motulus.aero

Integrated Crew Scheduling

MOTULUS

Introduction

Within an airline, crew management and planning is probably one of the most complex areas of its operations. Crew-related costs are responsible for about 1/3 of the airline operating costs. Therefore significant cost savings, productivity and schedule robustness improvements can be achieved through an automatic optimized planning system, even for small to medium sized airlines.

Due to the complex nature of the problem, some airlines still rely on manual planning, with non-optimal results as an outcome. As the airline grows, this non-automated planning grows even more unwieldy. Efficiency of the roster, expressed in terms of **cost and productivity, deteriorates** further.

Since the problem is mathematically very hard to solve due to the explosion of possible combinations, current commercial systems tend to split the problem in two parts. A pairing problem and a rostering problem.

By splitting the problem, one first creates sequences of flights – pairings – of multiple lengths and chooses the pairings with the lowest cost. This reduces the problem of millions of combinations into a manageable set of low cost pairings after optimisation.

In the rostering problem challenge, the algorithm tries to fit these 'optimal pairings' in the available space left between ground duties, off-days or other pre-assigned activities.

It goes without saying that this is a suboptimal solution, as the pairing optimisation step has no prior knowledge of the available space in the rosters of the crew members. Pairings which might have been more efficient, if the pairing optimisation had prior knowledge of space available, have been discarded in the pairing problem.

Motulus combines the two steps, resulting in a one-off calculation from pairing generation to roster generation, and deals with the aforementioned limitation and thus gives the possibility of a **global optimal solution**. A cost reduction of a few percent usually results in annual savings of millions of US dollars for large airlines. Therefore even improvements of as little as 1% generate significant savings, let alone the improved productivity and robustness of the rosters.

The challenge is that for large problems the number of pairings grows exponentially and the resulting crew rostering in the second step becomes very difficult, but with the latest generation of cloud computing and parallel processing, it is possible to find the global optimum.

Motulus worked the last couple of years together with a European airline to create advanced algorithms running in the cloud to obtain an integrated solution for the crew planning process. At this moment, no other commercial software provides this capability.

"The integrated solution finds a global optimum. No other commercial solution provides this possibility"

Problem description

The airline has a fleet with both long haul and short haul aircrafts. About 350 pilots and 800 cabin crew members are to be scheduled. Various crew bases exist, both in Europe and two other continents. Mixed fleet flying, right hand seat flying, multiple base flying, different part time systems and many more constraints are typical for the operations as well. Furthermore the planning process should comply with the EASA and company regulations and should take into account fatigue scores.

The integrated calculation takes a flight schedule and crew data as input, and creates optimized personal legal rosters as output, without re-iteration or manual intervention of a planner.

motulus.aero crew planning features

Motulus implemented following constraints in the mathematical model which simulates the business environment

- All EASA rules and regulations
- Company guidelines
- Mixed fleet flying
- Right Hand seat flying
- Relief pilot flying
- Recency planning
- Pre-assigned activities
- Optimised weekend assignment
- Multiple base flying
- Base switches
- Taxi own means
- Taxi sharing
- IATA flights API lookup to retrieve the most cost effective IATA flights
- Equal distribution feature
- Standby optimisation
- Comprehensive and intuitive cost function
- Different collective agreements
- Bidding module
- Integrated fatigue modelling
- Fatigue reduction optimiser
- ...

Objective function

The optimiser minimizes the objective function as defined by the user. Therefore it is important to reflect the complete business into this function, the closer the objective function matches the real costs or target settings, the better the resulting roster will reflect the target scenario. Aside from hard business costs, other requirements, such as the robustness of the roster, crew preferences, etc., can also be translated into contributions towards the objective function. The business can tweak the outcome of the roster to strike a balance between the business cost, crew comfort, and operational robustness by changing their weight in the optimizer's objective.

Business Costs

Below is an example of business costs which can be implemented.

1. Hotel costs:
    1. Nightly rate for each destination (from the airline database)
    2. Hotel transfer costs (from the airline database)
2. Positioning costs:
    1. Taxi (from the airline database)
    2. Taxi own means
    3. IATA (with discrimination between economy / business class tickets)
    4. Deadhead
3. Per diem costs (daily allowances)
4. Freelancer costs, hourly rate
5. (Optional) Crew wages

Point 5. is only relevant in what-ifscenarios when the optimal crew size is sought.

Soft costs

Soft costs are implemented to give a weight (or importance) to various 'soft rules' taken into account during optimization. Contrary to hard rules (e.g. EASA regulations) these rules are preferably respected, but can be violated when it is too hard (or even impossible) to generate a legal roster otherwise. The importance of respecting individual soft rules is determined by the (height of the) penalty cost assigned to each violation. Soft rules are used to implement a variety of business requirements and crew preferences.

