	0	0	0	0	0	2	2	0	0	1	1	0	0	0	0	0	1
AP2	1	2	1	1	2	1	3	9	10	6	4	3	3	5	2	0	5	6	5	7	2	6	4	1
AP3	0	0	0	1	1	0	0	2	1	6	3	1	5	2	0	3	6	3	4	4	4	2	2	1
AP4	0	0	0	0	0	0	3	2	4	3	2	1	2	2	1	0	3	1	3	1	0	3	1	0
AP5	0	0	0	0	0	0	3	2	0	4	1	0	3	0	0	1	3	1	2	2	1	2	1	0

LOWER BOUND

- ✓ maxAP = ∞
- ✓ maxMov = 10



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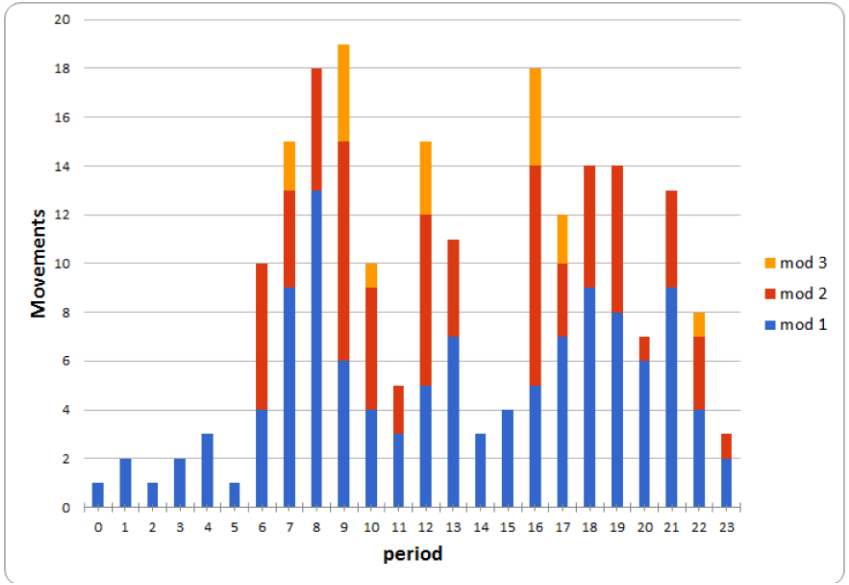
Minimizing the number of modules at RTC

Airports\Hours	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AP1	0	0	0	0	0	0	1	0	0	0	0	0	2	2	0	0	1	1	0	0	0	0	0	1
AP2	1	2	1	1	2	1	3	9	10	6	4	3	3	5	2	0	5	6	5	7	2	6	4	1
AP3	0	0	0	1	1	0	0	2	1	6	3	1	5	2	0	3	6	3	4	4	4	2	2	1
AP4	0	0	0	0	0	0	3	2	4	3	2	1	2	2	1	0	3	1	3	1	0	3	1	0
AP5	0	0	0	0	0	0	3	2	0	4	1	0	3	0	0	1	3	1	2	2	1	2	1	0

- ✓ **maxAP = 2**
- ✓ **maxMov = 10**



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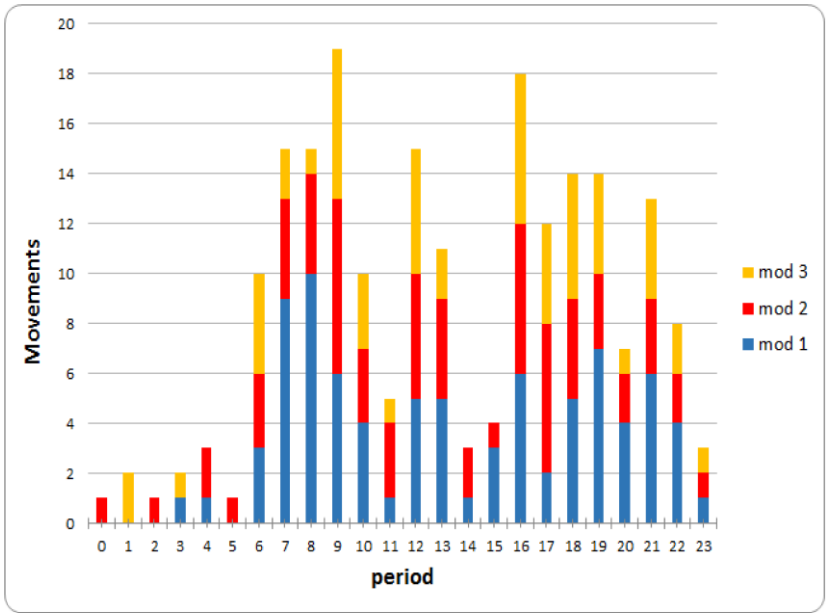
Balancing the load

