Improved Delivery of Airport Emergency Services

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A new methodology to improve delivery of emergency airport services is described. Important goals of airport response planning are to simultaneously maximize mobility and payload, and minimize arrival time. The Waterways Experiment Station of the U.S. Army Corps of Engineers has developed the Army Mobility Model and Transportation Model. These models were adapted for use at airports by the U.S. Department of Transportation, Research and Special Programs Administration, Transportation Systems Center. A case study was performed that demonstrates that the airport-specific methodology can be used to assess and improve delivery of emergency services. Combining the two models with airport-specific geography creates a situation in which it is possible to quickly investigate travel time sensitivity to changes in factors such as weight, gear ratio, or tire pressure. This experience indicates that properly applied geographic colocation can lead to integration of transportation models with models from other fields.

The time to develop and implement an emergency plan is long before an incident occurs. As Figure 1 shows, emergency response planning is separated into two elements—readiness planning and delivery planning. Readiness planning consists of emergency preparations that can be made in advance of an accident. Readiness planning is a deliberate long-term process designed to ensure availability of resources and development of procedures for coordination during an emergency. Examples of the readiness process are purchase of equipment; training of personnel; and establishment of mutual aid agreements with local hospitals, fire, police, and volunteer organizations. Delivery planning focuses on the time-critical and event-specific efforts by rescue and firefighting personnel to save lives and mitigate the impact of an accident. Examples of delivery planning actions are preselecting travel routes to potential airport accident sites and conducting periodic emergency drills.

Figure 2 shows a typical delivery process with the following sequence of events: after an alarm is received, personnel and equipment are mobilized; ground vehicles transport emergency resources to the scene; rescue and firefighting (RFF) services are deployed at the accident scene. Thus, the time needed to respond includes mobilization time (in practice, RFF vehicle and payload are ready to roll at all times, thus mobilization time occurs seconds after the alarm sounds); travel time (this period is often minutes rather than seconds); and deployment time (because the window of opportunity for rescuing victims, suppressing a fire, and mitigating the impact of an accident is short, deployment must occur immediately on arrival).

ALL-TERRAIN RESPONSE

The challenge of providing for public safety at an airport is unique because the airport seeks to provide all-terrain emergency response both for unpaved areas that often constitute a large portion of an airport and for paved areas such as those found near passenger terminals. Significant response factors to be considered include timeliness (which for aircraft incidents requires that RFF help must arrive within seconds) and payload (which requires that RFF vehicles must transport adequate quantities of water, chemicals, equipment, medical supplies, and personnel).

Timeliness

There is ample evidence that, when rescue and fire fighters arrive quickly, they are more effective in saving lives and reducing damage. Thus, all other things being equal, the faster the emergency response, the better. Current airport response planning is concentrated on procedures, training, and practice sessions for (a) rapid mobilization at a station, (b) on-pavement transport, and (c) resource deployment at an accident site. Until recently, no systematic method was available for analyzing the unique problems of rapid off-pavement response or to provide for timely payload delivery and pertinent training of personnel for this circumstance.

Payload

Because the standard method of transporting an airport emergency payload is by ground vehicle, timely payload arrival

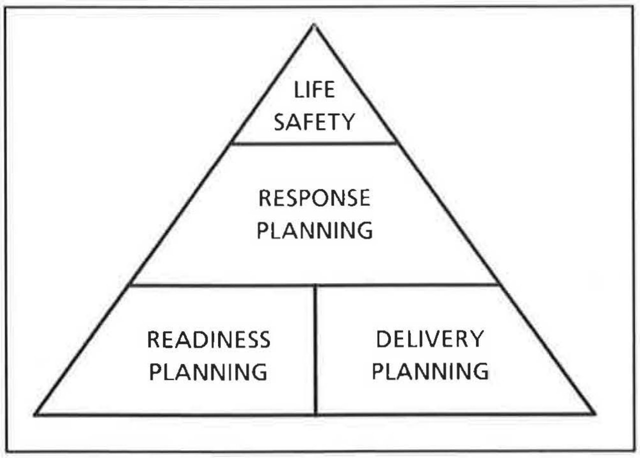

FIGURE 1 Emergency response planning.