One example of a soft rule is to schedule with a minimum margin on the legal rest to increase the robustness of the roster against flight delays. Under some circumstances, however, it is hard to crew all planes when the margin is respected. The optimizer will allow a violation against the rule when all other options increase the total cost by more than the penalty cost assigned to planning without a margin.

In cooperation with the airline, desired soft rules were identified and implemented.

Operational Robustness

One can define rules to be satisfied to create a robust roster. In an operations environment one wants to avoid creating a snowball effect in a crew member roster due to last minute changes, delays, cancellations, sickness...

Crew Size Optimization

The objective function offers the possibility to take into account the crew wages, allowing the optimizer to find the optimal crew size for a given publication period. We note that this is different from finding the minimal crew size required to be able to execute all flights. Indeed, in a minimal crew setting, all soft rules are necessarily disregarded and might even result in higher operational costs; All extra taxis, hotels, IATA flights, etc., that are required to cover all flights with the minimal crew may outweigh the cost of hiring additional crew.

What-if scenarios

The optimiser allows to perform multiple what-if scenario runs and to tune parameters. This gives important insight into the business itself and allows the user to fine-tune the outcome of the roster to the desired goal.

Multiple what-if scenarios have been run, where the objective function has been tuned, to evaluate the outcome of the roster. Results are visualised in the Motulus analytics dashboard.

In this section, three scenarios are compared and discussed:

» **Reference schedule.** This is the reference schedule made manually by the airline schedulers.
» **Base schedule.** The settings for this scenario will approximate the standard practice of the airlines schedulers the closest, resulting in the best one-on-one comparison.
» **Full potential schedule.** To get the most out of the optimiser, one should let the optimiser do its work, in other words give it as much optimisation room as possible by removing most of the pre-assigned activities. In this case however, requested off-days, holidays and special flight missions (US/Canada) were kept as pre-assigned activities. All others were removed.

Below is an overview of the different settings used in the calculations.

SCENARIO	SOFT RULES	ROBUSTNESS	BLOCK HOUR DISTRIBUTION	PRE-ASSIGNED ACTIVITIES
Reference schedule	V	V	V	V
Base schedule	V	V	V	V
Full potential	V	V	X	X

Table 1: Overview of the different scenarios with a high level view of the used settings.

Results

Motulus.aero features an analytics dashboard to compare different scenarios and its effect on KPIs. In this section we will describe the most important result. Additional KPIs can be added in the future.

Business costs

These are the real costs in euros of hotels, taxi's,...implied by the specific roster.

"Up to 25% in direct cost savings can be achieved"

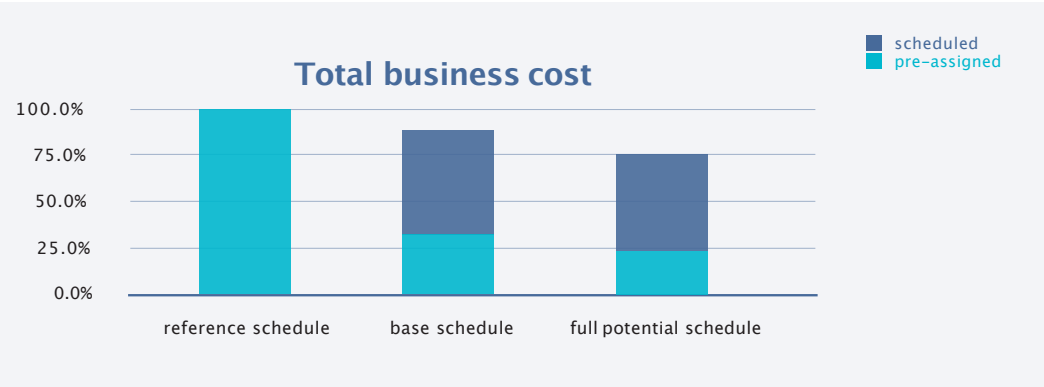


Figure 1: Business cost for the different scenarios.

The legend shows which costs were pre-assigned by the airline scheduling team before the calculation and which costs were "scheduled" by the optimiser.
E.g:

» The reference scenario only shows pre-assigned costs since the whole schedule was manually scheduled and thus "pre-assigned".
» The full potential scenario shows a relatively small pre-assigned business cost. This is related to the specific flight missions which were kept as pre-assigned activities in the calculation.