Airports\Hours	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AP1	0	0	0	0	0	0	1	0	0	0	0	0	2	2	0	0	1	1	0	0	0	0	0	1
AP2	1	2	1	1	2	1	3	9	10	6	4	3	3	5	2	0	5	6	5	7	2	6	4	1
AP3	0	0	0	1	1	0	0	2	1	6	3	1	5	2	0	3	6	3	4	4	4	2	2	1
AP4	0	0	0	0	0	0	3	2	4	3	2	1	2	2	1	0	3	1	3	1	0	3	1	0
AP5	0	0	0	0	0	0	3	2	0	4	1	0	3	0	0	1	3	1	2	2	1	2	1	0

- ✓ **maxAP = 2**
- ✓ **maxMov = 10**



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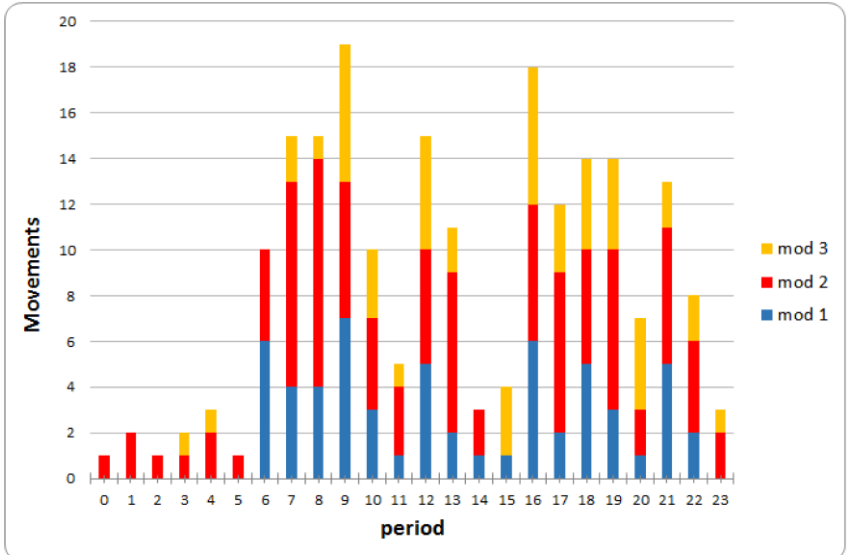
Minimizing the numbers of switches

Airports\Hours	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AP1	0	0	0	0	0	0	1	0	0	0	0	0	2	2	0	0	1	1	0	0	0	0	0	1
AP2	1	2	1	1	2	1	3	9	10	6	4	3	3	5	2	0	5	6	5	7	2	6	4	1
AP3	0	0	0	1	1	0	0	2	1	6	3	1	5	2	0	3	6	3	4	4	4	2	2	1
AP4	0	0	0	0	0	0	3	2	4	3	2	1	2	2	1	0	3	1	3	1	0	3	1	0
AP5	0	0	0	0	0	0	3	2	0	4	1	0	3	0	0	1	3	1	2	2	1	2	1	0

- ✓ **maxAP = 2**
- ✓ **maxMov = 10**



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Analysis of non-scheduled traffic

AIRPORT	TYPE OF TRAFFIC	NORMAL OPERATION	WORST CASE
AP1	FM HKP Skol Special other	3 5 1 2 1	10 17 3 5 5
AP2	FM HKP Skol Special other	1 1 5 14 2	3 4 20 60 10
AP3	HKP Skol Special other	4 2 4 4	12 8 10 4
AP4	FM HKP Skol Special	6 7 4 2	125 21 10 10
AP5	FM HKP Skol Special	8 8 3 4	20 20 8 12

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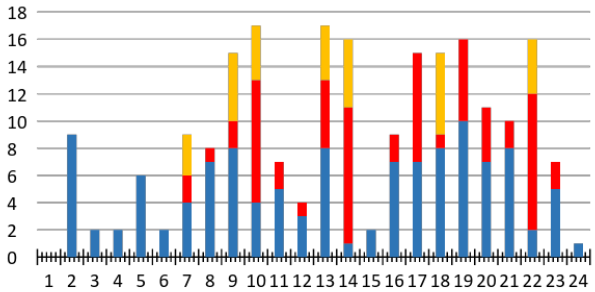
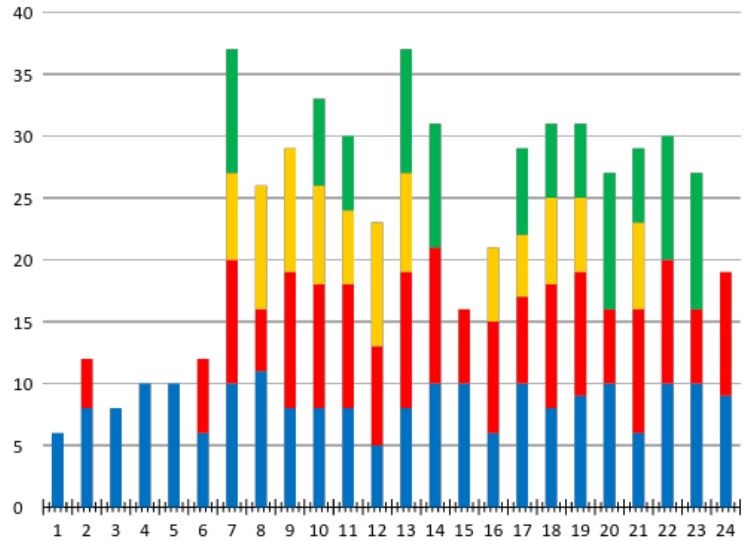
Scheduled traffic vs MAX extra traffic



