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# A Mobile Decision Support System for Aircraft Dispatch

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*SUMMARY & CONCLUSIONS*

Delays are costly to airlines in both money and image. A significant number of delays is caused by unexpected technical failures of aircraft systems or components. These failures, if not dealt with efficiently, can cause disruptions in the flight schedule and network. The annual costs of these type of disruptions add up to an estimated cost of €2.8 billion in Europe alone. Determining the optimal course of action when an unexpected failure occurs is currently troublesome, leading to inefficient dispatch decision making.

To minimize flight disruptions caused by unexpected failures, this research aims to optimize the dispatch assessment process by automating data collection and processing, and aid the AMT in decision making. For this purpose, a DSS framework was developed in cooperation with an airline and implemented through a use case. The framework includes the database detailing the individual sources, a 6-step decision making model and a user interface developed for mobile access. The resulting mobile tool has received positive feedback from end users and brings direct decision support for unexpected events to the workplace of the technician (i.e., the platform), while maintaining the ability to exploit the technician's expertise. Further novelty is added to the domain by including operational procedures in the research, closing the gap between theory and practice.

## 1 INTRODUCTION

While reliability and availability of aircraft are generally increasing as a result of extensive research in areas such as aircraft health monitoring and predictive maintenance [1], aircraft are highly complex systems that will continue to have unexpected failures. The aircraft dispatch process (i.e., the assessment whether an aircraft can safely perform the next flight) becomes significantly more complex when unexpected failures occur. Depending on the timing of unexpected failures, they can result in costly flight disruptions. The consequences add up to a total estimated cost of €2.8 billion annually, in Europe alone [2].

When sufficient time to troubleshoot the failure is available, the likelihood of flight disruption occurring is very small, because the troubleshooting department can determine and schedule the corrective maintenance action that results in minimal operational impact. However, when an unexpected failure occurs close to the scheduled time of departure, the time available for troubleshooting and planning appropriate action is limited. Moreover, the responsibility of troubleshooting is now shifted to the Aircraft Maintenance Technician (AMT) who is on the platform at the aircraft, with limited access to relevant information and documentation. This situation, with less time available for decision making while having less information to support the decision, typically leads to sub-optimal decisions and an increased likelihood of flight disruptions. This runs counter to the aircraft operators' aim to minimize flight disruptions and its resulting costs.

### *1.1 Objective*

This research proposes a Decision Support System (DSS) framework to aid in minimizing flight disruptions by 1) providing direct decision support for operational processes involving short time spans (i.e., approximately 45 minutes for an Airbus A320 turnaround [3]), 2) automating collection and processing of relevant data from multiple sources, and 3) providing ranked dispatch alternatives to the AMT on-site through a mobile tool. This research is part of the European AIRMES project [2] in the CleanSky 2 program, which aims to reduce the cost of operational disruptions due to aircraft technical failures in Europe by €1 billion annually. In collaboration with industry partners like Airbus and TAP Portugal, the DSS framework is implemented by means of a mobile application.

The remainder of this paper is structured as follows: section 2 provides a brief literature review to position the research with respect to the state of the art. In section 3 the dispatch alternatives, process and criteria are described, whereas section 4 elaborates on the developed framework, describing the model, database and user interface of the system. Section 5 presents implementation through a use case and section 6 discusses limitations of this research as well as opportunities for future work.

