Scheduling Air Traffic Controllers at the Remote Tower Center

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TEAMWORK with automation

Remote Tower Concept

- ✓ Provides ATS remotely to small airports
- ✓ Replaces local tower with cameras and sensors
- ✓ Increases efficiency: HR and ATS costs are split between several airports

Remote Tower Center in Sweden

- ✓ LFV + SAAB
- ✓ Within SESAR Joint Undertaking
- ✓ RTC in Sundsvall: operates 2 airports remotely
  + 5 airports in development

Photo from the visit in November 2016

Staff imbalance problem in ATC

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

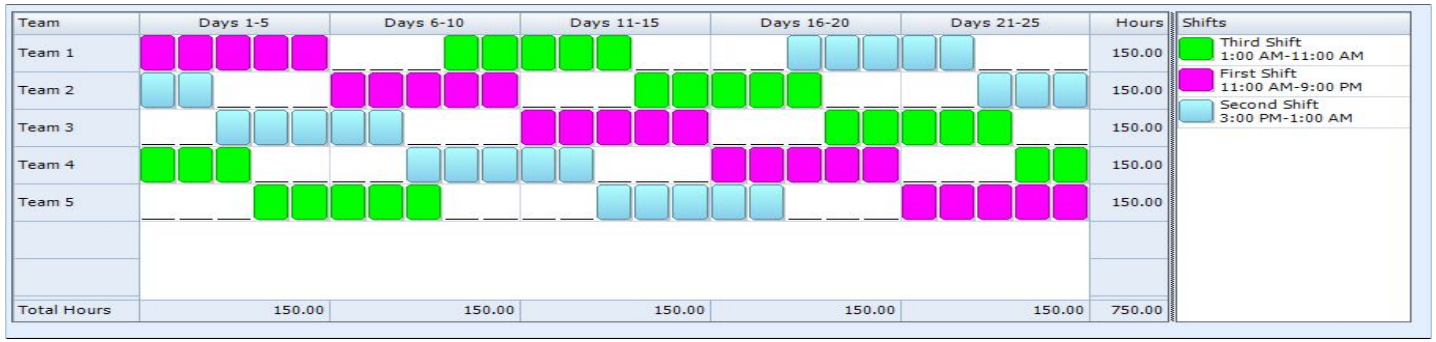
Do the Remote Tower Services help to solve the staff imbalance problem?

ATCO rostering at RTC - a complex problem

How are RTC personnel **shifts** organized?

Time “in position”, scheduled breaks
workload from several airports
endorsements and trainings
24/7 operation

Automation required!



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RTC ATCO shift scheduling problem

Input:

One-day flight schedules for five swedish airports (in 2016)

Output:

Optimal assignment of controllers to RTC airports per hour

Formulated as MILP (mixed-integer linear program)

Constraints

General for RTC:

- ✓ Max # movs per controller
- ✓ Max # airports per controller
- ✓ All open hours and all movements are to be covered

SHIFT-specific:

- ✓ Time at work
- ✓ Max hours “in position”
- ✓ Breaks: durations, max cont. time w/o break
- ✓ Endorsements
- ✓ Conflict avoidance
- ✓ … (controller-specific)