Scheduled



MAX extra traffic

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ATCO rostering at RTC

How are RTC personell ***shifts*** organized?

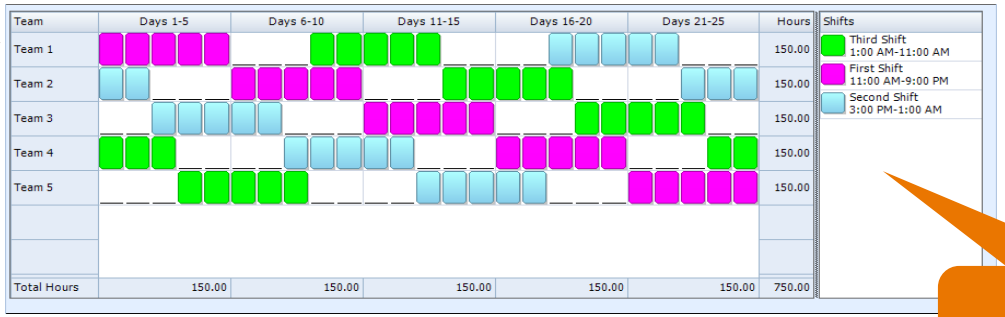
Workload from several airports

Endorsements and trainings

24/7 operation

Scheduled breaks

Time ”in position”



AUTOMATION REQUIRED!

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Staff imbalance problem in ATC

- ✓ ATCO working conditions
  – strict regulations
- ✓ Seasonal variations are not covered:
  - Overstaffing during low-traffic months
  - Staff shortage during high-traffic months
- ✓ HR costs are significant – up to 85% of ATS costs

Do the Remote Tower Services help to solve the staff imbalance problem?

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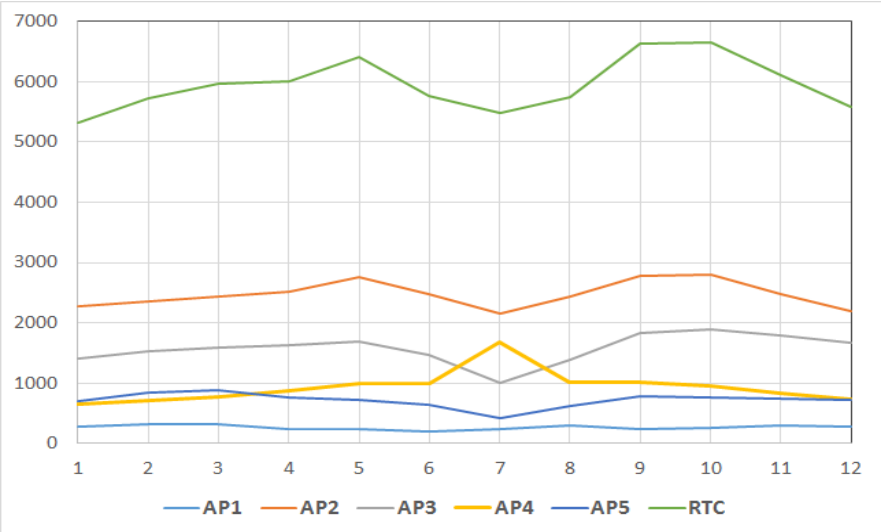
Traffic statistics for 2016



	1	2	3	4	5	6	7	8	9	10	11	12	2016
AP1	281	310	313	233	240	204	240	304	237	259	288	282	**3302**
AP2	2284	2348	2433	2518	2767	2469	2148	2435	2776	2793	2468	2189	**30626**
AP3	1398	1524	1581	1621	1682	1465	1011	1387	1832	1892	1785	1667	**19485**
AP4	658	702	775	870	992	988	1671	1014	1008	955	826	735	**11557**
AP5	702	841	874	758	729	646	419	612	790	762	743	716	**8882**
RTC	**5323**	**5725**	**5976**	**6000**	**6410**	**5772**	**5489**	**5752**	**6643**	**6661**	**6110**	**5589**	**73852**

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PROBLEM 2: RTC ATCO shift scheduling problem

