Airport Resource Management and Decision Aids for Airlines

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Airport surface management is fundamentally a task requiring decision making under uncertainty. For example, there is uncertainty about when an aircraft will be ready to push back, how long it will take a departing flight to taxi to the departure runway queue and how long it will take an arriving flight to taxi to its gate from the arrival runway. As a result, managing traffic on the airport surface, and coordinating this surface movement with airspace constraints, is a risk management task. Decision support tools which provide better access to airport surface data and predictions, as well as access to NAS-Status data such as airspace constraints, will reduce but not eliminate uncertainty. Therefore, to be effective, tools designed to support surface management decisions regarding events such as those listed above must reason about the inherent uncertainty in these events and assist airport users in their decisions regarding aircraft surface operations.

Introduction

In this paper we discuss the design and development of prototype tools developed to support NAS (National Airspace System) user decision making in regards to airport resource management and procedures that enable the effective use of these tools. These tools could not only increase operational efficiency on airport surfaces but could also result in a significant reduction in operational costs currently incurred by NAS users. Through the reduction of taxi times fuel burn can be significantly reduced; specific operator issues such as crew over-time, secondary de-icing, diversions and flight cancellations – which can be costly results of operational inefficiency on the airport surface – could also benefit from these types of tools.

As described in the Safe Flight 21 Pre-Investment Analysis Cost Benefit Analysis Phase II Report (May 1, 2001), Continental United States (CONUS) efficiency benefits for the introduction of better surface movement surveillance and planning tools were estimated to be $7.852 billion – two-thirds being attributed to “a reduction in taxi times as well as reduced arrival and departure delays”. Another statistic that was quoted by a major cargo carrier indicated that a reduction in departure delay for their fleet by an average of 1 minute per year would save them $1 million per year.

The developed prototype was given the name ARMADA (Airport Resource Management and Decision Aid) and was developed as either stand alone software or to be integrated into the NAS user’s existing software environment. Throughout the course of this work our objectives have included:

- Developing a concept of operation based on the use of programmable alerts to call the user’s attention to important events that have been detected using airport surface data (integrated with other data sources as appropriate), and to provide active decision support for pushback planning decisions.
- Designing and implementing an interface design concept to demonstrate the nature and feasibility of this concept of operation and to identify important interface design features to enhance the usefulness and usability of these alerts.
- Developing an algorithm that provides predictions regarding the earliest that a runway queue is likely to run dry, and developing an interface to display this information to an airline Ramp Tower Administrator in order to support pushback planning decisions.
- Completing a formative evaluation of these prototype tools, eliciting input from prospective users regarding the potential usefulness, usability and value of the tools.

Our work in this area has been based on three fundamental premises:

- The availability and accuracy of technologies to provide real-time data on airport surface activity are reaching a point where they represent a viable source of information to improve airport operations.
- Uses of these data sources offer the potential to increase throughput on the airport surface as well as in the surrounding airspace. They also offer a means for NAS users to increase the efficiency and cost-effectiveness of their operations and they provide a means to enhance safety.
In order to achieve these benefits in terms of throughput, efficiency and safety, it is not sufficient to provide only the NAS service provider (the FAA) with tools that access and make use of such airport surface data. NAS users must also have tools that make use of these surface data sources in order to plan and run their operations, and in order to coordinate effectively with FAA staff.

**Users**

Our focus has been on tools for organizations that support their flights with centralized operations centers and/or ramp control operations (including a significant number of General Aviation (GA) corporations and fractional ownership firms such as NetJet that make use of centralized operations centers to manage their flights), and that are therefore supported by specialists who, directly or indirectly, are helping to plan and coordinate the execution of airport surface activities. This means that our potential users are airline Dispatchers and Aircraft Routing Staff, ATC Coordinators, Ramp Tower Controllers, Ramp Tower Administrators, Gate Assignment Specialists, Gate Management Staff and Maintenance Staff. In addition to these direct users, the impact due to explicit communication or implicit coordination with other individuals will need to be considered, including FAA traffic managers and controllers at ATC Towers, Terminal Radar Approach Controls (TRACONs), Air Route Traffic Control Centers (ARTCCs) and the Air Traffic Control Systems Command Center (ATCSCC), as well as the crews of the affected flights. Our contention is that support of these user groups offers one of the major leverage points for increasing throughput and cost-effectiveness in the use of the NAS.

**Approach**

Our investigations have indicated that a mixed initiative interaction design is called for. In some cases, the user will recognize the need to look at a display to check for certain information. In others, however, the software needs to be monitoring for an important event and to alert the user about it. Our approach involved developing new display design concepts as well as algorithms that provide users with the information they need at the time they need it and in a form that they need it. We define these two areas as:

1. Programmable alerts and critiquing functions to support airport surface management.
2. Algorithmic support of pushback and sequencing decisions (using integrated airport surface and NAS-status information).

Due to space constraints, we will focus primarily on the design and development of programmable alerts and their associated displays.

