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DOGMA: A Diversion Management Decision-Support System in Airline Operations

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***Abstract--* This paper will describe the Diversion Off-Gate Management Assistant (DOGMA) system, a decision-support tool that uses airline-articulated policies to critique dispatcher initiated diversion decisions to ensure that these plans will not only maintain safe operating practices, but will also go further toward providing decision makers with the broad and diverse set of concerns from various stakeholders in their diversion decisions. Diversion management is the decision of which incoming flights to divert and where to divert them to in the face of reduced landing capacity at original destination airports. Multiple airline operational departments can be negatively impacted by diversion decisions that can have complex consequences due to the interdependent nature of resources and schedules; however, current practice typically involves only minimal consideration of how diversion decision will impact airline operations due to time pressures and inadequate situation awareness resulting from the difficulty of acquiring and analyzing the relevant data. Policy is used to capture the goals and priorities of all stakeholders that currently do not have a prominent voice in diversion decisions. DOGMA is a policy-based system that interacts with the user via a critiquing approach in which dispatchers' input to a diversion plan is reviewed by a computer partner that offers feedback on the potential solutions and their ramifications for all stakeholders. The impact of this increased awareness and broader input into the diversion decision should be better and more consistent diversion decisions that minimize the negative impact of diversions and improve an airline's ability to recover from severe schedule disruptions.**

Keywords: **Decision-support, policy, diversion management, critiquing systems**

I. INTRODUCTION

The Diversion Off-Gate Management Assistant (DOGMA) system is a decision-support tool that critiques diversion decisions of airline dispatchers. Potential diversion decisions are evaluated against a set of policies in order to provide dispatchers with insight into the consequences that the plan has for the broad and diverse stakeholders who are directly or indirectly affected by the diversion decisions. This paper will describe the DOGMA tool, and the human-centered process by which it was developed.

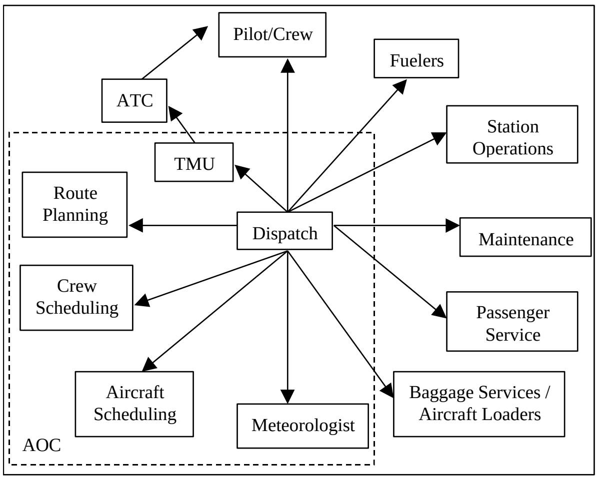

Figure 1. Dispatcher Communication network in the Airline Operations Center (AOC).

Dispatchers are the focal point of the Airline Operations Center's (AOC) mission of flight and schedule management. In the course of their duties, dispatchers typically interact with the pilots and crew, meteorologists, crew scheduling and tracking, ATC coordinators, station managers and gate coordinators, passenger service managers, fuelers, baggage services and aircraft loaders, operations engineering/route planning, and maintenance and engineering – as illustrated in Figure 1. Airline dispatchers are responsible for routing flights and keeping them on schedule. However, the schedule is frequently subjected to disruptions resulting from unpredictable factors like weather, mechanical failures, and other unforeseen circumstances that affect the airline's ability to execute the schedule as planned. If a flight is unable to land at its original destination, dispatchers must decide to which airport to divert that flight. Diversion decisions have dramatic consequences in terms of disruption to the airline's four inter-linked schedules:

1. aircraft fleet schedule,

2. crew schedule, since crews often move from one aircraft to another in the course of their working day,
3. maintenance schedule, with aircraft arriving at maintenance bases for scheduled maintenance checks, and
4. passenger schedule.