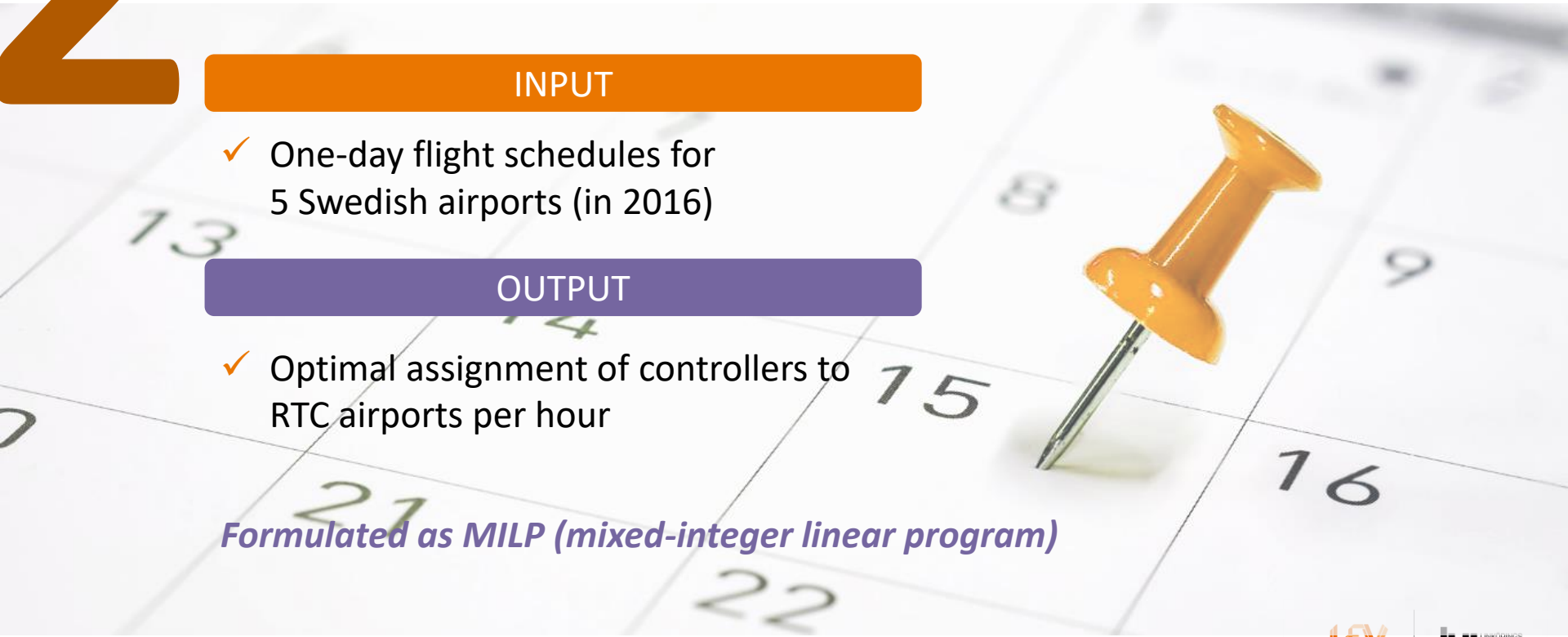
INPUT

- ✓ One-day flight schedules for 5 Swedish airports (in 2016)

OUTPUT

- ✓ Optimal assignment of controllers to RTC airports per hour

Formulated as MILP (mixed-integer linear program)



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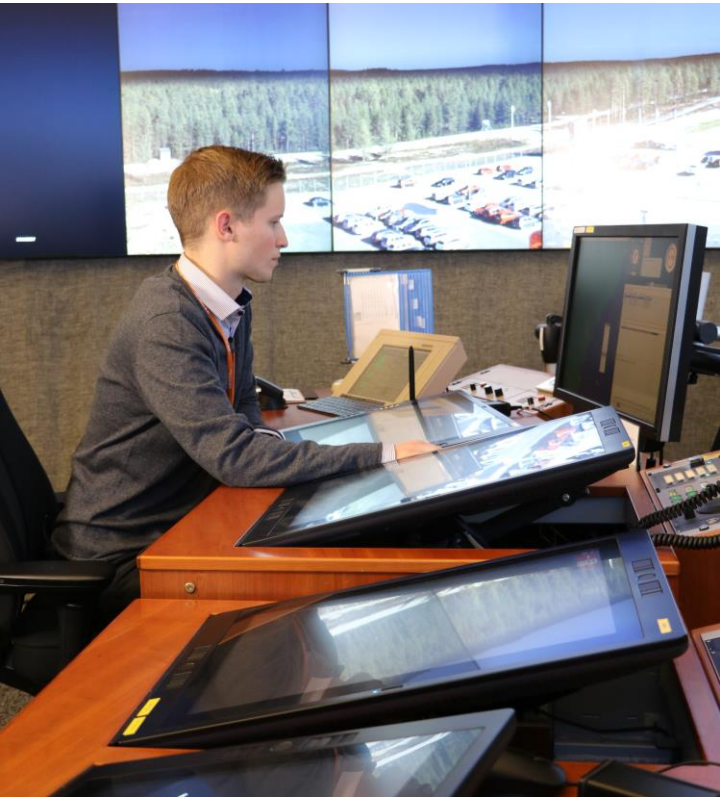