Objectives

✓ Minimize total # controllers at RTC

✓ Minimize average # controllers per airport

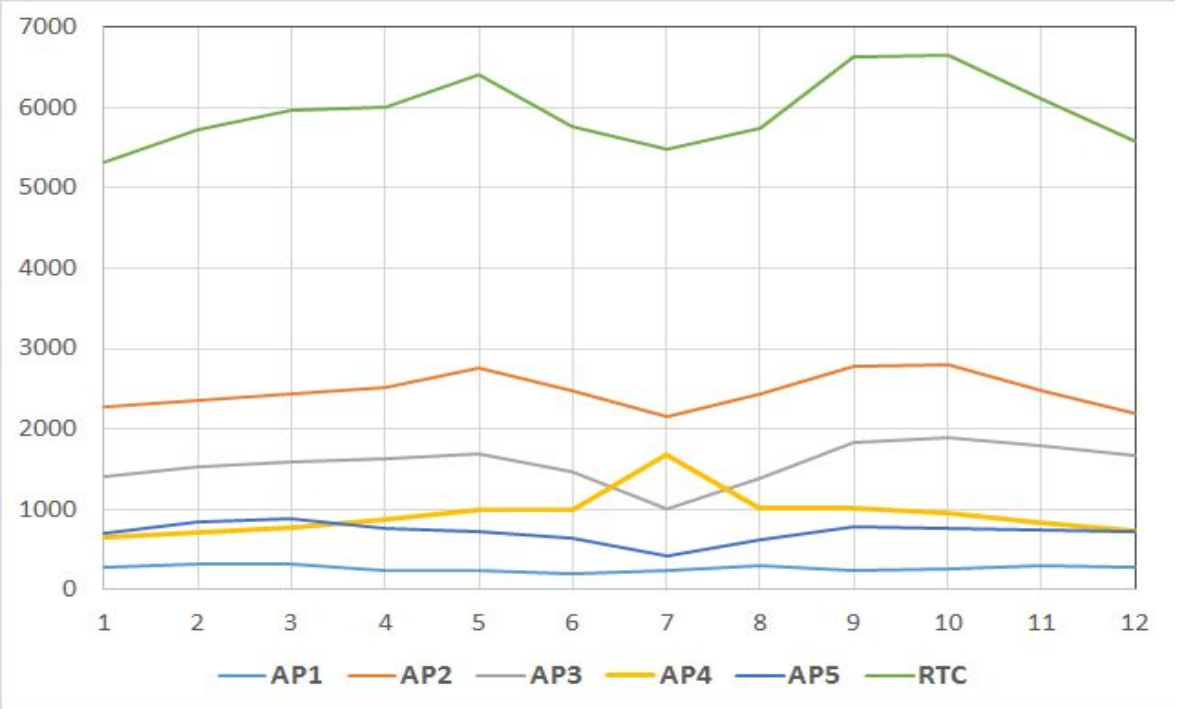
= Minimize average # endorsements per controller

✓ Minimize the # of assignment switches

Experimental evaluation

- ✓ Data analysis for the year 2016
- ✓ Solved MILP using AMPL CPLEX 12.6 solver
- ✓ Example solutions with different objectives
- ✓ Compare solutions for high and low traffic days
- ✓ Avoid potential conflicts in airport schedules
- ✓ Remote Tower efficiency evaluation

DATA : 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**

Data samples

- ✓ 2 days with the lowest traffic load:
  - January 9
  - July 23
- ✓ 2 days with highest traffic load:
  - May 25
  - October 19

(All seasons are covered)

Data samples

✓ 2 days with the lowest traffic load:

January 9

July 23 low traffic day (104 movs)

✓ 2 days with highest traffic load:

May 25

October 19 high traffic data (286 movs)

(All seasons covered)

Initial assumptions (parameters)

- ✓ Max # movs per controller = **10**
- ✓ Max # airports per controller = **2**
- ✓ Max # controllers per airport = **1**

SHIFT:

- ✓ Time at work: **4 .. 10** hours
- ✓ Max time “in position” = **8**
- ✓ Breaks: **1 .. 3** hours total
- ✓ Max cont. time w/o break = **4** hours
- ✓ Endorsements enforced
- ✓ Conflicts avoided