There are other stakeholders in the diversion decisions as well, such as marketing (e.g. "don't divert a flight that has been heavily marketed as a new reliable service"), or station operations (e.g. "do not overload one airport with too many diverted flights"). Accordingly, multiple stakeholders are impacted by the diversion decision made by the single decision-maker, the dispatcher. However, due to time pressures and limited access to information, dispatchers do not have time to consult directly with each department when making diversion decisions. IN current practice, the dispatcher's decision is driven by safety concerns only with fuel limits as, obviously, the most important criterion, since aircraft must be safely on the ground well before their fuel expires. While safety should always be the primary concern, in many cases, fuel limits are the only criterion upon which diversion decisions are based. There are typically, however, , other safety-relevant concerns which should be considered. Furthermore, there are also generally multiple diversion plan possibilities, all that will maintain safe flight and landing profiles, and yet which differ widely in their impact on various aspects of airline operations, profits, and customer convenience and satisfaction.

We have used an approach to solving this problem that we call 'policy' [1][2]. Thus within the space of safe operations there are better and worse decision that can dramatically affect the airline's ability to recover from the disruption and get back on schedule ("recover the schedule"). Current practice is characterized by limited access to information in a timely manner, due to information being spread across different systems and different departments. Given time pressures and their regulatory priorities, dispatchers do not consistently consider how their decisions will impact airline operations. In fact, one dispatcher, when asked how much time he usually has to make a diversion decision, replied, "0-10 minutes." Additionally, the "quality" of diversion decisions often is dependent on the experience level of the dispatcher, where more experienced dispatchers have learned about the priorities and operations of other sectors of the airline and take these into consideration when making diversion decisions. While dispatchers have a good awareness of the weather and operational conditions of the flights he or she is dispatching, he or she does not have a good awareness of other aspects of airline operations (e.g. the current crew scheduling, maintenance, or marketing constraints). It is impractical, with the amount of information theoretically available, to maintain general situation awareness of all aspects of airline operations. What is needed is a way of capturing the goals and priorities of the other stakeholders, and using this information to inform the dispatcher's decision only when it is relevant to the decision at hand.

II. Approach

A *policy* is an abstract, general, a priori statement expressing a value or goal and some notion of the priority of that goal. In its simplest form, policy provides a method for human operators to mathematically define what constitutes "goodness". A set of individual policy statements can be bundled together, and these *policy bundles* can be used to flexibly define the priorities that apply in a given situation (priorities can change given different circumstances). One domain that represents a highly constrained system where the specific situation greatly impacts the optimal strategy is airline flight and dispatch operations, and thus decision-support systems in this domain would benefit greatly from a flexible definition of priorities that is context-dependent. The notion of Policy as an interaction method for human-machine systems is described in more detail in [2]. Table 1 represents a set of policy, with different weights for each policy representing the priority of that goal in different operating environments (i.e. normal vs. holiday operations).

Table 1. Policy bundles for normal and holiday operations.

Policy	**Normal Ops Bundle**	**Holiday Ops Bundle**
Do not exceed crew duty limits	10	8
Do not divert international connecting passengers	8	7
Do not delay flights greater than 15 minutes	8	3
Do not cause passengers to fail to reach destination (even if late)	3	8
Do not divert a flight with an unaccompanied minor	10	10
Do not divert to an airport that has its maximum capacity of aircraft	8	8
Do not divert a flight in a protected market	4	1

DOGMA is a policy-based system that interacts with the user via a critiquing approach in which dispatchers' input to a diversion plan would be reviewed by a computer partner that would offer feedback if there was problem with the input. This system could be characterized as an interactive critiquing system that has been shown experimentally to be an effective form of decision support [3](Guerlain et al, 1999). Other research has indicated that interactive critiquing systems have less obtrusive interaction styles than traditional decision support which results in greater user acceptance [5]. This style of interaction was chosen to mitigate the "brittleness" problem [7] while maintaining the preferred role of being in control of automation [6].

Brittleness occurs whenever any computer-generated solutions are subject to the system modeling assumptions that are necessarily an incomplete representation of the world (i.e. the system model does not account for all possible scenarios) and therefore subject to erroneous solutions when an important, but un-modeled, feature of the problem space impacts the choice of optimal solution. By requiring dispatchers to construct their own solution, they will maintain adequate situation awareness and direct control over the solutions, while minimizing complacency problems (i.e. over-reliance on system recommendations biases operator to not consider some factors and accept computer recommendation without adequate review). The use of policy to critique the solutions makes available feedback that is relevant to their decisions only, thus minimizing the potential for information overload. Additionally, dispatchers are given feedback on the consequences of their decisions, which will help them assess the best strategies for minimizing downstream disruptions, allowing airlines to "recover the schedule" more quickly. Finally, domain issues such as FAA regulations, the dispatchers' union, and organizational personality preclude auto-generated solutions as well.

