

Uses for Field Communication Data in Designing Air Traffic Management Decision Support*

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ABSTRACT

In this paper, example uses of field communication data are provided and how these data impact the evolution of the Route Availability Planning Tool (RAPT) for air traffic management is introduced. Simple communications analyses are provided that illustrate how communications can be used to improve what decision support is provided, who it is provided to, and in what context to present the support. Communications data is also shown to aid in contextualizing the decision support to better fit within the decision support framework in existence, which is critical to the success of situation awareness systems.

Keywords

Communication, Coordination, Field Study, Air Traffic Management, Decision Support, Iterative Design

1. INTRODUCTION

The over-arching purpose of the Air Traffic Management (ATM) system is to ensure efficient traffic flows and to shield the air traffic controllers from excessive traffic. Every Air Route Traffic Control Center (ARTCC) and most large Terminal Radar Approach Controls (TRACONS) and Air Traffic Control Towers (ATCTs) house a Traffic Management Unit (TMU) of Traffic Management Coordinators (TMCs) that perform the ATM function for the facility. The beneficiaries of this function are the controllers themselves, who, in larger facilities, reside in "areas." Each area contains the controllers, who are responsible for separation and communication with the aircraft, and the area supervisor, who oversees the controllers in the area.

While the overarching purpose of the ATM system is a single one, each individual facility may have different constraints that affect the amount of traffic that can be handled (e.g., weather impacts, amount of airspace in the facility boundaries) and/or dominant traffic flow patterns. Because of these differing dynamic constraints, the ATM system in the US is fueled by communications and coordination between facilities. Communications occur to relay facility status, make requests, and negotiate or broadcast traffic management initiatives to aid in achieving safety and efficiency. The primary forms of communication include telephone communication between different facilities' TMUs, face-to-face within a facility's TMU, and face-to-face between a TMC and the areas or air traffic control (ATC) sectors.

Developing decision support for the ATM environment requires understanding of the communications processes and how any tool

developed fits into this process. In this paper, a tool to improve traffic flow efficiency throughout convective weather (i.e., thunderstorms) is introduced, and how communications analyses are used to continually improve the tool's design and implementation is described.

1.1 Traffic Management Coordinator

The TMC is the key decision-maker for determining if a traffic management restriction is required to reduce demand into the facility or in a particular spatial area (such as a fix or a route).

Traffic management functions can be complicated, thus we will focus on the description of the departure management process, for which decision support was designed, shown in Figure 1. First, the TMC must monitor demand on the departure routes (e.g., number of flights planning to fly on J75 route from each of the New York airports) and combine this knowledge with known constraints (e.g., downstream restrictions from Washington Center, ZDC) and dynamic capacity of the routes themselves (e.g., thunderstorm impacts on the route). Not only does the TMC evaluate demand/capacity imbalances for the current time, but predict it for the future to ensure a restriction can be implemented in time to have the desired effect. The TMC then evaluates whether the demand/capacity imbalance is sufficient to act upon. If so, the TMC coordinates a traffic management plan, which may require coordination within and between facilities. This plan is then implemented in terms of traffic management initiatives (TMIs). A TMI can be the closing of a route (if the weather is severely impacting it) or reducing the amount of traffic that can travel on the route (e.g., Miles-in-trail, MIT, which increases separation between aircraft over a fix or on a route).

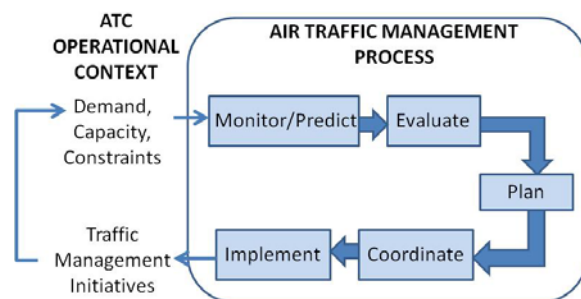


Figure 1: Air Traffic Management Functional Processes

One issue that requires decision support is assessing the departure route capacity impact that convective weather can have. The Route Availability Planning Tool (RAPT) was designed to aid TMCs in this area.

