Airline maintenance task rescheduling in a disruptive environment

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Maintenance is an important factor of airline operations performance as it takes up around 10% of the total available time, and about 15% of total operational cost. As the potential revenue for using a wide body aircraft for commercial operations equals around €180.000,- per day (*rough estimate*), efficient maintenance scheduling is of key importance for the earning potential of a commercial airline. In the past, extensive research has gone into optimization of maintenance schedules, with the aim of decreasing maintenance cost and increasing operational availability.

However, despite potentially having one efficient maintenance schedule prior to the start of operations, disruptions during operations are very common. These disruptions, in the form of unanticipated maintenance tasks, maintenance slot adjustments, and resource availability alterations, compromise the efficiency and feasibility of the initial schedule. Creating new schedules each time after a disruption emerges is not practical, as stability is of key importance for operational reliability. For this reason, maintenance schedules are required to be continuously adapted such that all tasks are executed in time.

This is the first time that disruption management is considered for aircraft maintenance task scheduling. Up until now, research on airline maintenance scheduling did not include schedule flexibility and the occurrence of disruptions. In this paper, an innovative continuous maintenance task rescheduling framework is presented to improve maintenance task scheduling in a disruptive environment. The core of the framework is an efficient mixed integer linear programming (MILP) optimization model that considers a hierarchy of rescheduling objectives and is constrained by the availability of material, machinery, method and manpower (4M).

Problem definition

Within commercial airlines, disruption maintenance management and, in particular, the process of constantly rescheduling maintenance tasks takes place manually. As this is a both complex and time demanding task, doing this manually can lead to inconsistent and inefficient decision making. The implementation of a framework for maintenance task rescheduling can assist a maintenance scheduler in the decision-making process. Where a manual approach is only able to create a schedule for the short-term, it is difficult to identify the underlying consequences for the long-term. Considering the long-term consequences during scheduling is of importance as there is a risk that tasks indefinitely are postponed until their due date reaches where this causes an operational disruption. By means of the framework presented in this paper a scheduling window of 120-days can be used. While for manual scheduling this is currently limited to around 10 days. With the extended scheduling window, it is possible to identify problematic task up front

To increase the scheduling performance and assist the maintenance scheduler, the framework presented in this paper aims for the following objectives:

1. Minimize maintenance ground time, to increase schedule efficiency.
2. Limit number of rescheduling actions, to improve schedule stability.
3. Consider long-term consequences during scheduling, to improve schedule robustness

By means of the scheduling objectives defined above, the framework contributes to an improvement in maintenance scheduling in multiple ways. Increasing schedule efficiency consequently leads to an increase in operational availability and thereby an increase in potential revenue for an airline. In terms of schedule stability, a decrease in last-minute schedule changes contributes to maintenance reliability for operations. A stable schedule allows for better allocation of resources as well as more reliability towards the operational domain. At last, taking long-term consequences into account increase schedule robustness as problems potential scheduling problems are identified up front.