Objectives

✓ Minimize total # controllers at RTC

✓ Minimize average # controllers per airport

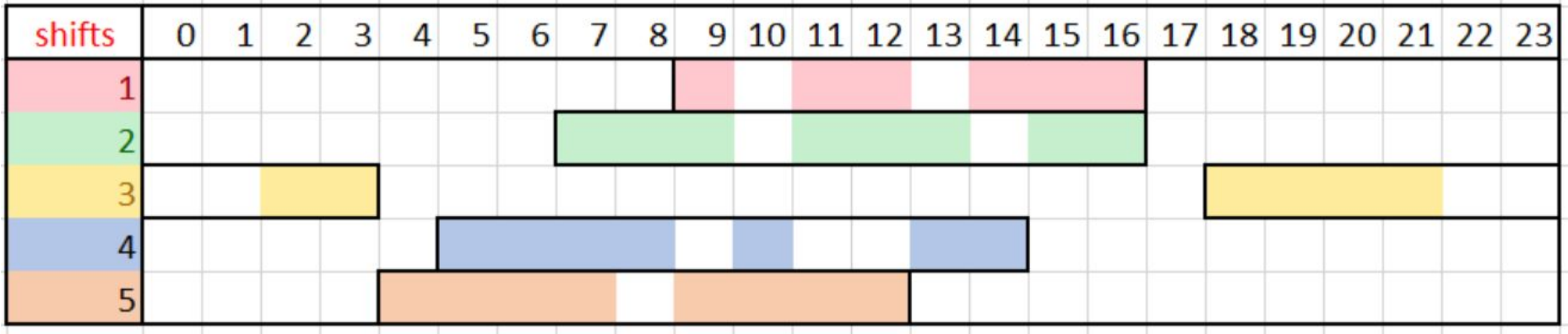
= Minimize average # endorsements per controller

✓ Minimize the # of assignment switches

1. Lower Bound: Min total # controllers at RTC

low traffic (104 mov)

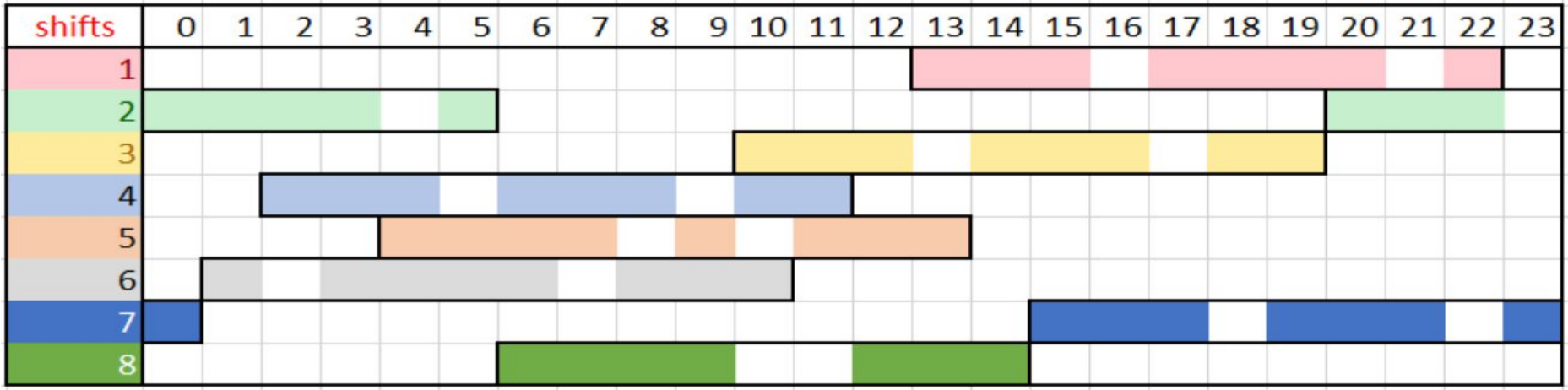
23-Jul-16	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AP1	0	0	0	0	0	0	0	1	1	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0
AP2	0	0	1	1	3	3	3	1	2	5	2	2	4	5	2	1	3	3	1	2	4	2	0	0
AP3	0	0	0	0	0	0	3	0	0	1	2	1	1	0	0	0	1	0	0	0	0	0	0	0
AP4	0	0	0	0	0	0	4	3	3	3	3	1	4	1	0	4	3	0	0	1	0	0	0	0
AP5	0	0	0	0	0	0	1	0	2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