Objectives

- ✓Minimize total # **controllers** at RTC
- ✓Minimize average # **airports per unit endorsements**

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Initial assumptions (conservative)

SHIFT

- ✓ Time at work = 4 – 10 hours
- ✓ Max active hours = 8 hours
- ✓ Breaks: 1 – 3 hours total
- ✓ Max cont. time w/o break = 4 hours
- ✓ Endorsements enforced
- ✓ Conflicts avoided
  (5 min granularity -> period)

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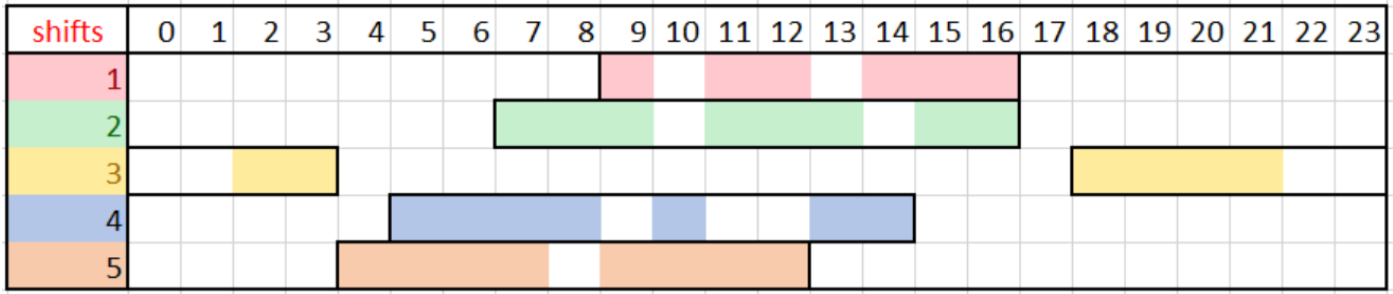
OBJECTIVE 1: Min total # controllers at RTC

Low traffic (104 mov)

23-Jul-16	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AP1	0	0	0	0	0	0	0	1	1	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0
AP2	0	0	1	1	3	3	3	1	2	5	2	2	4	5	2	1	3	3	1	2	4	2	0	0
AP3	0	0	0	0	0	0	3	0	0	1	2	1	1	0	0	0	1	0	0	0	0	0	0	0
AP4	0	0	0	0	0	0	4	3	3	3	3	1	4	1	0	4	3	0	0	1	0	0	0	0
AP5	0	0	0	0	0	0	1	0	2	1	2	2	2	0	0	0	0	0	0	0	0	0	0	0



Min 5 controllers are needed during low traffic season

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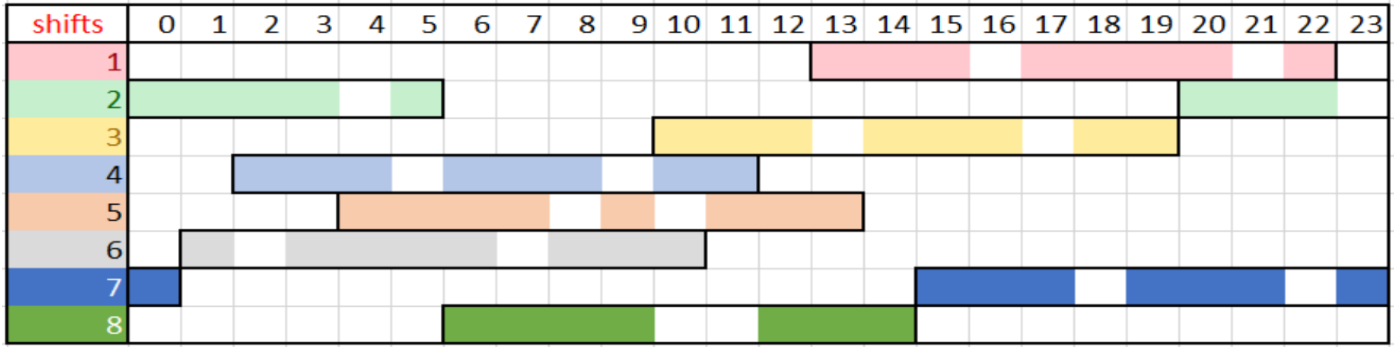
OBJECTIVE 1: Min total # controllers at RTC

High traffic (286 mov)