1.2 Route Availability Planning Tool (RAPT)

RAPT [1] is an automated decision support tool (DST) designed to help air traffic managers determine the specific departure routes and departure times that will be affected by operationally significant convective weather. RAPT helps users to determine

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when departure routes should be opened or closed and to identify alternatives to closed departure routes that are free of convective weather. RAPT, whose interface is shown in Figure 2, assigns a status color- “red” (blocked), “yellow” (impacted), “dark green” (insignificant weather encountered) or “green” (clear) - to each route for departure times up to 30 minutes into the future.

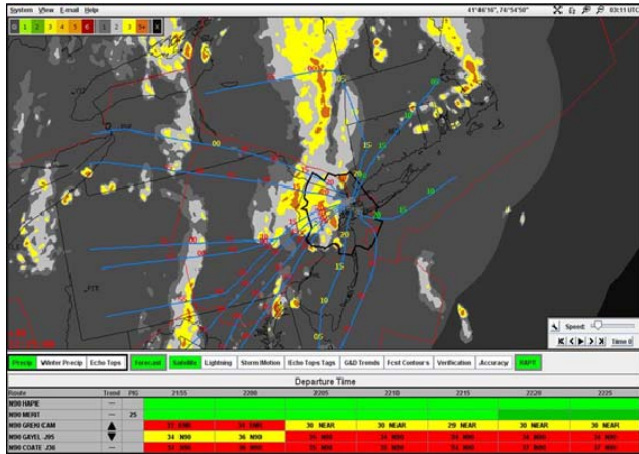


Figure 2: 2009 Route Availability Planning Tool (RAPT) Interface.

The map segment of Figure 2 depicts the key departure routes out of the New York area overlaid on a precipitation forecast. The bottom segment shows the RAPT timeline display. Each row represents a departure route with subsequent rows showing the next route progressing counter-clockwise from the east. Each of the colored-block columns indicates the blockage status along the route for a particular departure time, progressing in 5 minute intervals. The number within the colored block is the altitude of the echo tops (a measure of storm height) at the point of the blockage in thousands of feet. The text following the number indicates the location of the blockage (e.g., “N90” is in the New York TRACON). The “trend” column summarizes the route availability trend over the preceding 30 minutes (improving, deteriorating, stable, or uncertain). The “PIG” column (PIG= Post-Impact “Green”) indicates how long a departure route has been “green” after a storm has passed through. RAPT was deployed in the New York air traffic control facilities in late 2002 and has been continually updated each year since then.

Because RAPT is a situation awareness tool that is not required to be used by traffic managers, it is critical for it to demonstrate usefulness and be consistent with the TMC’s decision-making framework or it will not get used. Extensive field evaluations of RAPT have been completed, and subsequent traffic analyses, benefits evaluations and observational/communications analyses were used to improve RAPT’s concept of operations and ability to support ATM decision-making. In this paper, a discussion of how field communication data were used and can be used to improve the RAPT decision support tool is provided.

2. METHOD

Salas and Wildman [2] discussed the need for field studies to complement the team and coordination research achieved by experiments and researchers such as Salas & Cooke. In the field, often the constraint is time allowed in a facility, exposure to the appropriate facilities, or ability to gather the critical data. The primary method for communications data collection for the ATM

process in this instance was the field blitz, which is an effective means of capturing these data. A convective weather period was identified that was forecasted to affect the NY ATC facilities. This provided an excellent period to witness the usage of convective weather decision support. Field observers (who were familiar with ATM and previously shadow-trained) were deployed to multiple facilities for the convective weather period, which could last up to several days. At the facility, key ATM coordinator(s) who managed departure routes were identified and shadowed. Blitzes were conducted 3-7 times each summer from 2007-2010. From 2007-2009, a general weather/ATM observation form was used (Level 1) and in 2010 a communications form was added that collected communications data more methodically (Level 2).