min 5 controllers are needed during low traffic season

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

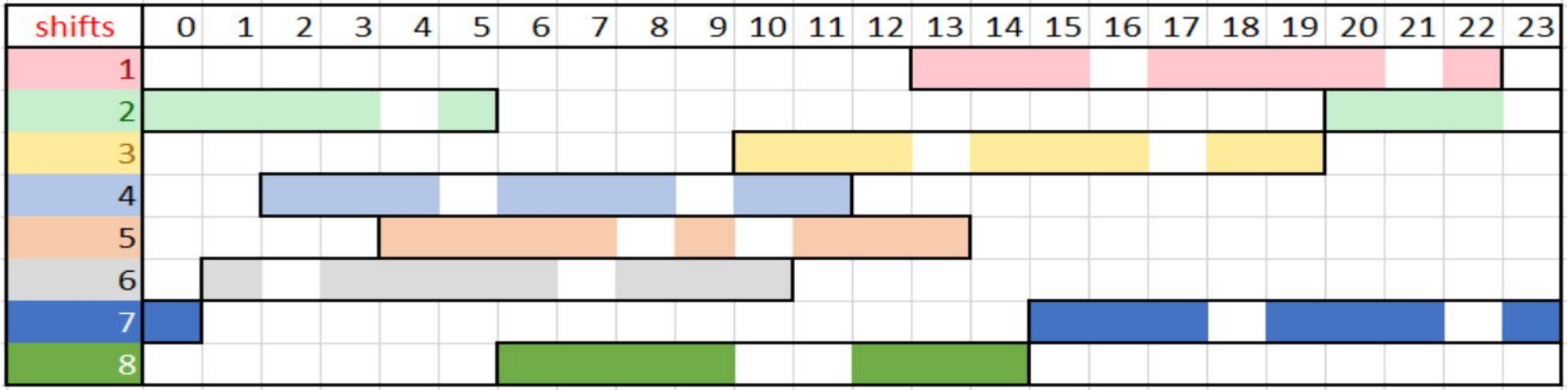


Total #. of ATCOs	Av. # of ATCOs per airport	Av. # endorsements per ATCO	Av. time in position	Av. time at work	COP
8	7.2	4.5	7.88	9.88	0.8

min 8 controllers are needed during high traffic season

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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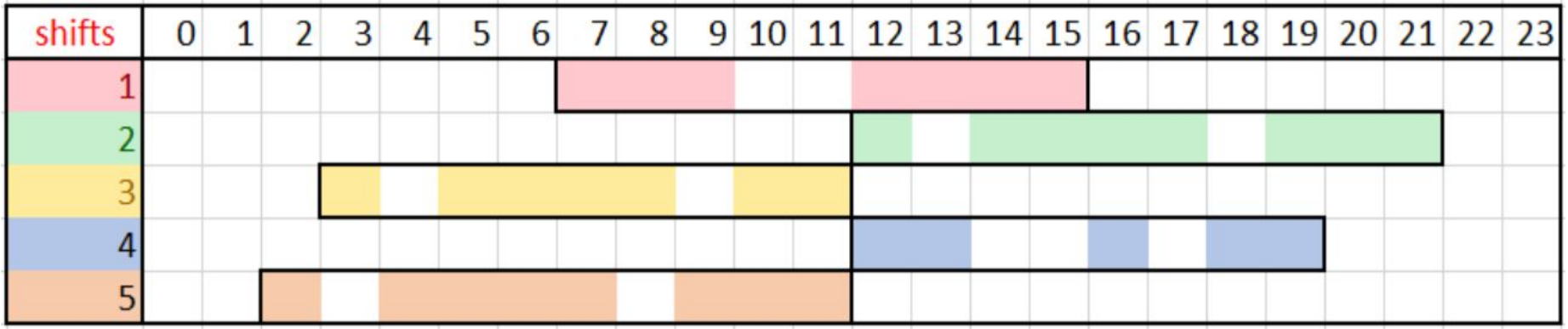
2. Minimize average # controllers per airport