Table 2 summarizes the cost savings realized by the optimizer. From the results, it is clear that, to unlock the full potential of the optimiser, one should allow as much empty space in the roster as possible. This can be done by limiting the pre-assigned ground days and other pre-assigned non flying activities.
The savings mentioned are business costs: taxis, hotels, iata flights, per diems and cost of freelancers.

	Business cost savings
Reference schedule	–
Base schedule	11.2%
Full potential schedule	25.0%

Table 2: Total business cost savings

Soft rule violations

The dashboard also shows how many times soft rules are violated in the different scenarios. A subdivision in violations is made between activities which were pre-assigned and activities scheduled by the optimiser.

"The full potential scenario shows a reduction of 80% in violations against scheduling guidelines"

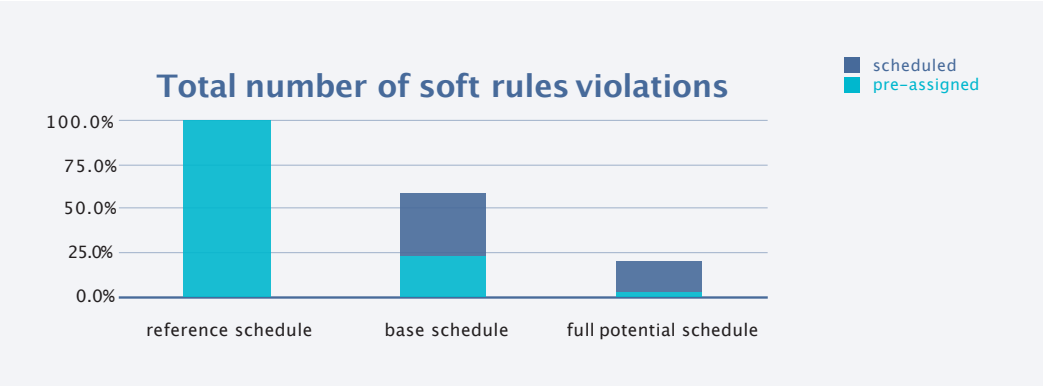


Figure 2: the number of soft rules violations for all the scenarios mentioned.

We highlight some observations:

» The base scenario has limits the number of soft rule violations to less than 60% than the reference scenario. The optimiser generates a reduction of 41% in scheduling guidelines violations, with modest costs assigned to each rule violation. Larger reductions in the number of violations are possible by increasing these penalty costs in the objective function.

» The largest violations in the reference schedule occur against the 1-hour margin on rest Rule. In the optimized planning, a very limited number of violations against the rule are made by the calculator, with most violations due to pre-assigned activities.

» The base scenario seems to schedule less flights below rank, but more long taxi rides, this is an indication that the optimiser still finds benefits on the total cost by scheduling longer taxi rides. By increasing the penalty of long taxi rides the number of violations can be reduced.

» The same observation as for the business cost holds for the soft rules: The results improve dramatically when the optimizer is provided with more freedom, as in the full potential scenario. The total number of soft-rule violations is reduced to less than 20%(!) of the number of violations in the reference schedule.

Operational efficiency

Operational efficiency can be best described as the ability to cope with unexpected delays and propagation of these delays in the roster of a crew member. An important parameter is the margin on legal minimum rest, if too close to minimum rest is planned and a delay occurs, it might invalidate the next duty, creating a snowball effect in the whole roster. Figure 3 shows a drastic decrease in the number of violations of this rule, realizing a reduction of 59% in the base scenario where the majority of the remaining violations is due to pre-assigned activities. Extra freedom given to the optimizer results in increased robustness as well: in the full potential scenario only a handful of duties are planned without the margin on rest.