Level 1: The primary goal of the field data collection was to identify what the weather/traffic situation was, what ATM decisions were made, and if/how TMCs used RAPT during this process. The most basic level of data reported was in the form of observation logs obtained from each person participating in the field blitz. In the beginning of data collection (2007-2009), the field data logs were qualitative in nature. Communications data were interweaved into these observations, capturing the key topic, but in analyzing the data for communications, the data were found to be generally incomplete. An excerpt from such a log is shown in Table 1 below.

Table 1: Level 1 Observation Log Example

Time of Obs	Weather Impact on Air Traffic & ATM plans/ RAPT status & usage
2010	Stop ORD, hotline activated but still no SWAP
2014	Parke released (6 miles-in-trail), exclude IAD (J6 for LGA)/RAPT solid red for 30 min.
2022	TMC questioning why J80 is closed- made a call to his friend. Thinks it should be open. Spoke with Command Center. There is one cell just east of IND and he thinks that should not close entire route. All green on RAPT

Level 2: A second observation log was developed in 2010 to specifically capture communications frequency, mode, originator, receiver, and topic. During a blitz, since recording communications was not possible, manual transcription occurred that captured an estimated 95% of the communications. This method provided a more unbiased view into the system (i.e., captures the wide array of communications occurring, not only those relating to weather and RAPT routes) and allowed more thorough examination for communications inefficiencies. In addition, post-blitz coding was performed to identify communications as providing information (P), information solicitations (S), negotiations (N), and identifying a course of action (A), modified from a technique discussed in Cooke, Gorman, & Rowe [3].

Table 2: Level 2 Observation Log Example

Time	Comm. Mode	Originator	Receiver	Topic
1930	Phone	ZNY TMC	EWR TMC	Stop ORD J36
1930	Face-to-face	EWR TMC	All Tower	Stop ORD J36, look for reroutes

				from ZNY
2011	Phone	N90 ?	EWR Cab Coord.	Stop departures (from NY)
2015	Phone	Port Authority	EWR Cab Coord.	(Taxiway) K-H open

3. SELECTED RESULTS

Naturally, the data collection described above is abundant with information that can be harvested for years to come. Below are selected results that have already provided useful information for RAPT design and implementation. The first analysis reveals the decision-making context including communications flows, modes, and content. The second analysis evaluates the decision support design choices by providing a completeness check on the departure routes displayed on RAPT from a coordination perspective. The third analysis identifies an opportunity to reduce impediments to effective decision making using RAPT—by providing the ability to input departure route status.

An initial analysis performed was simply depicting who is talking to whom and how frequently. Multiple days were analyzed for this communication structure of different TMCs. Below, Figure 3 is depicting who the Newark (EWR) Supervisor/TMC communicated with and how frequently over a single, typical 7-hour day in which operations were affected by convective weather. The length of the communication line is inversely proportional to frequency of communications. Communications were limited to operational communications, filtering out personal conversations and conversations about training and staffing issues.

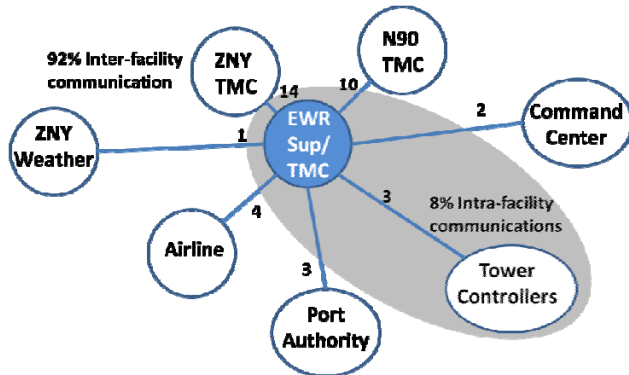


Figure 3: EWR Tower TMC Communication Structure

The most frequent conversations took place with the New York Center (ZNY) TMC involving EWR Sup/TMC requesting new routes for departing flights and ZNY broadcasting openings/closures and restrictions. Conversations with N90 TRACON involved N90 issuing and rescinding restrictions on EWR departures.