## 2 LITERATURE REVIEW

Research in Decision Support Systems (DSS) really gained momentum in the early seventies of the last century, at the start of the computer era [4]. While there is an overall consensus that the use of DSS for decision making leads to better decisions, recent work stresses that there is still a lack of correlation between the theoretical systems and the actual system use [5, 6]. When looking at the state-of-the-art in decision making in the maintenance domain, contributions are focused on tactical and strategic maintenance planning. However, for operational decision making, with time horizons as short as the turnaround time of an aircraft, there is still a gap in literature [7]. Work of Papakostas et al. [8] does contribute to the subject of operational decision making for aircraft maintenance, but focuses on decision making for maintenance tasks that had been scheduled previously, and is specifically aimed at reducing unscheduled maintenance events of health monitored components. Hence, the following gaps in the state-of-the-art were identified: 1) a lack of correlation between theory and operational application, 2) the majority of current research does not cover decision support for operational decisions and 3) a lack of support for decision making when unexpected failures occur. This research aims to address these gaps. Firstly, the system will include a user interface on a mobile tool that enables validation through prototype testing with AMTs at a partner airline, to overcome the gap between theory and practice. Secondly, the system is aimed for real-time decision support in aircraft dispatch, having a typical timespan of a turnaround. Finally, it focuses on reactive decision making for unexpected failures.

The true state-of-the art in industry is hard to determine. Generally, information found on vendor websites or product brochures is more of a sales pitch than a technical description of their functionalities [9-11]. With this limitation for researching the state-of-the-art in industry, to the best of our knowledge it was found that these solutions are 1) either vendor specific (i.e., one would need multiple applications for a mixed fleet), or 2) focusing on health monitored parts (i.e., less suitable for non-monitored parts or (older) aircraft without advanced sensor systems), or 3) don't support automated knowledge-based troubleshooting (i.e., while relevant information is provided, the troubleshooting procedure is still manual), or 4) the solutions are "black boxes" (i.e., it is unclear what data is considered and what criteria are used for decision making), or finally 5) the applications are platform specific (i.e., only iOS/Android or no dedicated app at all, limiting hardware options). The solutions found in industry have at least one of these drawbacks, sometimes multiple. We aim to overcome these issues by developing a vendor-independent, multi-platform application that has the flexibility to support decision making for all unexpected failures, automates the troubleshooting procedure without neglecting the technicians' expertise and of which the functionality is completely transparent.

## *3 AIRCRAFT DISPATCH*

Before each departure an assessment has to be made if the aircraft is able to safely perform the next flight, known as the aircraft dispatch assessment. The dispatch assessment typically leads to a "fix" or "fly" decision, but in fact the alternatives for aircraft dispatch are more complex.

### *3.1 Dispatch Alternatives*

Based on previous work from Tiassou et al. [12] and feedback from industry experts, the following dispatch alternatives were defined, in order of least to most disruptive:

- *GO*: no defect or failure is found on ground by the AMT (i.e., No Fault Found (NFF)). The aircraft can safely continue flight operations without any restrictions.
- *GO-IF(P)*: a defect or failure is found, but does not concern an item described in the Minimum Equipment List (MEL). The failure can be deferred if it is not otherwise safety or performance related, but operator-specific restrictions may be imposed (e.g., a seat with a defective in-flight entertainment system is not sold); the aircraft can safely continue flight operations without operational restrictions.
- *GO-IF(O)*: a defect or failure is found and concerns an item described in the MEL. This so-called "dispatch by MEL" refers to the situation where a failure can be deferred for a specified period in order to minimize flight disruption and enables shifting corrective maintenance actions forward to a more convenient time and/or location. The failure can only be deferred if no conflicts with other already deferred items exists, but operational restrictions may be imposed; the aircraft can safely continue flight operations, but restrictions may apply. An example of such an operational restriction is a temporary restriction in the Extended Operations (ETOPS) certification, defining the maximum amount of single-engine flying time away from the nearest suitable airport (e.g., ETOPS-180), as long as the defect is deferred.
- *GO-IF(M)*: a defect or failure is found and can't be deferred, because it is a safety critical item or conflicts with an already deferred item. Corrective maintenance has to be performed, after which the aircraft can safely continue flight operations without further restrictions.
- *NO GO*: a defect or failure is found and can't be deferred, because it is a safety critical item or conflicts with an already deferred item. Corrective maintenance has to be performed, but requires more time than available before the next scheduled departure, including any accepted delay (i.e., depending on operator preference). The flight is cancelled or recovery measures will be applied (e.g., an aircraft swap [13]).