III. DOGMA

The research prototype DOGMA was developed utilizing a human-centered design approach. Requirements were gathered through extensive interviews with the target user group (dispatchers) as well as various stakeholders to inform design requirements. Interview transcript statements were put into an indexed table, categorized into one of the following: actions, policy statements, strategy, info requirements, responsibilities, motivations, operational process, organizational culture, design suggestions, and other. A secondary category would be listed when appropriate. A sub-category, or subject, was listed and could be one of the following: metric, pre-planning, scope, consequences, resources, collaboration, definitions, priorities, causes, recovery, regulatory, integration requirements, deployment, training. The table could then be sorted on category or subject and was used to develop use cases. All use case elements were referenced back to the table to ensure that traceability to original user comments. A modified, iterative Rational Design approach [4] was employed to plan the development process. After initial use case development, paper prototypes where developed. Paper prototypes consisted of initial sketches of design ideas for both graphical user interface and the interaction design. A second round of interviews with stakeholders presented the paper prototypes to elicit feedback, comments, and suggestions. The sketches were deliberately kept rough and unpolished to emphasize the extreme malleability and plasticity of the design state. The hope was that the users would not "hold back" their comments in any sense due to the assumption that the system had already been largely designed. The approach helps to pull stakeholders into the design process, gives users something tangible to react to when introducing entirely new decision-support tool concepts, and makes the user community a part of the design team without letting individual idiosyncrasies distract from the task focus. Interview data was added to the categorized tables, and use cases where developed in more detail, prioritized for development, interactions were identified, and were related to the architectural design. An iterative development plan consisted of which use cases to design, implement and test at each iteration, where each iteration expanded the scope of the tool by adding policies and information domain models of another set of stakeholders (e.g. aircraft, maintenance, passengers, crew, etc.). In addition, later iterations (maintenance, crew) were conducted utilizing Six Sigma tools like the Thought Process Map (TMP), Quality Function Deployments (QFD), and Failure Mode and Effects Analysis (FMEA).

Initial interviews with airline operations personnel identified the need for decision support tools to support the situation awareness of dispatchers. What was needed was a common data view across the airline (e.g. central operations, station operations), where presently data access is difficult and inconsistent across functional areas of operations. On the problem of diversion management, one airline supervisor related that "it's [diversion management] always been a problem. [In] 26 years, my entire career has been in dispatch, and there's never been a good way of managing [it]." One typical example of the problems of situation awareness and lack of collaboration is coordination of alternates by dispatchers, where during a major disruption too many planes are diverted to a station. One major airline’s dispatch director summed up the needs as follows, “The biggest thing we can give the dispatchers is information: …[so] they can make their choice based on better information rather than just where’s the flight coming from and where’s it going." In addition to better information, dispatchers need tools at the operation end that enable the airline to recover from multiple diversions. A dispatcher said, “We know we're going to get hit, don't know when or where, but what you need is the tools to recover when you do.” The key point made by interviewees over and over is the ability to see the associated affects of diversion decisions. We received near unanimous endorsement for the application of policy to the diversion management domain as a way to quickly understand the effects of decisions on downline operations and the ability of the airline to recover. The domain experts resonated to the idea of having stakeholders' voices present at the decision point. They felt that "the more people involved in a decision the better both economically and for safety." DOGMA integrates multiple information sources to improve dispatchers situation awareness of the current state of flight, aircraft, maintenance, crew, passenger schedules. Policy can capture the goals and priorities of all interested parties in the diversion decision, thereby integrating their interests into the decision making process.