In Figure 4, a communication frequency diagram is provided for the ZNY TMC for a single, typical convective weather day spanning 10.5 hours. From this diagram, it is clear that the ZNY TMC communicates significantly more frequently with more entities than the EWR TMC. With N90, most of the communications involve ZNY broadcasting restrictions, and the N90-initiated communications are questions about the restrictions. With the ZNY Sector Supervisors, the TMC received feedback about whether there is too much/too little traffic on routes for the controllers in ZNY. Exchanges with the ZNY Departure Director (DD) and the Pit (the group of TMCs who make the flight plan

changes) involved planning and executing reroutes. On the Severe Weather Action Plan (SWAP) teleconference, ZNY broadcasted restrictions for all facilities to hear and answers questions about openings/closures as well as specific flights. Communications with specific airports' TMCs involved ZNY making exceptions to restrictions for specific flights, questions about specific flights and responding to airport questions about openings/closures.

In Figures 3 and 4, communications that occur within the facility lie within the gray ovals. Tallying the percentage of communications that occurs within the facility, as compared to between facilities, reveals that the ZNY TMC conducts significantly less communication with other facilities (63%) than the EWR Sup/TMC (92%). It could be argued that the workload cost of an inter-facility communication outweighs that of an intra-facility communication due to the TMC needing to potentially understand a completely different operational circumstance while also representing his or her own facility in an official capacity. However, the sheer amount of communication that the ZNY TMC performs (146 communications in this case) clearly outweighs the communications of the EWR Sup/TMC (37 communications). Thus, while the individual communications of the EWR Sup/TMC may be more workload-inducing, the quantity of these (among other) communications clearly puts the ZNY TMC under heavier communication workload.

Initially, when RAPT was first implemented, it was conceived as a tool primarily for the Tower facilities, who actually finalize flight plans and clear the flights for takeoff onto departure routes. After taking note of the communication patterns and flows, such as those in Figures 3 and 4, it became apparent that the key decision makers who allow release of flights onto a departure route reside at ZNY, not in the Towers. Thus, to improve decision support with RAPT during convective weather, the tool should be placed not only in the Tower, but also in ZNY. Because route opening/closing decisions are often coordinated between facilities, RAPT was also placed in N90, with the Sector Supervisors (SSs) in ZNY, with adjacent centers (ZBW, ZDC, and ZOB), and with key airlines operating out of NY for situation awareness purposes. Only then did RAPT begin to affect departure routing decisions [5, 6].

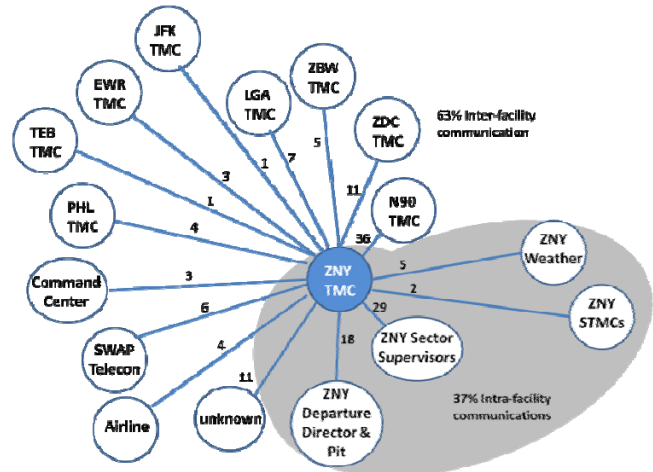


Figure 4: ZNY TMC Communication Structure

Another analysis that was performed was parsing the frequency that a departure fix/route is communicated over different blitzes, as shown in Figure 5. Because of the limitations of Level 1 data collection it is possible that the 2007 blitz data is not quite as representative of the communications as the 2010 data. Depending on the weather system moving through the area, blitzes reveal the differently impacted areas. The frequency of communications does not only reflect the impact of the weather, but also the coordination required in managing traffic (e.g., a route through multiple congested facilities). In the figure below, the RAPT routes are parsed to identify how frequently they are mentioned during a blitz. On 7/18/2007 the weather and coordination impacts are focused on the south and the northwest routes. On 8/16/2007 the impact is more on the southwest routes. The lack of communication on the eastern HAPIE route is likely due to the internal management of impacted traffic with ZNY's oceanic area.