Figure 1 shows a basic example of a dispatch decision tree for an unexpected failure, starting at the top with a defect report and working towards one of the 5 dispatch alternatives at the bottom by Boolean decision logic. The decision alternatives at the bottom are arranged from left to right with increasing operational impact. Subsequently, an operator will try to find a feasible dispatch alternative as far to the left as possible. In the top right, Figure 1 includes a short description of the decision logic. Question 1 determines if the unexpected failure can be found on ground by the AMT (i.e., NFF). If there is a fault, question 2 determines if it concerns a MEL item. If so, question 2a is used to check if a deferral would conflict with already deferred items (i.e., check with the Deferred Item List (DIL)) and question 2b subsequently checks if a deferral would lead to restrictions that conflict with scheduled operations. If it is not a MEL item, question 3 determines if it is a safety or performance critical item not covered in the MEL, and if not, 3a checks whether potential restrictions for deferral are acceptable to the operator. Finally, when immediate repair is required, question 4 determines if there is enough time available to perform the maintenance task, leading to either a GO-IF(M) or a NO GO.

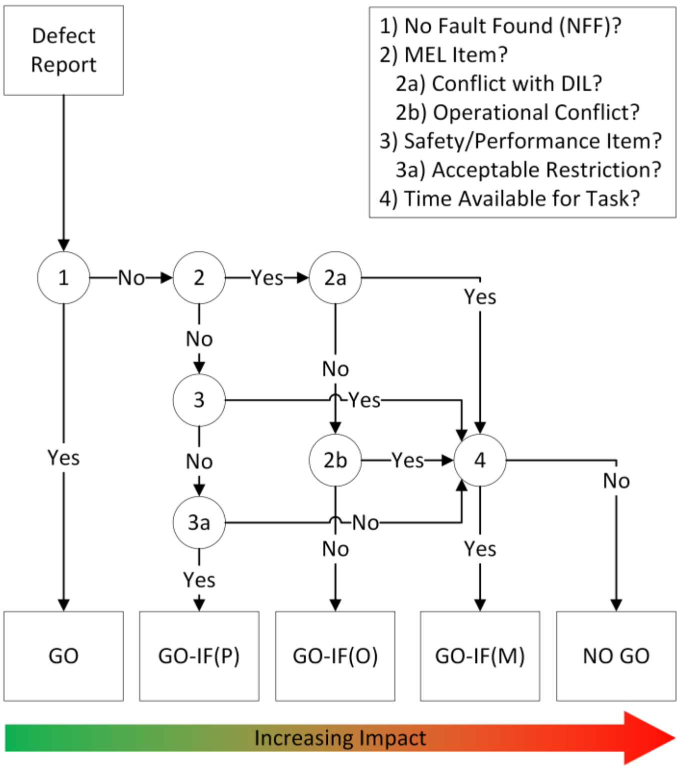


*Figure 1: Basic Example of a Dispatch Decision Tree*

### *3.2 Dispatch Process*

When a failure has occurred, determining whether an aircraft can safely perform the next flight can be a complex task. The first step in dispatch assessment is troubleshooting the task to determine the most likely root cause. This is done by consulting the Troubleshooting Manual (TSM) for a given failure and follow the step-by-step procedure that leads to a corrective maintenance task, described in the Aircraft Maintenance Manual (AMM). Next, the feasible dispatch alternatives need to be determined, which requires an estimation of the time required to perform the corrective maintenance task. There might be the opportunity to defer the item if the MEL allows for it, but operational constraints may apply. Hence, the Operational Control Center (OCC) has to be consulted to verify that flight operations can continue as scheduled. Moreover, the current defective item could conflict with other items that were already deferred on this aircraft. Furthermore, the location of the aircraft is of importance because operators prefer to perform maintenance at their home base, where all the necessary facilities, spare parts and skilled technicians are available. When at an outstation, costly outsourcing of corrective maintenance is only considered as a last resort. But even if the aircraft is at the home base, operators prefer deferral of the failure to avoid flight disruption and to be able to schedule the maintenance task to a more suitable timeslot (i.e., to an already scheduled maintenance check). The Maintenance Control Center (MCC) can provide relevant information with respect to task execution and maintenance planning. The operator will opt for immediate corrective maintenance execution only if deferral leads to extensive operational impact or when deferral is not an option according to the MEL.