19-Oct-16	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AP1	0	0	0	0	2	0	0	2	1	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0
AP2	1	1	2	3	4	9	10	7	5	3	2	5	7	4	5	10	8	7	6	8	8	2	0	2
AP3	1	0	2	1	6	5	2	6	4	3	5	4	2	5	6	4	6	8	6	4	3	1	2	2
AP4	0	0	0	0	2	3	3	3	2	1	2	3	2	2	2	4	3	3	0	2	0	0	0	0
AP5	0	0	0	0	3	2	0	4	3	1	2	1	0	2	4	3	2	2	1	2	0	1	0	0



Total #. of ATCOs	Av. # of ATCOs per airport	Av. # endorsements per ATCO	Av. time in position	Av. time at work	COP
8	7.2	4.5	7.88	9.88	0.8

Min 8 controllers are needed during high traffic season

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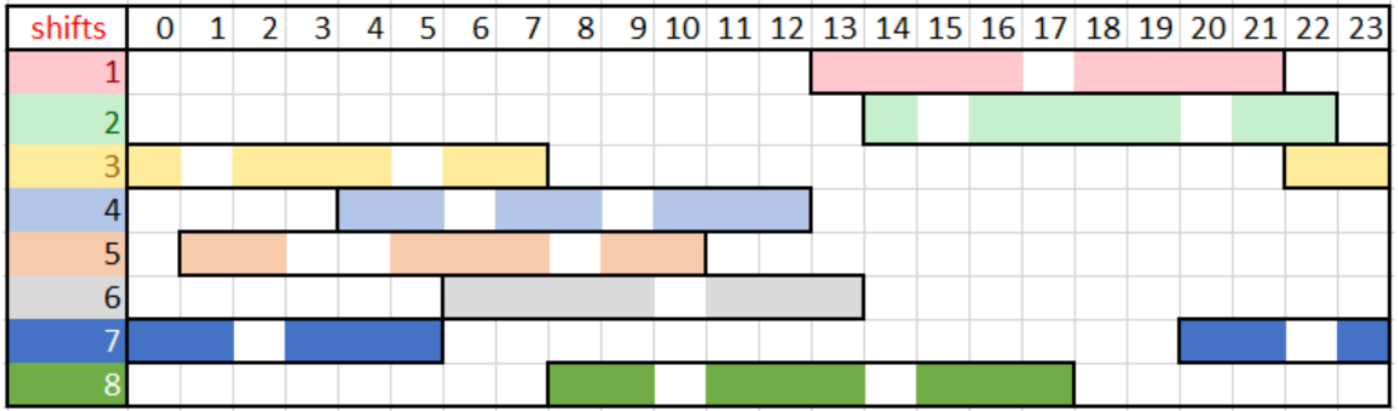
OBJECTIVE 2: Min average # controllers per airport

High traffic

19-Oct-16	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AP1	0	0	0	0	2	0	0	2	1	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0
AP2	1	1	2	3	4	9	10	7	5	3	2	5	7	4	5	10	8	7	6	8	8	2	0	2
AP3	1	0	2	1	6	5	2	6	4	3	5	4	2	5	6	4	6	8	6	4	3	1	2	2
AP4	0	0	0	0	2	3	3	3	2	1	2	3	2	2	2	4	3	3	0	2	0	0	0	0
AP5	0	0	0	0	3	2	0	4	3	1	2	1	0	2	4	3	2	2	1	2	0	1	0	0



Total #. of ATCOs	Av. # of ATCOs per airport	Av. # endorsements per ATCO	Av. time in position	Av. time at work	COP
8	3.4	2.13	7.5	9.38	0.8

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Average # controllers per airport: compare statistics

High traffic day

Total #. of ATCOs	Av. # of ATCOs per airport	Av. # endorsements per ATCO	Av. time in position	Av. time at work	COP
8	7.2	4.5	7.88	9.88	0.8

Total #. of ATCOs	Av. # of ATCOs per airport	Av. # endorsements per ATCO	Av. time in position	Av. time at work	COP
8	3.4	2.13	7.5	9.38	0.8

For the same total # controllers we get less per airport =

Less training for unit endorsement

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OBJECTIVE 3: Minimize the # of assignment switches

HANDOVERS

ADDITIONAL WORKLOAD

✓ Often switches in the controller assignment lead to

19-Oct-16	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AP1	0	0	0	0	2	0	0	2	1	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0
AP2	1	1	2	3	4	9	10	7	5	3	2	5	7	4	5	10	8	7	6	8	8	2	0	2
AP3	1	0	2	1	6	5	2	6	4	3	5	4	2	5	6	4	6	8	6	4	3	1	2	2
AP4	0	0	0	0	2	3	3	3	2	1	2	3	2	2	2	4	3	3	0	2	0	0	0	0
AP5	0	0	0	0	3	2	0	4	3	1	2	1	0	2	4	3	2	2	1	2	0	1	0	0

Total #. of ATCOs	Av. # of ATCOs per airport	Av. # endorsements per ATCO	Av. time in position	Av. time at work	COP
8	5	2.75	7.88	9.38	0.84

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Min # of assignment switches vs Min # controllers per airport: compare statitics

Objective 2

Total #. of ATCOs	Av. # of ATCOs per airport	Av. # endorsements per ATCO	Av. time in position	Av. time at work	COP
8	3.4	2.13	7.5	9.38	0.8

Objective 3

Total #. of ATCOs	Av. # of ATCOs per airport	Av. # endorsements per ATCO	Av. time in position	Av. time at work	COP
8	5	2.75	7.88	9.38	0.84

Trade-off between the objectives

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Conflict: 2 movs at 2 airports within 5 min

Potential conflicts in airport schedules

The number of conflicts in schedules for each airport pair durig the year 2016.