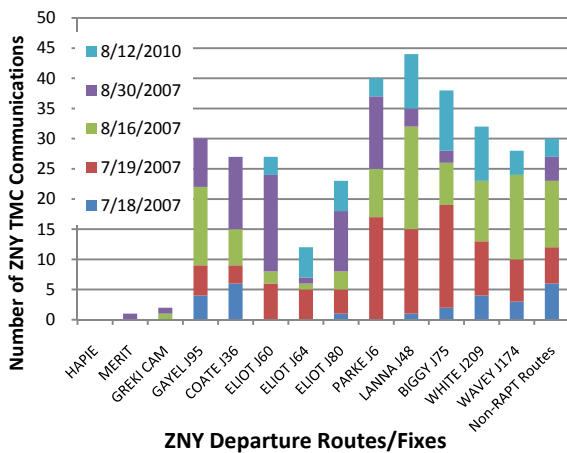


Figure 5: Communication Frequency of Departure Routes/Fixes

The few communications on the northern routes MERIT and GREKI CAM introduces an interesting issue. While MERIT is a very busy route, there were very few discussions that involved this route. This could be due to a more efficient inter-facility communication procedure between ZNY and Boston Center (ZBW) over ZNY and Washington Center (ZDC). It could be the result of airspace design differences between the intersection between ZNY and ZBW versus ZDC resulting in stress points between the ZNY/ZDC facilities. Or perhaps it is personality-driven, and there was an understanding between TMCs at ZNY and ZBW. Further analysis is required to uncover the reason for this lack of communication, and, potentially, additional clues to the secret to effective inter-facility coordination.

Communication frequency analyses can become one means to help to determine if the routes RAPT is showing are the key routes. Over 200 individual flight plans can be filed out of NY and providing this number of routes to TMCs would be overwhelming. While 200 are available, only certain routes are actually used. The analysis above suggests that the RAPT routes displayed are appropriate (at least for coordination purposes). The routes/fixes discussed but not displayed only amounted to a few discussions per route/fix, and these were often overlapping a

displayed route. According to these results, perhaps the RAPT routes were displayed less efficiently than they could be. The first three routes displayed are the routes that are least discussed. One improvement to RAPT could be to begin the display of timelines with GAYEL J95 and proceed counter-clockwise instead of beginning with HAPIE.

The next analysis considers the content of the communications more deeply. The ZNY TMCs function is to make the decisions on if a traffic management restriction is needed, and if so, what that restriction should be. It is useful to consider whether the communications that occur are of a "broadcast" nature or of a "point-to-point" nature. Some communications broadcast information that is useful for several facilities. Issuing a notice of whether a departure route is open/closed is a communication that is of a "broadcast" nature. Because of the importance of these communications, the verbal broadcast should, in theory, be accompanied by a more persistent level of information (e.g., electronic logs accessible by all facilities). Other communications are of limited scope and interest amongst facilities, such as individual flight queries. These communications can be considered "point-to-point" communications.

The content of the communications falls into several categories: communicating/requesting information on route status, answering questions about the reasoning behind restrictions, discussing issues with individual flights, and predicting how the situation will change in the future. In the detailed communication data collected in 2010, 33% of communications were found to communicate the route status or question the status of routes. While RAPT provides information on current and predicted blockage due to weather, the tool does not currently provide information on whether the route is actually open to traffic or not (i.e., J75 could be "red" on RAPT, but still "open" to flights on the route, however unwisely). Every time a route status changes, ZNY TMC often informs the SWAP telecon, the DD, and the SSs. It is not uncommon after the SWAP telecon announcement for the TMC to call out a facility in particular to ensure that the closure was heard. It is also not uncommon for facilities to question whether a route is open or closed after a telecon broadcast has been made.