It is clear that an AMT has to consult many sources of information to be able to make a well-informed dispatch decision. However, access to relevant information on the platform, especially to maintenance manuals, is either limited or non-existent. Moreover, finding relevant information for the task at hand in maintenance documentation is burdensome and time-consuming [14-16]. Troubleshooting a failure can already require more time than available in a typical turnaround (i.e., approximately 45 minutes for an Airbus A320 [3]). Hence, there is implicit pressure on the AMT to act both fast and accurate, two conflicting goals in aircraft maintenance [17].

### *3.3 Dispatch criteria*

To be able to differentiate between feasible dispatch alternatives and select the optimal alternative, criteria are used to evaluate them. All the dispatch alternatives described in Section 3.1 mention the word *safely*, except for the NO GO alternative that leads to cancellation of the flight. In aviation, safety always is the number one priority. Although 2018 didn't start off particularly well [18], aviation remains one of the safest modes of modern transportation [19]. In order to maintain that status, safety is the key criterion in dispatch decision making. Next to other regulations concerning airworthiness, safety in dispatch decision making is achieved through the MEL. Operators prefer to avoid disruptions in the flight schedule not only due to the costs they invoke, but also because delays hurt their image. Hence, to assess the timeliness of the dispatch alternative, time is another dispatch criterion. A third criterion is the current location of the aircraft. Operators prefer to perform all maintenance at their own maintenance facilities, because outsourcing of maintenance is far less cost effective. Subsequently, operators will always try to defer a defect when the aircraft experiences an unexpected failure at an outstation. A final criterion is the operational impact, specifically with respect to costs. Arguably, the criteria time and location can be translated into costs as well. However, data on these types of costs are hard to obtain, especially when they need to be assigned to individual cases. Therefore, cost is accounted for separately in the criterion operational impact, giving the opportunity to exclude it all together when no cost data is available (e.g., by assigning a weight of zero to the criterion).

Except for the safety criterion, the relative importance of each criterion may be different for each operator. The dispatch assessment is a typical Multi-Criteria Decision Making (MCDM) problem, and the operator-specific importance of a criterion can be accounted for by implementing MCDM methods like the Weighted Sum Method (WSM). However, the use case provided in this paper will only focus on the criterion time due to limitations in data availability. More specifically, the time required to execute corrective maintenance is compared to the time available to perform that task. Nevertheless, it is acknowledged that addition of the other three criteria, as well as suitable MCDM methods, is essential for operational implementation and therefore will be addressed in future work.

## 4 *DSS FRAMEWORK*

The DSS framework developed to aid AMTs in aircraft dispatch decision making comprises the three fundamental DSS components [20]: the database, the model and the user interface. This section elaborates on the components in detail.

### 4.1 *The Database*

The database provides the information to make a well-informed dispatch decision. Some of the data sources are provided by project partners, indicated as *external* source. The current DSS framework includes the following sources:

- *Electronic Logbook (ELB)*, external.
  The ELB is the digital version of the maintenance log of an aircraft and therefore includes all reported failures, logged as a defect report. A defect report includes information such as the tail number of the affected aircraft, date of origin and the fault message.
- *Maintenance Documentation*.
  Maintenance documents are available in SGML or XML format, which are semi-structured data sources that separate semantic elements by tags. To access relevant information efficiently, a generic crawler algorithm was written that retrieves the tag properties (e.g., type, index) from tagged data sources, such as SGML and XML, and stores it in a JSON object. This object is then used to retrieve relevant information from the original SGML or XML string. Currently, two document types are included: the Troubleshooting Manual (TSM), providing procedures to determine the root cause of a failure, and the Aircraft Maintenance Manual (AMM), describing maintenance task execution procedures.
- *Fleet Data*.
  Entails relevant information of the aircraft in the airline fleet, such as the tail number, the aircraft manufacturer, the aircraft model and the Customer Serial Number (CSN), which is used to determine applicability of maintenance manuals.
- *Flight Information*, external.
  The flight schedule for a given tail number to determine arrival and departure times, as well as current and future locations. The developed prototype can use a live feed or a fixed schedule. For the use case in this paper the live feed was used, in later stages of the project the fixed schedule will be used for prototype testing.
- *Knowledge Database (KDB)*, external.
  To aid the AMT in troubleshooting, a knowledge database of previous successful corrective maintenance tasks for the given defect is used. The tasks are ranked on historical rate of success and can be filtered on fleet, aircraft model and tail number level.
- *Maintenance Elapsed Time Control (METC)*, external.
  Each time a maintenance task is performed, the time required to complete this task is recorded. Based on historical task durations for a given task, the average time to complete this task is computed to estimate the time

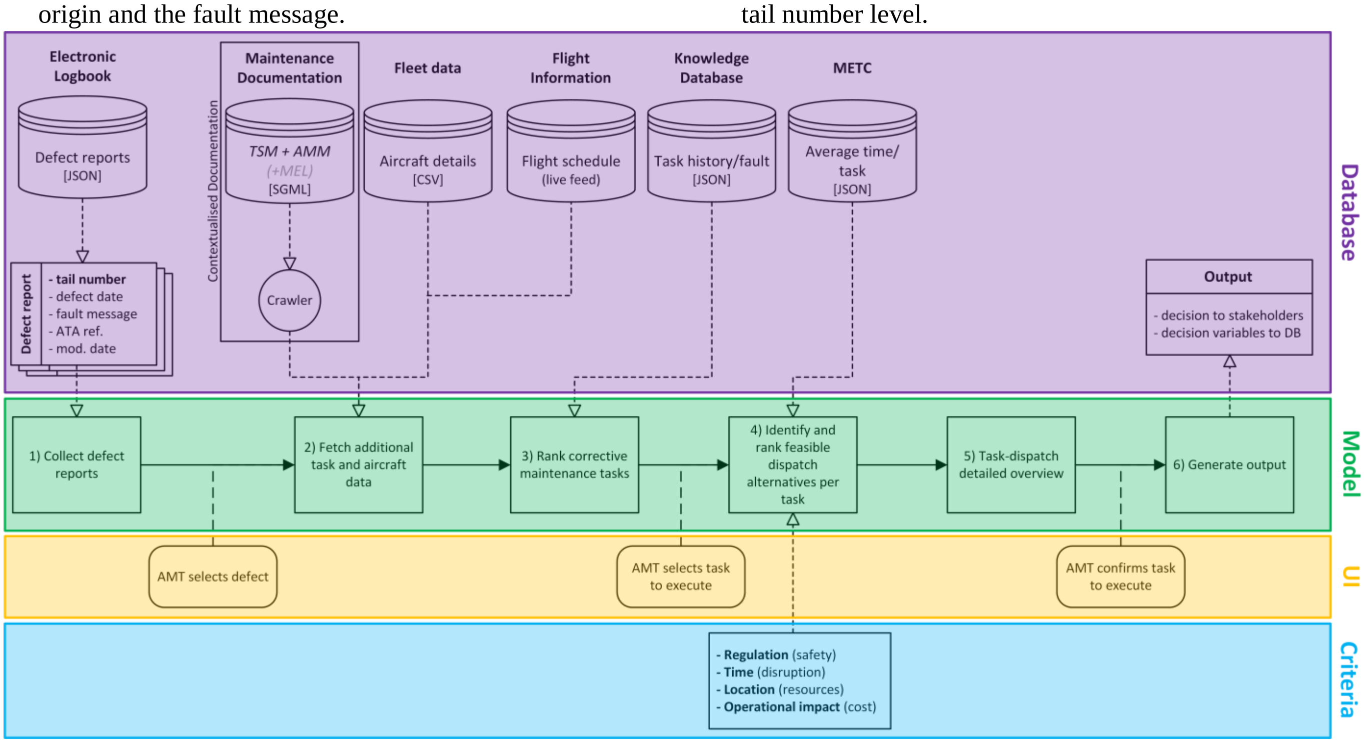


*Figure 2: Overview of the complete DSS framework.*

required for the task at hand.