In the remainder of this paper we will discuss the display design and functionality associated with the various ARMADA alerts and critiquing functions. There are numerous types of alerts that could be implemented and made operational very quickly (once a suitable design has been developed and appropriate surface data is made available at an airport). Some types of alerts would rely only on a combination of NAS user data (such as filed off time) and aircraft surface or terminal airspace positional data, while others would require the types of predictions generated by tools such as NASA’s Surface Management System or SMS (Smith, et al., 2002). These alerts would not require any changes in current ATC practices and would be of use to all NAS users that make use of Ramp Control facilities at an airport and/or make use of a centralized operations center for dispatch functions.

Note: The distinction we make between alerts and critiquing functions is that critiques are a special type of alert made in response to some decision or action made by the user, rather than in response only to data input from the environment, while alerts in general can be triggered by external data and inferences made from these data. This requires special attention to the interaction design as, to provide a well-designed critiquing system, the interface between the user and the software must provide an unobtrusive source of data regarding the intentions or decisions of the user.

All of the various ARMADA alert displays have been designed to provide:

- Timely access to critical information including:
  - Actual and predicted OOOI times (OFF – departure time, ON – arrival time, OUT - gate push-back time and IN – gate parking time)
  - Inefficient operations or surface conflicts
- Access to context-sensitive detailed data displays upon demand. Display concepts include:
  - surface maps
  - airspace maps
  - timelines
  - tables (sortable)
- A communications function to support the efficient creation and sending of messages relevant to that alert
- Alert-specific user-customized parameters including:
  - Turning the alert on or off
— Determining which flight(s) or category of flight(s) to include in terms of a given alert
— Specifying alert timeframes (making the alert active only during specific times, such as during a departure push)
— Specifying how the alert will be presented (as a pop-up, or as some integrated display within an SMS display or an airline-specific display)
— Indicating the trigger(s) for the alert (location and/or flight status; spot involved; timeframe, etc.)
— Customizing the specific displays to include in the overall detailed display

Also, all ARMADA displays share certain general features including linked displays (if the user highlights an object in one display, information about that flight is highlighted in all displays where it appears) and a Find function (for finding and highlighting classes of objects in the display).

**User Tasks**

The various user tasks that the prototype tools were designed to support can be defined as either Departure Management, Arrival Management, Information Sharing/Coordination or Irregular Operations (Obradovich, et al., 1998; Smith, et al., 2002; Spencer, et al., 2003a; 2003b; 2002a; 2002b; 2002c; 2001). A comprehensive discussion of the tasks we have studied can be found in these papers.

Over the course of this work, we have conducted numerous studies including three site visits for data collection at the FedEx Ramp Tower and Global Operations Center in Memphis, and one site visit to Memphis ARTCC (ZME). These visits included the demonstration of interface designs and partial implementation of illustrative information displays and an algorithm that models uncertainty regarding taxi and departure times. We have also completed a formative evaluation providing data that is strongly supportive of the efficacy of our design concepts.

Interviews with Flight Operations, Ramp Tower and Dispatch staff at FedEx identified 12 tasks that these individuals thought would be of particular value.

- Delayed EDCT flights
- ESPed (Enroute Spacing Program) flights
- 18C/36C Runway departures
- Late Arrivals
- Spot Conflicts
- Gate Changes
- Long or Short Runway Queues
- Closed Routes (due to weather)

- Delays Associated with Deicing
- Runway Assignment Changes
- Diversions
- Pathfinder Selections

Based on this list, we selected four specific areas for concentration in our prototyping of alerts and associated displays:

- Late Arrivals
- Spot Conflicts
- Delayed EDCT flights
- 18C/36C Runway departures

These four areas were selected as they represent a range of different types of issues in terms of the underlying functionality and the required information displays. All four deal with performance by the Ramp Tower Administrator, but the general functionality applies to potential alerts for other airline staff as well. Due to space constraints we will limit our discussion below to details regarding alerts for late arrivals and spot conflicts.

**Alert for Late Arrivals:** Late arrivals can cause many different types of airline operational issues including issues regarding cargo or passenger connections, conflicts with departing flights (particularly in cases where the flight is arriving during a departure push and is therefore “traveling against the flow” of outgoing traffic), crew scheduling and gate assignment issues. This alert was designed to assist decision makers (who are often multi-tasking and working within a highly dynamic environment) in avoiding surface operations that may lead to these and other issues and in quickly finding appropriate solutions.

The Alert for Late Arrivals is designed specifically for the Ramp Tower Administrator (who oversees all ramp area operations, coordinates aircraft and surface vehicle movements and with FAA personnel, AOC staff and individual Ramp Tower Control positions as needed). As with all of the ARMADA alerts, this warning regarding a late arrival provides access to context-sensitive displays to aid in situation assessment and decision making. It is triggered whenever a late arrival reaches a certain state. As noted earlier, the user could set the various alert parameters to (for example) identify only certain flights, choose the flight state at which they want to be notified such as In Range, On Final or ON, and indicate how the alert should be presented - as a pop-up, or as some integrated display within an SMS display or an airline-specific display. If the user has chosen for alerts to be displayed within ARMADA then the first display is a pop-up alert window (see...
Figure 1). This display contains critical information about this situation including the aircraft ID (ACID), flight status (In Range), predicted ON time, predicted IN time, assigned spot and parking gate. Note also that the interface allows the user to change the pre-set alert time (for example, the user can request to be alerted again when the flight is ON).