low traffic

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

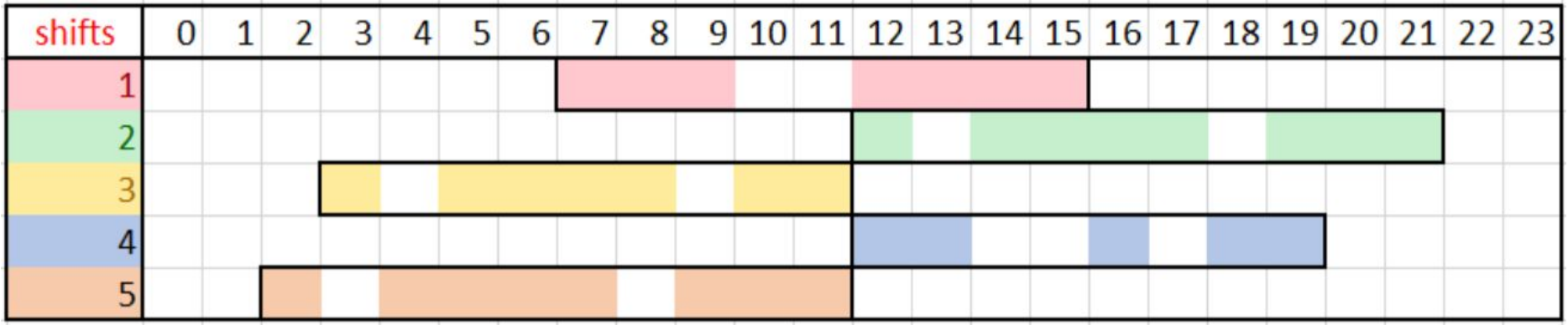


Total #. of ATCOs	Av. # of ATCOs per airport	Av. # endorsements per ATCO	Av. time in position	Av. time at work	COP
5	2.4	2.4	6	9.2	0.65

2. Minimize average # controllers per airport

low traffic

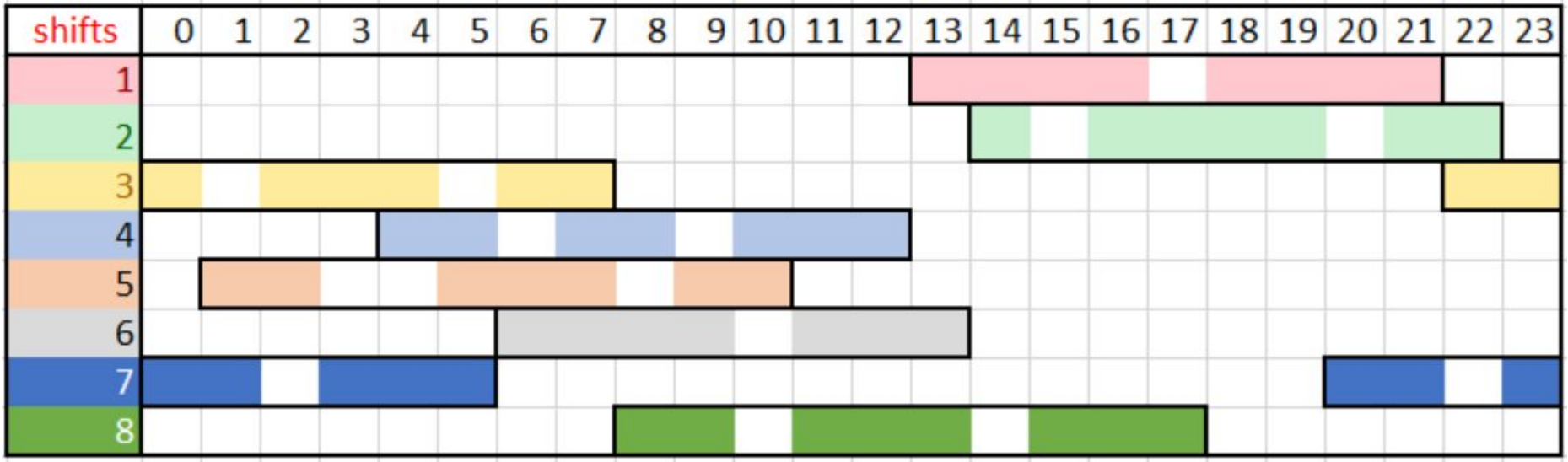
23-Jul-16	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AP1	0	0	0	0	0	0	0	1	1	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0
AP2	0	0	1	1	3	3	3	1	2	5	2	2	4	5	2	1	3	3	1	2	4	2	0	0
AP3	0	0	0	0	0	0	3	0	0	1	2	1	1	0	0	0	1	0	0	0	0	0	0	0
AP4	0	0	0	0	0	0	4	3	3	3	3	1	4	1	0	4	3	0	0	1	0	0	0	0
AP5	0	0	0	0	0	0	1	0	2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



Total #. of ATCOs	Av. # of ATCOs per airport	Av. # endorsements per ATCO	Av. time in position	Av. time at work	COP
5	2.4	2.4	6	9.2	0.65