Conflict count	AP1	AP2	AP3	AP4	AP5
AP1		1058	621	366	339
AP2	1058		6473	3400	3021
AP3	621	6473		2603	2517
AP4	366	3400	2603		1449
AP5	339	3021	2517	1449	

The number of days with the potential conflicts in schedules.

Conflict days	AP1	AP2	AP3	AP4	AP5
AP1		341	316	278	285
AP2	341		366	363	365
AP3	316	366		362	362
AP4	278	363	362		359
AP5	285	365	362	359	

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Conflict avoidance

19-Oct-16	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AP1	0	0	0	0	2	0	0	2	1	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0
AP2	1	1	2	3	4	9	10	7	5	3	2	5	7	4	5	10	8	7	6	8	8	2	0	2
AP3	1	0	2	1	6	5	2	6	4	3	5	4	2	5	6	4	6	8	6	4	3	1	2	2
AP4	0	0	0	0	2	3	3	3	2	1	2	3	2	2	2	4	3	3	0	2	0	0	0	0
AP5	0	0	0	0	3	2	0	4	3	1	2	1	0	2	4	3	2	2	1	2	0	1	0	0

conflicts	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AP2-AP3				■	■	■	■	■	■	■	■	■		■		■	■	■	■	■	■			
AP2-AP5					■	■		■	■		■	■		■	■	■	■	■	■	■		■		
AP2-AP4						■		■	■			■		■	■	■	■	■		■				
AP2-AP1					■			■				■												
AP3-AP1								■	■			■												
AP1-AP5					■			■																
AP1-AP4					■							■												
AP3-AP4					■	■		■	■		■	■			■	■	■	■		■				
AP3-AP5					■	■		■			■	■		■	■	■	■	■	■	■				
AP4-AP5					■	■	■	■	■		■	■		■	■	■	■	■						

Total #. of ATCOs	Av. # of ATCOs per airport	Av. # endorsements per ATCO	Av. time in position	Av. time at work	COP
10	3.4	1.7	7.9	9.8	0.81

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Conflicts avoidance: compare statistics

w/o conflicts

Total #. of ATCOs	Av. # of ATCOs per airport	Av. # endorsements per ATCO	Av. time in position	Av. time at work	COP
8	3.4	2.13	7.5	9.38	0.8

wrt conflicts

Total #. of ATCOs	Av. # of ATCOs per airport	Av. # endorsements per ATCO	Av. time in position	Av. time at work	COP
10	3.4	1.7	7.9	9.8	0.81

Extra 2 ATCOs are needed to cover for the potential conflicts

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2-weeks rosters

ATCO	Mon 03.10		Tue 04.10		Wed 05.10		Thur 06.10		Fri 07.10		Sat 08.10		Sun 09.10	
1	14:00	18:00	6:00	10:00			23:00	0:00	0:00-8:00	23:00-0:00	0:00-6:00	22:00-0:00	0:00-9:00	23:00-8:00
2			20:00	23:00	0:00-8:00	23:00-0:00	0:00-9:00	20:00-0:00	0:00-6:00	14:00-17:00				
3			8:00	12:00			9:00	17:00	15:00	23:00	16:00	22:00	6:00	16:00
4	19:00	0:00	0:00-2:00	22:00-0:00	0:00-6:00	19:00-0:00	0:00	6:00	19:00	0:00	11:00	16:00		
5			9:00	14:00	7:00	19:00	8:00	20:00	7:00	11:00				
6	0:00-8:00	16:00-21:00	6:00	12:00	13:00	21:00	8:00	17:00						
7	8:00	14:00	6:00	18:00			19:00	23:00	7:00	16:00				
8			15:00	22:00	8:00	12:00	16:00	23:00	9:00	14:00			11:00	23:00
9			20:00	0:00	0:00-7:00		14:00	18:00	10:00	14:00				
10	19:00	0:00	0:00	6:00					19:00	0:00	0:00-7:00	20:00-0:00	0:00-6:00	21:00-0:00
11	8:00	22:00	6:00	18:00	7:00	15:00			11:00	15:00				
12	0:00	9:00			10:00	21:00	6:00	10:00	6:00	18:00				
13	19:00	0:00	0:00	6:00			6:00	18:00						
14	11:00	18:00			20:00	0:00	0:00-8:00	20:00-0:00	17:00	21:00	6:00	15:00		
15	11:00	15:00	10:00	14:00	10:00	14:00					7:00	19:00	9:00	21:00
16					8:00	20:00	6:00	18:00						
17			9:00	20:00	17:00	0:00	0:00-1:00	9:00-13:00						