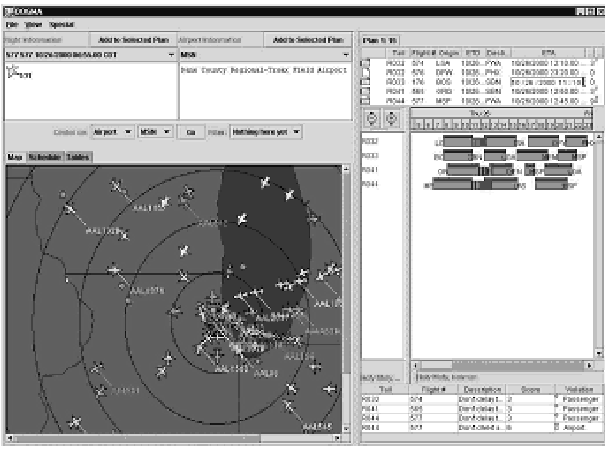

Figure 2. Diversion Off-Gate Management Assistant

The DOGMA prototype, illustrated in Figure 3, is divided into two principal spaces: (1) the Information Space, and (2) the Diversion Plan Workspace. The Information Space, found on the left half of the interface, provides an integrated view of available information. The primary goal of the information space is to maintain the dispatcher’s situation awareness across multiple information sources by allowing for rapid access to relevant information. The lower half of the display provides a view of the available data such as airline schedules, crew schedules, maintenance schedules, current aircraft position, and airport characteristics (e.g. current airport arrival rate). This data can be seen in multiple formats depending on task needs (Map Display, Schedule View, Tabular View). Users can filter and sort information on various criteria using either predefined sorts (e.g. by tail number, by time, by arrival/departure airport, by dispatcher, by fleet multi-criteria) or user-defined sorts (via a sort-query builder). The upper half displays detailed information about the user-selected aircraft and airport. Users can add selected aircraft or airports to the Diversion Plan Workspace

The right side of the interface contains the Diversion Plan Workspace where dispatchers construct diversion plans by selecting aircraft and deciding where they should be diverted. The upper third lists the candidate aircraft chosen for diversion. The user diverts the aircraft by changing its destination airport and its estimated time of arrival (ETD). Policy violation scores and categories are listed per aircraft. Any other aircraft that suffer policy violations are also listed, to highlight dependencies that result in propagating policy violations from a single decision. The middle third of the Diversion Plan Workspace displays the aircraft schedule of the relevant aircraft in order to highlight dependencies between aircraft, crew, and maintenance schedules. Thus diverting Flight 123 may result in Flight 234 being delayed due to a lack of a crew since Flight 123’s crew was supposed to transition to Flight 234 when they arrived at the original destination. The lower third lists the policy violations, sorted initially by severity of the violation (the list can be re-sorted by category or flight). Dispatchers are presented with a set of policy violations relevant to each diversion plan. The associated penalties are added up to give a total score for the plan. By viewing the policies, dispatchers are informed of the airline priorities that the plan violates, and dispatchers can choose to modify the plan accordingly. For instance, a decision to divert flight 123 may violate the policy of “Do not divert a flight with an unaccompanied minor on board". The dispatcher did not need to know an unaccompanied minor was on board until that fact impacted his or her diversion decisions. In this way policy is used to present relevant information to a dispatcher only when he or she needs it. The total policy violation score for a particular diversion plan is displayed at the top, on the tab for the particular plan. Multiple plans can be created (each with its own page accessible via a tab) and compared.

IV. DISCUSSION

The Policy-based DOGMA system can capture the goals and priorities of all interested parties in the diversion decision, thereby integrating their interests into the decision-making process. This broader awareness of the various concerns in the decision is, currently, something that is only learned gradually over time. Thus, one impact of DOGMA is expected to be superior decisions from less experienced dispatchers. The use of policy has enabled the efficient and seamless integration of enterprise-wide goals at the decision point, thus enabling organizational control and effect over decisions. Furthermore, policy systems facilitate the propagation of high-level enterprise goals, such as customer satisfaction, down to the operational level via relevant policy feedback (e.g. don't delay a passenger twice on a trip). Such a system improves visibility into other stakeholders' priorities thus minimizing "bunker mentality" within departments of an organization. Another impact of this increased awareness and broader input into the diversion decision should be better and more consistent diversion decisions that minimize the negative impact of diversions and improve an airline's ability to recover from severe schedule disruptions. Moreover, critiquing reduces workload by providing feedback about only those policies that are violated by a user action. The system further reduces workload by enabling a quick comparison of diversion options by providing a simple metric - total policy penalty points on a selected flight. This approach also accommodates both novice and expert dispatchers. The interaction does not interfere with an expert's workflow unless a decision violates a policy; and policy feedback provides learning experiences for novice dispatchers. Consistent outcomes are also insured by the systematic and automated evaluation of user actions.

V. ACKNOWLEDGEMENTS

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