Figure 1. Late Arrival Pop-up

The pop-up interface also allows the user to temporarily minimize the alert and continue with other work for the time being (accessing it again later), close the alert, or choose to “Open Alert Detail Displays”. Figure 2 is an example of the resultant displays if the user chose to view the alert detail displays.

Other functionalities related to the alert would enable quick access to other information, such as which flights should or could be held to prevent back ups (and extra waiting) in the ramp area, but would not explicitly include this information unless or until it was requested by the user.

In terms of the Alert for Late Arrival Detail Displays, note that:

- The inset map (upper left) is configured to show the airspace around the airport. In this display, we see that the late arrival has been enlarged on the map and is surrounded by a gold box. (In general, flights that ARMADA knows are directly involved in a situation triggering an alert are shown on the maps surrounded by gold boxes.)
- The more detailed surface map (upper right) shows all active flights as triangles color-coded by runway, and shows those flights with beacons (flights ready to push) as circular dots color coded by runway. Only those flights at the gates with beacons are shown as those are the departures that are still at their gates that could potentially interact with this arrival as they depart.
- The legend for the detailed map shows the numbers of active flights and flights with beacon by runway.
- The display subwindows are contained in a single larger alert detail display window so that they can be minimized or closed as a group.
- This display also provides functionality that allows the users to change their request for another later alert (at ON), and to close this alert permanently if desired.
- The Find function (upper left) was intended to allow the user to enter a specific aircraft ID or labels for categories such as “Heavy” aircraft or “ZNY” (New York ARTCC) departures and have the associated objects highlighted on the map.

Above we have indicated the proposed functionality and interaction design for the Late Arrival Alert. Overall, the response of the Ramp Tower Administrators and flight operations management to this approach, using programmable alerts to provide timely access to critical information, and providing access to context-sensitive detailed data displays upon demand, was extremely positive, both in terms of the potential usefulness and usability of our designs.

Spot Conflict Alert: Spot conflicts can cause considerable disruption to surface operations – it can take 45+ minutes to dispatch tugs to pull one of the involved aircraft out of the way. When these potential events are predicted there are several choices that an Administrator has: contact the FAA Tower and request that the arrival be held out of the ramp area or request that the arrival be brought in via a different spot, hold any involved departures at the gate or send any involved departures to a different spot. The time at which the potential conflict is detected determines, in part, what action the Ramp Tower Administrator may take. For example, if the arrival and possible spot conflict is detected at In Range, then the Ramp Tower Administrator would be more likely to direct the ramp controller(s) to move any departures to a different spot, or hold them at the gate. If the event involves an arrival and is detected at Final Approach, then the Ramp Tower Administrator would more likely contact the FAA Tower and ask them to hold the arrival out of the ramp area or request that they direct the arrival to a different spot. The reason for this is that if the potential spot conflict were not detected until Final Approach, then any involved departures would likely already be active.
Again, this alert is designed specifically for the Ramp Tower Administrator. Also, this alert is similar to the Alert for Late Arrivals in that it most likely deals with the unexpected event of an arriving flight attempting to enter the ramp area while departing aircraft are exiting the ramp area (or when a departing flight needs to return to its gate due to unexpected maintenance or other issues).

Note that, unlike the Alert for Late Arrivals which defines the relevant set of departures as those flights that are currently active or have a beacon (flights ready to push), the Spot Conflict Alert requires a more sophisticated set of predictions. In this sense, these two alerts illustrate our evolutionary approach. If the technology to predict spot conflicts is not yet mature enough, the Late Arrival Alert can be used to support the same user need (but requires additional assessments by the user) based on the information presented in the detailed display.

The Spot Conflict Alert requires acceptably accurate predictions of the taxi paths, spots and runways for departures and arrivals as well as predictions of the times associated with these different locations for a flight on the airport surface. This could be handled by using the deterministic modeling contained in SMS (based on fixed parameters for taxiway movement rates and departure rates), or by developing statistical models that use historical data to develop context-sensitive estimates of the uncertainty associated with different airport surface movements.

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Conclusion

Considerable evidence for the importance of this form of interaction, making use of software alerting functions, has been noted during our observational studies, structured interviews and focus groups. It is our conclusion based on our studies to date that many of the potential benefits from surface data will not be realized unless such alerting functions are developed to support the use of surface information by NAS users. It is not enough for the information displays in systems like SMS to be useful and usable when considered in isolation. The interaction design must be based on a realistic understanding of the operational demands of the user’s environment (including all of the other tasks and information displays involved as part of his/her job).

Our conclusion is that this means that, in many cases, viewing of surface information needs to be supported on as “as needed” basis, with an alert triggering the user to check relevant surface information when some important situation arises.

This integrated, human-centered approach to the design of airport surface management decision support tools offers great potential as a strategy for enhancing the functioning of the NAS.

References


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Figure 2. Late Arrival Alert Detail Displays