These exchanges appear to be the result of a lack of persistent means of communicating route status. The verbal communication is important to convey the information quickly and broadly for the most immediate effect on the operation. However, during SWAP operations, TMCs are often busy with multiple tasks and occasionally miss the broadcasted information. Hence, the more persistent log would be useful in this case. Because of the lack of a centrally managed (and well-maintained) log, flurries of point-to-point communications occur as a result of missed information. In New York, these point-to-point communications are fielded by the ZNY TMCs, which likely contributes greatly to their communication workload discussed in an earlier analysis in this section.

In Figure 6 below, an exchange about the J75 route is relayed. ZDC notified ZNY of J75's imminent closure and ZNY TMC subsequently passed on this information to the DD and the SSs. Discussion then occurs about whether the NY metro airports could let the departure lineups on the surface go on J75, and then the decision is passed to the DD, N90, and the airports. Three hours later, LaGuardia (LGA) asked why J75 is still closed (J75 on RAPT shows "green" now). ZDC downstream weather was

used as the reason for continued restriction. A “pathfinder” flight (PF) was then requested to ZDC to fly J75 and determine if the weather was clear enough to open the route. A pathfinder aircraft from LGA was found. Fifteen minutes later (before the pathfinder had a chance to explore the route), ZNY opened J75 with ZDC permission. In an additional question on the SWAP teleconference, Philadelphia (PHL) asked 20 minutes later whether J75 was open yet, which is not an uncommon occurrence.

For every minute TMCs are not aware of a route re-opening, flights on that route may be prevented from departing, wasting fuel and passenger time as well as adding to surface congestion. Not being aware of a route opening unnecessarily reduces the efficiency of the system, and in this case, the departure efficiency of PHL and any flights prevented from departing were affected by the lack of effective communication.

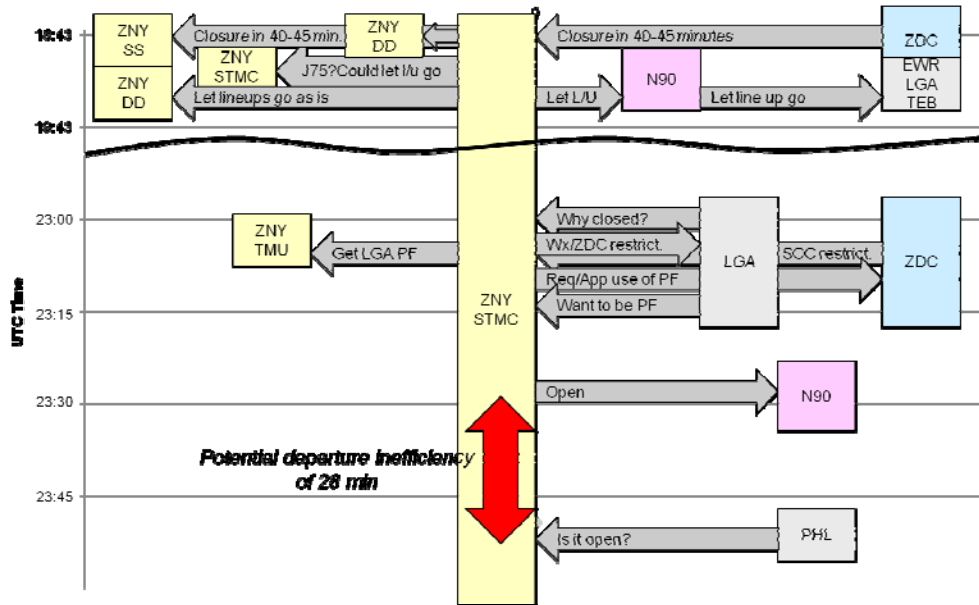


Figure 6: Example communications surrounding J75 departure route status.