### 4.2 The Model

The model for the dispatch DSS has a 6-step approach:

1) *Collect defect reports*: as input for the system all defect reports are retrieved from the ELB.
2) *Fetch additional task and aircraft data*: each entry in the ELB at least contains the tail number and the fault message. The tail number is used to retrieve information from the fleet data (e.g., CSN, aircraft model), which is used for document and KDB filtering. The tail number is also used to retrieve the flight schedule, in order to determine the time available for maintenance as well as the current and future stops (i.e., check for maintenance opportunities). Using the crawler algorithm, the related troubleshooting task in the TSM is identified through the fault message. The troubleshooting task refers to multiple possible corrective maintenance task in the AMM, which are also identified using the crawler algorithm.
3) *Rank corrective maintenance tasks*: the corrective maintenance tasks are ranked on historical success rate, as provided by the KDB.
4) *Identify and rank feasible dispatch alternatives per task:* in this step, first the feasible dispatch alternatives must be identified for each corrective maintenance task identified in step 2. For example, the MEL must be checked for the given failure to determine if a deferral opportunity ("GO-IF(O)") exist and, if so, if it imposes operational restrictions or requires reconfiguration tasks. A more trivial example seems to exclude the "GO" option, given that there is a failure to be evaluated. However, there are instances where a failure that occurred during flight cannot be reproduced on-ground. These failures need to be monitored for re-occurrence. Once the feasible dispatch alternatives are determined, they need to be ranked according to the criteria. Currently only time is included to rank from least ("GO") to most disruptive ("NO GO") dispatch alternative. The leading criterion safety will be incorporated by dismissing dispatch alternatives that violate the MEL (i.e., this requires integration of the MEL). Once the other criteria are included, MCDM methods can be introduced to evaluate for example with respect to safety, time, location, costs, or combinations thereof.
5) *Task-dispatch overview*: for every corrective maintenance task identified in step 2, the ranked, feasible dispatch options are displayed. This enables the user to quickly switch between tasks and compare the expected dispatch outcome.
6) *Generate output*: once the task with the most preferred expected dispatch outcome is selected, confirmed and agreed upon by the captain, the decision and relevant variables are stored. In continued development of the DSS the aim is to include this information, as well as the actual outcome, to improve decision making for similar cases in the future. Moreover, the DSS automatically informs other stakeholders, such as the Operations Control Center (OCC) and Maintenance Control Center (MCC) are informed.

### 4.3 The User Interface

The final component of the DSS is the user interface (UI). The UI is essential for the effectiveness of the support system. It should be intuitive and provide the flexibility for additive difference compensatory decision making, a strategy where the AMT can iteratively compare alternatives [5] and put their expertise to use. Having a UI on a mobile tool not only adds the great benefit of bringing relevant information together, but also bringing the information to the location where it is needed; in the case of aircraft decision support to the platform. The fact that the information is currently not available at the platform sometimes lead to the majority of available assessment and maintenance time being wasted in acquiring relevant information.

The UI of the developed DSS has three instances where input of the AMT is required. Firstly, the AMT has to select the defect from the ELB to assess, where the UI will show relevant information about the defect and aircraft, such as related TSM tasks and the flight schedule. Here, the AMT can directly access the relevant TSM task to review information or perform manual troubleshooting. The second interaction is required when step 3 of the model is done (rank corrective maintenance tasks). The AMT can filter the historical success rate of the tasks on fleet, aircraft model or tail number level. When a task is selected, the UI displays the time required to perform the associated task(s) based on the METC data and provides access to the AMM task information. The AMT can review the expected dispatch outcomes for each task and select the task with the most preferred outcome. The third and final interaction is when the AMT confirms which task is going to be executed, after confirmation of the captain.

