Scheduling Air Traffic Controllers at the Remote Tower Center

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Constructing rosters for air traffic controllers (ATCOs) is a complex problem, and in the context of Remote Tower it becomes even more challenging. An effective method to produce real-world rosters requires the ability to model shifts and breaks, distribute the varying workload between several remote tower working positions, rotate staff through all the tasks for which they are qualified to maintain endorsements, fulfill the requirement to train staff whilst continuing normal operations, and re-roster due to unexpected events.

In the civilian air traffic control (ATC) world there are very strict and legally binding regulations defining ATCO's working conditions [7]. These regulations do not take seasonal traffic variations into account, resulting in overstaffing during lower-traffic months and staff shortages during peaks.

Remote Towers Services (RTS) are one of several technological and operational solutions that the SESAR Joint Undertaking delivers to the ATM community for deployment. RTS was proposed as a cure for staff demand imbalances, from which most small airports (30-120 movements a day) suffer, by splitting the cost of air traffic serivices and staff management between several airports. Maximizing the efficiency of human resources is of particular importance because labour accounts for up to 85% of air traffic service costs [14].

Researches studied various aspects of the RTS concept. Oehme and Schulz-Rueckert [12] propose a sensor-based solution for aerodrome control that removes the dependency on visibility conditions and tower location. In a safety assessment of the Remotely Operated Tower (ROT) concept, Meyer et al. [10] suggest functional hazard analyses and pinpoint the issue of getting reliable probability values for the models. In [8], [11], and [13] various aspects of work organization and human performance issues related to the remote operation are considered. Assigning airport traffic to Remote Tower Modules (RTMs) was considered in [1].

ATC rostering inherits some features from the related staff scheduling problems, such as e.g. nurse scheduling [3], university course timetabling [4], multi-skilled staff planning [9]. An overview of early works on ATC shift scheduling is presented in [2]. The survey [5] presents the methods for effective staff rostering: Linear Programming, Tabu Search, Simulated Annealing, Constraint Programming, Case-Based Reasoning, and some more. Conniss et al. [6] proposed a greedy heuristics to solve the ATCO scheduling problem. Their problem description is close to the one we formulate in this work, but naturally lacks constraints related to the RTC.

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I. Remote Tower Air Traffic Controller Shift Scheduling Problem

In this work, we present a generic optimization framework designed as a flexible tool for future RTC staff planning. In particular, We identified several issues related to staff scheduling when multiple airports are operated from a single center. The main question is: How to automate and optimize the scheduling of air traffic controllers at the RTC with respect to the corresponding constraints on their shifts?

The input to our problem is a one-day airport flight schedule, and the output is the optimal assignments of controllers to the RTC airports per hour, which takes into account constraints on the operation possibilities.

We propose the following objectives:

(1) Minimize the total number of active controllers in the RTC during the given period
(2) Minimize the average number of controllers per airport
(3) Minimize assignment switches

We integrate the following safety and efficiency requirements for personnel operation as constraints to our model:

(a) Maximum number of airports assigned to one controller
(b) Maximum number of movements per controller
(c) Maximum number of controllers per airport
(d) Potential conflicts in schedules are to be avoided
(e) Upper and lower bound on controller shift length
(f) Maximum total time "in position" (i.e. the time when an ATCO is assigned to control some airport)
(g) Maximum continuous time "in position" without break
(h) Endorsements (ATCOs are assigned only to those airports, for which they hold endorsements. Each controller has to undergo the corresponding training in order to obtain the endorsement for each specific airport.)

We formulate our problem as a MILP, which in general is NP-hard to solve. We use the AMPL modeling language and the CPLEX solver to model and solve the MILP for five Swedish airports planned for remote operation.

II. Experimental Study

We feed the model with real flight data samples (from EUROCONTROL's Demand Data Repository (DDR)).

First, we estimate the theoretical lower bound on the number of controllers for the day with highest traffic in 2016, October 19, and for the day with the lowest traffic in 2016, July 23. The resulting assignments show that a minimum of 8 controllers would be needed to handle all traffic at the RTC during the highest traffic day, while only 5 would suffice for the day with the lowest traffic.

Next, we compare the number of controllers that are necessary to manage the traffic at each of the five airports individually for the days with minimum and maximum traffic. Two of the airports participating in our studies are operated 24/7 all year round, and the variations in the number of controllers necessary for operation are insignificant (variation of 15-20%); for the other three airports, we observe a noticeable variation in the necessary number of controllers—about 50%. Our results show that at the RTC the difference between the staff demand between July 23 and October 19 is 37.5%, which confirms that the RTC suffers less from staff imbalances, even when we consider only lower bounds. For operation, a buffer of about 33-45% is added to compensate for weekends, vacation, sick leave, maternity and paternity leave, control of non-regular special traffic, bad weather conditions, and possible technical problems. For the day with the highest traffic, our framework yields 17 controllers as the minimum number of controllers that are needed when the traffic is managed in regular towers individually. After accounting for the buffer at each airport separately, all airports together need to employ 26-34 controllers. At the RTC, adding the maximum buffer of 45% to the lower bound of 8, our model outputs that 15 controllers should be employed at the RTC at that day. This immediately provides staff savings of 42-55%, confirming that significant HR savings can be achieved because the corresponding buffer is shared between the remotely operated airports at RTC.

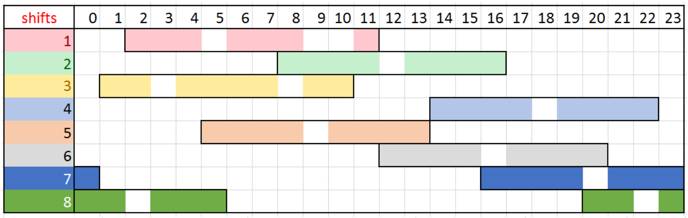
We apply different optimization objectives and play with the input parameters to compare the resulting optimal assignments. Moreover, we study the trade-offs between the three objectives. A smart combination of them should be used in order to achieve reasonable assignments, which is subject of further discussions with operational experts.

Figure 1 shows an example assignment of controllers to remote airports per hour with the number of movements in the table cells for the objective function of minimizing assignment switches. Figure 2 illustrates the actual controller shifts and the table below the chart gives the corresponding statistics. Each controller is monitoring one or two airports during his shift with at most 10 total movements per hour.

The model under development was discussed with operational experts in LFV (Luftfartsverket, the Swedish ANSP) to provide a picture on staffing constraints as close as possible to reality. We prove that RTS increase HR efficiency, thereby providing significant cost savings. The model easily incorporates individual controllers' preferences and airport specifics, and helps to predict the required number of endorsements per controller, making it a handy support tool for future staff planning. The designed techniques and tools will be applied to other sets of airports being considered for remote operation.

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

Fig. 1. Controllers-to-airports assignment with the minimum number of switches (objective 3) for the highest traffic day. The table entries give the number of movements per airport. Different colors indicate different controllers.



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

Fig. 2. Controller shifts for each of the eight controllers assigned to work at the RTC during the day with the highest traffic. The rectangular boundaries indicate the complete shift, while the colored cells indicate the hours "in position" for each controller.

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