When observing the communications (or considering the data, which indicates 1 out of every 3 communications involves route status), it becomes apparent that a significant amount of NY TMC communications could be reduced by providing a means to publish and distribute openings and closures around the facilities. A Google docs page has recently been created to allow the sharing of route status between facilities. However, since ZNY does not appear to directly benefit from this, it is difficult to motivate the ZNY TMCs to constantly update this page in dynamic conditions. A potential solution is to incorporate the route status into RAPT, which already displays the key routes and whether they are “red” or “green” based on weather blockage and customizes them by facility. By combining route status with RAPT, it not only would reduce communications, but knowledge of whether routes were open/closed could allow RAPT to generate a notification to a TMC to reconsider opening the route if a route is “closed” but RAPT displays that weather is no longer affecting the route (and vice versa). By just providing information on when a route is now clear of weather, departure efficiency has improved in NY [4], and actually drawing TMCs’ attention in a busy, dynamic environment could potentially maximize these benefits.

Interestingly, when route status was suggested to the RAPT users during a user group session in 2008, the option was rejected as “redundant” to another electronic log (that is rarely maintained to operational sufficiency). Perhaps introducing the impact on communication workload that route status communications have as presented in this paper and directly linking added RAPT benefits to

the input of route status would establish the idea more favorably in users’ minds.

4. DISCUSSION

In this paper, several uses of field communication data were demonstrated to improve the RAPT decision support tool. The above analyses revealed the decision-making context (including communications flows, modes, and content), evaluated the decision support design choices, and identified opportunities to reduce impediments to effective decision making.

This method of analyzing and evaluating communications is valuable because it combines a quantitative (frequency and direction of communications) analysis with a qualitative (content of communications) analysis. Many operational evaluations rely on subjective evaluation of communications (e.g., Hoang & Swenson [7]). An additional benefit of this approach is considering communications from multiple facilities, which is more representative of the TMC function. Many operational evaluations concentrate on a single facility (e.g., Lee & Sanford [8]).

One point to make using those analyses is that the analyses do not have to be complicated and overly statistical to have an impact on improving decision support. Often in development, time is not readily available to collect and analyze extensive amounts of data. If enough data can be collected to reach a point at which the researcher can reasonably establish that the data is representative of the context, design directions can be established. In field data collection, often the pitfall is collecting data in the wrong context rather than

collecting sparse data. For example, collecting communications data in fair weather conditions would have yielded very different communication data results and the communications structures would have changed entirely.

To summarize, communications analysis in the simplest form can be useful in general decision support tool design.

Communications reveal:

- what information/decision support is needed
- who the decision makers are and who needs the decision support for situation awareness purposes
- motivations about why this information is needed

Analyzing communications data can also aid in contextualizing the decision support tool to ensure that the tool fits within the decision-making framework of the users. It reveals the level of information in which the parties are interested (e.g., providing not only weather blockage estimates but the location of the weather and height of the storm). The format of information is also transparent (e.g., routes are generally indicated using either the fix name, PARKE, or the route, J6, so RAPT should indicate them interchangeably PARKE J6). Communications also indicate actions that are available to users (what the decision tool is supporting) and actions most often taken (e.g., departure routes can be “open,” “closed,” or “restricted” with a MIT restriction).

One issue that remains for future research is that in some areas, a decision support “tool” is not required, but a decision support “procedure” is. For example, the communication of route status may be too complicated to address in a tool, given the possible exceptions and restrictions (e.g., resume WAVEY at 30 MIT except for flights to RDU and northern destinations). It may be more appropriate to implement a communication procedure to address the information gaps. (For example, it may be more effective to require ZNY to input each route opening/closure on the National Traffic Management Log (NTML) to ensure that there is a widely accessible current status of routes available.) Effective means of convincing sponsors/facilities to implement such communications procedures and the method for doing so is a further research topic.

5. ACKNOWLEDGMENTS

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