A complete overview of the DSS framework with the database sources, the 6-step model along with the criteria and the entry points for user input are shown in Figure 2.


*Figure 3: UI for selecting a defect.*

## 5 CASE STUDY

The DSS framework was implemented by means of a prototype to verify the functionality of the data integration, the model and the user interface. A case study was used based on the Electronic Centralized Aircraft Monitor (ECAM) message "Wing A.Ice L Valve Open", indicating that the left wing antiice valve is in open position. Several entries of this defect were created in the ELB for different tail numbers with different flight schedules. When the AMT selects a defect, additional information is fetched from multiple data sources: aircraft details, the flight schedule and related TSM tasks. The resulting UI is shown in Figure 3.

Once the AMT proceeds to the next screen, the KDB and METC data are accessed to retrieve information on the success-rate of corrective maintenance tasks and their average duration. As seen in Figure 4, the AMT can filter the KDB data on the left, while on the top right links to the AMM for the relevant tasks are available and the bottom right displays the expected dispatch outcome. The current prototype only considers the criterion time, limiting the dispatch alternatives to GO-IF(M) and NO GO. The time required is for a task is determined using the METC data, while the available to perform the task is determined by the difference between the current local time and the next scheduled or expected time of departure. If an aircraft is still in-flight, the time available is determined using the scheduled or expected time of arrival instead of the current local time, as no maintenance can be performed while the aircraft is not on ground. Additionally, the operator can indicate a number of minutes that are deemed as acceptable delay. Figure 4 also shows that the maintenance can be performed without any delay. When in future work the MEL will be integrated, the system will check if the given fault message has a deviation procedure available in the MEL and whether reconfiguration tasks are required before dispatch. The time required to execute such a task will be included in the dispatch alternative evaluation.

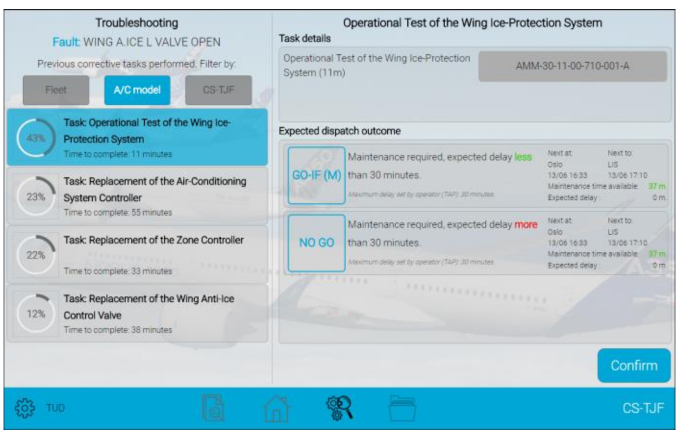


*Figure 4: UI for ranking and selecting tasks, as well as the expected dispatch outcome.*

During a first hands-on experience, the prototype received positive feedback from the AMTs with respect to usefulness and user friendliness, while they also provided valuable feedback for further improvements of the UI and functionality (e.g., having a back button, display more relevant information and include more dispatch alternatives).

## 6 LIMITATIONS AND FUTURE WORK

As mentioned in this paper, the current prototype has some limitations that are mainly due to missing input data, such as evaluating dispatch options by the time criterion only. The focus of future work will be on the integration of data sources (e.g., the MEL and location information to assess deferral options) to include all decision alternatives and adding more decision criteria, thereby enabling the option to include and evaluate MCDM methods. Furthermore, the final prototype developed within the scope of the AIRMES project will be validated during test sessions with AMTs in an (simulated) operational environment. A final limitation of the current prototype is that it only functions with an active internet connection, future work could explore offline capabilities.

## 7 ACKNOWLEDGEMENT

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