ATCO	Mon 10.10		Tue 11.10		Wed 12.10		Thur 13.10		Fri 14.10		Sat 15.10		Sun 16.10	
1				22:00-0:00	0:00-10:00									
2	9:00	15:00	7:00	14:00			18:00	21:00	10:00	16:00	10:00	19:00	6:00	10:00
3					6:00	12:00								
4	20:00	0:00	0:00-7:00	18:00-0:00	0:00	6:00								
5	14:00	23:00			10:00	20:00			14:00	19:00	19:00	0:00	0:00	7:00
6	8:00	15:00			13:00	19:00	7:00	19:00	8:00	15:00			20:00	0:00
7	19:00	0:00	0:00-3:00	20:00-0:00	0:00-1:00	21:00-0:00	0:00-6:00	16:00-20:00	11:00	17:00			19:00	23:00
8	18:00	0:00	9:00	22:00										
9					8:00	14:00			17:00	22:00	6:00	18:00	6:00	18:00
10	0:00-9:00	18:00-22:00	6:00	12:00										
11			14:00	19:00	10:00	21:00	6:00	16:00			7:00	16:00		
12	19:00	0:00	0:00	6:00			11:00	16:00	17:00	22:00	18:00	0:00	0:00-6:00	21:00-0:00
13					19:00	0:00	0:00-7:00	23:00-0:00	0:00	11:00			8:00	20:00
14	14:00	18:00	6:00	18:00										
15	8:00	19:00	19:00	0:00	0:00	6:00								
16			8:00	20:00					8:00	20:00				
17	9:00	13:00	7:00	11:00			20:00	0:00	0:00-8:00	22:00-0:00	0:00	7:00	12:00	19:00

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RTC efficiency evaluation

NUMBER OF CONTROLLERS	INDIVIDUAL 5 AIRPORTS	SAME 5 AIRPORTS AT RTC
Seasonal variations	Up to 50% at small airports	~37%
Lower bound for the highest traffic day (October 19, 2016)	17	8
With the buffer of 33% – 45% for the highest traffic day (October 19, 2016)	26–34	12–15

According to our model RTC provides 42–55% savings

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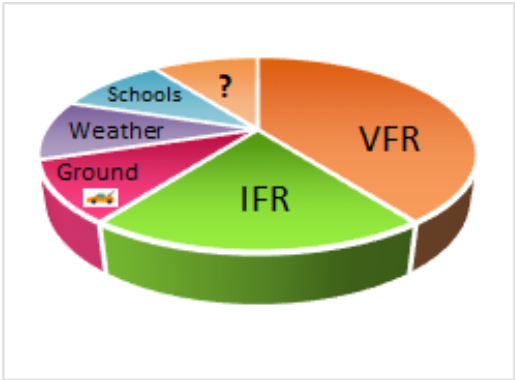
CAPMOD: Project description

✓ The project will focus on complete and descriptive ***capacity modelling,*** which will quantify the total controller's workload.

✓ Continuation of **KODIC**, where we ***designed mathematical models for controllers rostering in a RTC***, using the **number of IFR flight movements** as an indicator of staff *workload*.

As IFR traffic accounts for only ***~40% of the workload,*** we need to look at the other ***important aspects***:

- **ground traffic movements**
- **bad weather conditions**
- **VFR and extra traffic movements**



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Motivation

- ✓ ***Mental workload*** - limitation on number of tasks a human can perform during a certain period of time
- ✓ ***Complexity measures influencing workload*** the number of aircraft in a sector, voice messages, radar screen clicks etc...
- ✓ ***New workload factors*** appear in connection with the emerging technologies (CPDLC, RTC).
- ✓ ***A generic single metric for workload measurement is missing***

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Research questions

- ✓ Which ***factors*** contribute into controller's ***workload***?
- ✓ How different ***weather*** influences controller's workload?
- ✓ How the ***workload at RTC*** differs from the workload at the ***traditional towers***?

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Methods

- ✓ Simulation data analysis (DLR data, SID 2018)
- ✓ Observations and data collection in the towers at different airports (Brooma visit, March 2019) – video-recording, simple questionaries
- ✓ Mathematical analysis

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Conclusions

- ✓ Universal flexible automation tools for Staff Rostering
  - Easy to implement individual controllers' preferences + easy to include airport's specifics
- ✓ Optimized schedules presented for real remote airports
  - Reality checks with the experts in the first Remote Tower Center in Sundsvall
- ✓ Avoid potential conflicts in schedules
- ✓ Confirmed RTS efficiency in providing staff savings
- ✓ Outlined challenges in RTC staff planning

Open for discussions and collaboration

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