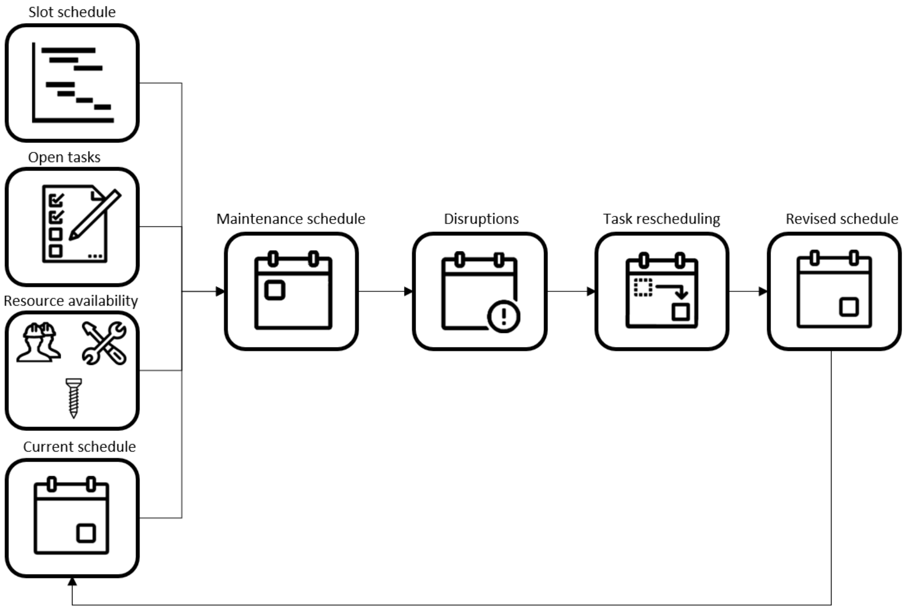

Figure 1: Outline of maintenance task rescheduling framework (Icons from: Flaticon.com)

A general overview of the maintenance task rescheduling framework is provided in Figure 1. On the left side, the four inputs of the framework are outlined. Before a disruption occurs, tasks and resources are allocated to maintenance slots in an already existing schedule. Maintenance schedules are continuously updated over time and are adapting to disruptions that take place. In an airline maintenance environment, tasks arrive continuously and slots change dynamically.

The type of disruption that are included within the scope of this framework relate to the inputs defined in Figure 1 and come in the following forms:

1. Irregular arrival of new tasks
2. Adjustments to the slot schedule. This includes the change in duration, removal or addition of maintenance slots
3. Adjustments in the availability of resources. This includes a decrease or increase in the availability of skilled workforce as well as a change in the availability or unavailability of required machinery and material.

When a disruption takes place as defined above, the framework can be used to evaluate if there are any infeasibilities in the schedule and if task rescheduling is required. If necessary, rescheduling takes place according to the scheduling objectives defined above. Within commercial airlines, this takes place frequently throughout the day and the framework continuously keeps track of the schedule and keeps it in a feasible state.

The process of scheduling and rescheduling tasks is constrained by the availability of resources, in the form of 4M requirements. An explanation of each of those requirements is provided in Table 1. Each of the 4M requirements needs to be satisfied in order for a task to be able to be scheduled.

Table 1: Formulation of 4M requirements within the analysis

4M's	Explanation
Method	The estimated execution duration of a task needs to fit within the scheduled duration of a maintenance slot
Machinery	The scheduled execution date needs to be after the Estimated Time of Arrival (ETA) of the required machinery.
Material	The scheduled execution date needs to be after the ETA of the required material.
Manpower	Workforce which satisfy the skill requirements of the task, need to be scheduled to the corresponding maintenance slot for the required amount of workforce hours.

Case study

A 5-month case study on a fleet of 60 aircraft showed that implementation of the framework in the airline decision making process contributes in an increase of both schedule efficiency (a reduction in ground time) and schedule stability (a limited number of schedule changes during disruptions). In one hand, the number of last-minute schedule changes decreased by 47.2%. On the other hand, the ground time was reduced by 2.95% by using a larger scheduling window. The airline can benefit from this in terms of an increase in potential revenue due to the decrease in required ground time. In terms of operational availability, this can result in €1.16 million of additional potential revenue on a yearly basis for the current scope.

The value of a 120-day scheduling window is confirmed by a stochastic disruption analysis. Compared to perfect information, the model was capable of scheduling around 94.6% of the tasks. Both the case study and the stochastic disruption analysis show the need of a maintenance scheduler supervising the framework. Instead of automating a manual process this framework aims to combine the best of both worlds by means a decision support system supervised by a maintenance scheduler. Where the modelling framework is able to achieve an increase in scheduling efficiency and stability, a maintenance scheduler can provide additional scheduling opportunities if required. This approach will yield in an increase in schedule stability, efficiency and robustness.