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

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 endorsements

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

Often switches in the controller assignments

- ✓ Handovers, additional workload
- ✓ Need to minimize the # of assignment switches

3. Minimize the # of assignment switches

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	5	2.75	7.88	9.38	0.84

Min # of assignment switches vs. Min # controllers per airport: Compare statistics

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

Potential conflicts in airport schedules

Conflict - 2 movs at 2 airports within 5 min

The number of conflicts in schedules for each airport pair during 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	

Conflict avoidance

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

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

Conflict avoidance

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

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

Conflict 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

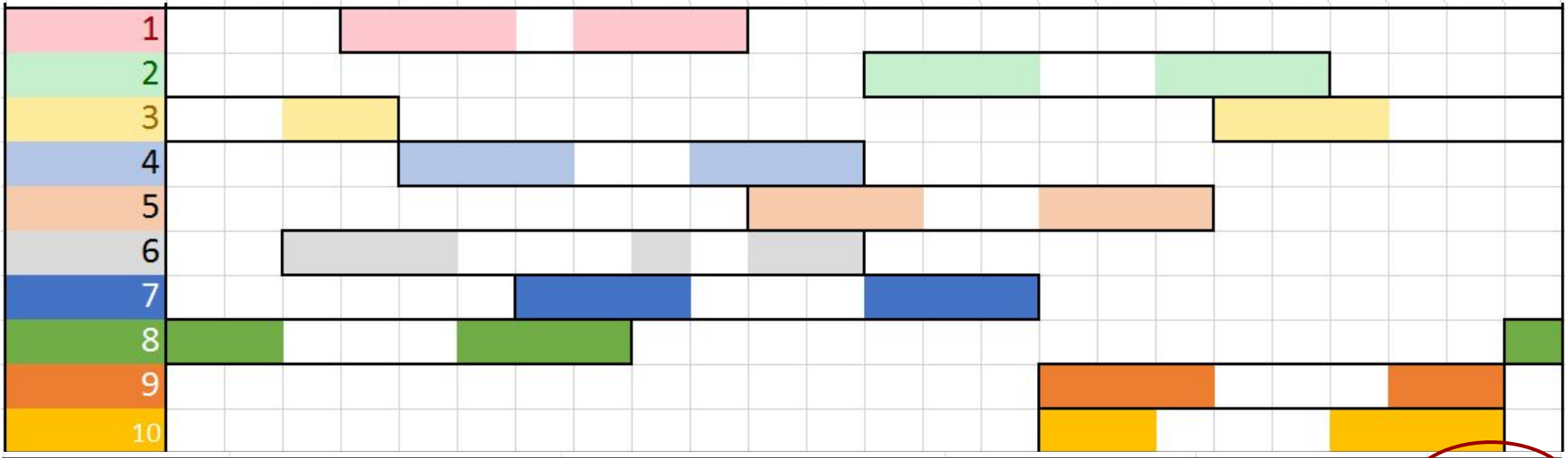
Total #. of ATCOs	Av. # of ATCOs per airport	Av. # endorsements per ATCO	Av. time in position	Av. time at work	COP
10	3.4	1.7	7.9	9.8	0.81

Extra 2 ATCOs are needed to cover for the potential conflicts

Alternative set of input parameters

time “in position” <=6h, cont. time w/o break <= 3h

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
10	5.6	2.8	5.7	8.5	0.67

Alternative set of input parameters Compare statistics

old input: time "in position" <=8h, cont. time w/o break <= 4h

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

new input: time "in position" <=6h, cont. time w/o break <= 3h

Total #. of ATCOs	Av. # of ATCOs per airport	Av. # endorsements per ATCO	Av. time in position	Av. time at work	COP
10	5.6	2.8	5.7	8.5	0.67

Extra 2 ATCOs are needed to provide better working conditions

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

Conclusions

- ✓ Universal flexible automation tool
  - 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 provide staff savings
- ✓ Outlined challenges in RTC staff planning

Future work

- ✓ Solve trade-offs between switches and # controllers
- ✓ Rosters with respect to actual modules
- ✓ Rosters for the whole weeks

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Thank you!