No margin on minimum rest

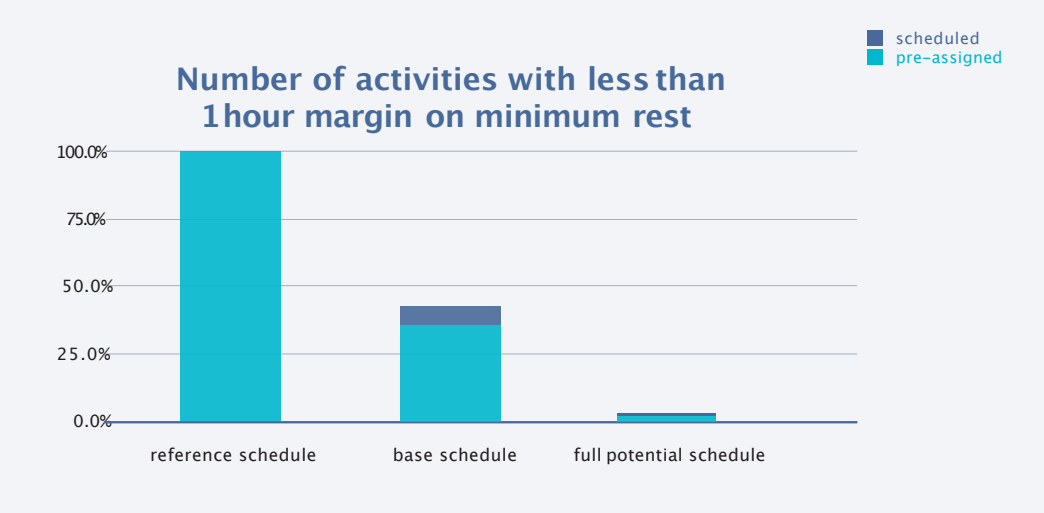


Figure 3: The number of duties planned with less than one hour margin on minimum rest.

Standby

The optimiser will generate standby duties based on the flights on a given day. It will then adjust the length of the standby to capture as many flights as possible, given the rules set in the collective agreement. This allows a large percentage of flights to be covered by a specific standby, in contrast to the reference schedule standbys of 6 hours. It also makes sure that the worst case flight regarding rest time is taken into account, thus it will plan rest between activities based upon this. The result is a standby which will not generate a snowball effect in a crew member's roster if filled in.

"The optimiser can bring productivity levels for the current fleet, to levels of 7 years ago, when the overhead and inefficiencies were lower due to the smaller fleet"

Crew productivity

A good KPI to describe the efficiency of a crewmember is to look at the **duty versus blockhour ratio**. This factor will increase if a crewmember has many non-flying days or a lot of positioning time and therefore is not scheduled efficiently in terms of flying hours. Therefore it is best to keep this factor as low as possible.

As an airline grows, the overhead and inefficiencies grow as well. This specific use case proved that the motulus.aero optimised planning calculator was able to lower these ratios and create productivity improvements of the crew members up to levels of 7 years back in time for a fast-growing airline.

Impact of pre-assigned activities

The results clearly indicate that the amount of manual pre-assigned activities has an important effect on the efficiency of the optimiser. Pre-assigned activities count for 41% of the total space in the base scenario roster, which is quite inefficient. In the full potential scenario the pre-assigned activity ratio dropped to 7%. Associated with the resulting extra space in the roster large improvements in cost, rule violations, robustness and crew productivity can be realized. The impact on the business cost is shown in Figure 4.

The more activities are pre-assigned, the less space there is for the optimiser to schedule activities, one should therefore try to lower this ratio, as it improves all KPIs.

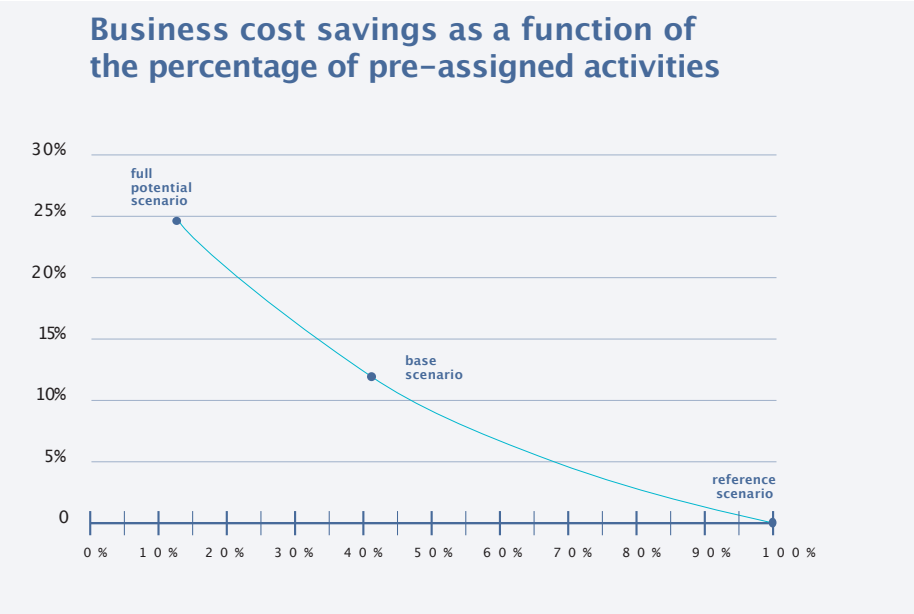


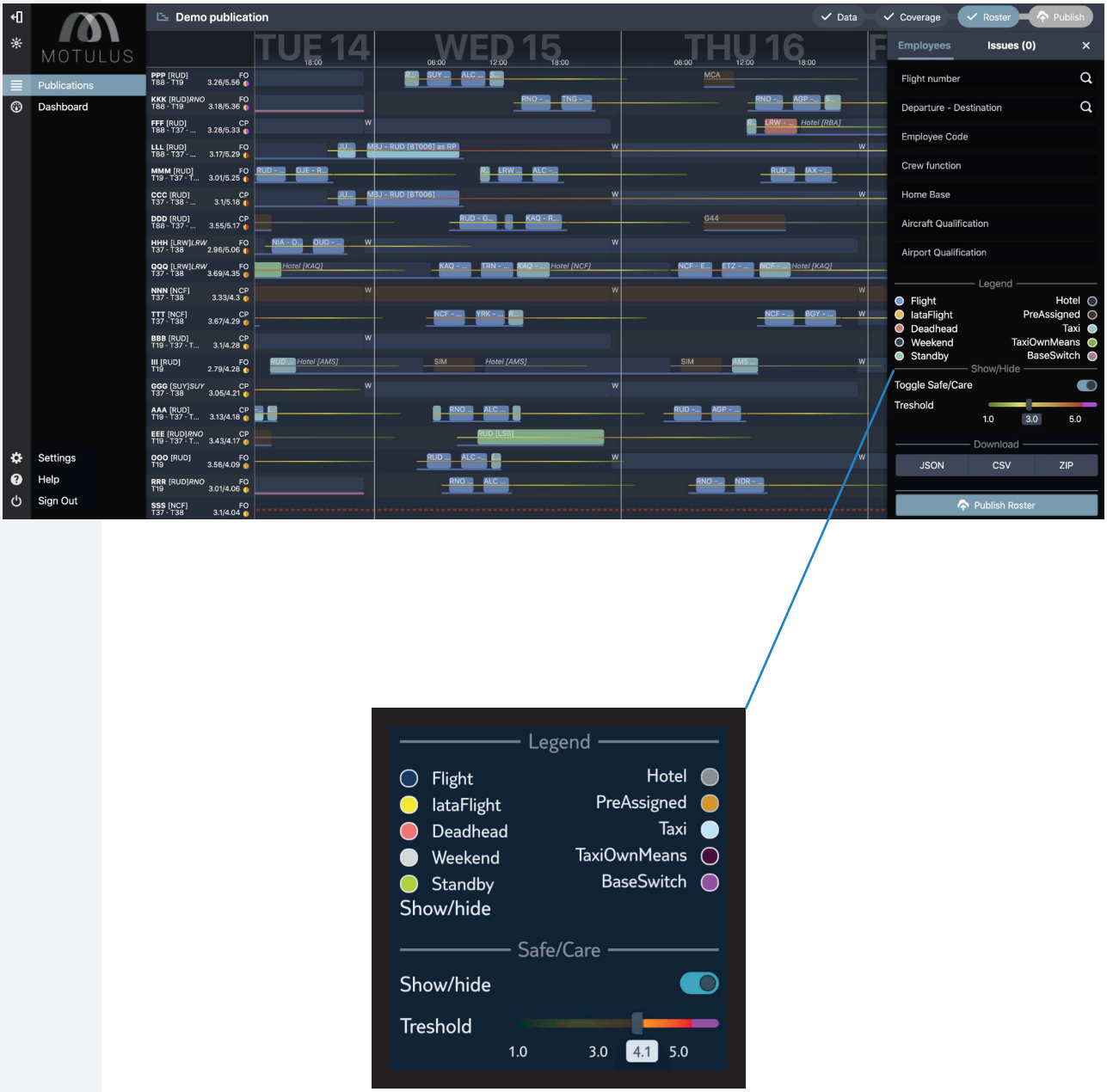
Figure 4: Cost savings against the percentage of pre-assigned(i.e. manually planned) activities.

Conclusion

Picking the most optimal schedule by creating a roster manually is nearly impossible. The amount of possible roster combinations would run in the billions. No human being would ever achieve this. This is where combining high performance cloud computing and state of the art algorithms is an enormous opportunity..

With the use of an automated schedule optimiser, an airline can gain significant benefits on cost, operational efficiency and productivity. It facilitates the use of what-if scenarios to gain insight into the business and improve short term and long term planning. The airline can track growing inefficiencies, improve productivity and reduce cost in a data driven approach instead of using a manual trial and error based approach.

Automated, optimized planning radically reduces the time needed to create a roster, which gives more flexibility in the airline's operations. It also assures full transparency as all rules and constraints are explicitly defined and taken into account by the calculator.



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