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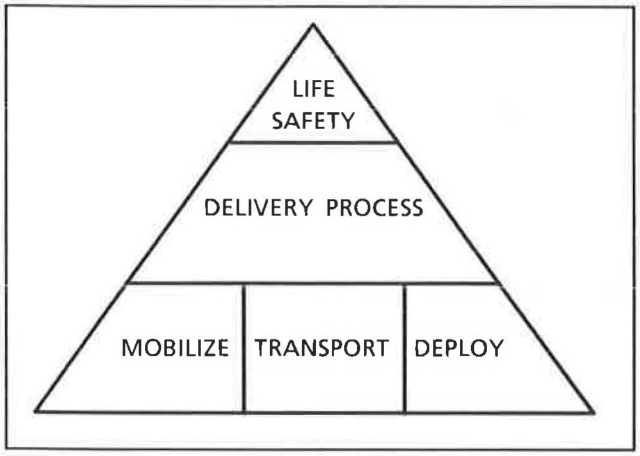

FIGURE 2 **Typical delivery process.**

should be determined from an analysis of vehicle performance. Unfortunately, most vehicle statistics are limited to on-pavement performance, which does not adequately predict payload arrival for airport conditions. In addition, airports are faced with the paradox that improving vehicle performance may not improve public safety levels. For example, one method of improving vehicle performance is to decrease vehicle weight by reducing the payload. This in turn means fewer resources (water, chemicals, equipment, medical supplies, and personnel) available to ensure safety. All other things being equal, when lives are at risk, having more resources is better than having less.

Mobility

Mobility is defined as the capacity for movement, that is, the speed at which a vehicle moves under various environmental conditions. Because rapid arrival of an adequate payload is key to mitigating accident severity, important goals of airport response planning are to maximize mobility, maximize payload and minimize travel time. Solutions to this complex problem can best be found with analytical models.

Since 1946, the U.S. Army Corps of Engineers, Waterways Experiment Station (WES), has performed research on and modeling of vehicle, terrain, and operator interactions under a variety of environmental conditions. This work included development of techniques for quantifying the effects on vehicle mobility of grade, slope, vegetation, obstacles, linear features, human factors, and seasonal conditions. The primary focus for WES has been to evaluate vehicle performance using the single-patch Army Mobility Model (AMM). Recently, WES developed the Transportation (T-) Model, which quantifies travel time over a sequence of patches.

Army Mobility Model

Conceptually, the AMM sums the physical forces affecting a vehicle's motion as it moves at constant speed over a single patch of ground. The Army applies the AMM to military problems of ground movement in a particular region of the world (e.g., tank movement in Europe). Each region is represented by patches (Figure 3) with large and small features typical of that area (e.g., urban, mountain, farm, and rocky). The model then computes average vehicle speed and fuel consumption per patch and provides a set of diagnostic data for each type of patch. A typical set of computations performed by this model requires less than 50 min. The same set done by hand would require approximately 50 man-years.

FIGURE 3 **Global regions and patches.**

Transportation Model

Conceptually, the T-Model sums the times used as a vehicle moves from an origin over a route to a destination. Usually, an origin-destination pair is connected by a network of intermediate nodes and route segments as shown in Figure 4. Travel time along a single route is calculated by dividing speed along each segment of the route into each segment length and summing over all the segments in one route.

AMM and T-Model Colocation

When the AMM patches and T-Model network are superimposed, a relationship is established between variables from the two models. The superimposition shown in Figure 5 was created by colocating network nodes and patch center points. For this geometry, segment length (T-Model) is equal to the distance of a patch side (AMM), and speed per segment (T-Model) is equal to average speed per patch (AMM).

Adaptation for Airport Use

With WES assistance, the models have been adapted for use at airports by the U.S. Department of Transportation, Research

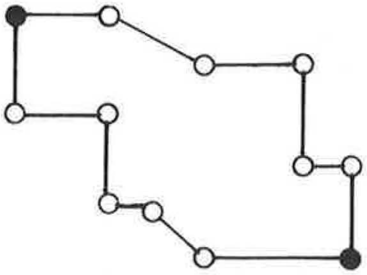

FIGURE 4 **T-Model network.**

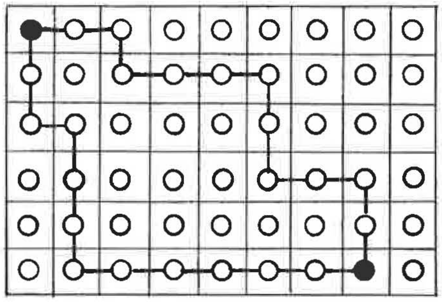

FIGURE 5 Geometry of AMM and T-Model colocation.

and Special Programs Administration, Transportation Systems Center (RSPA/TSC). The resulting capability is the new methodology to improve delivery of emergency airport services (IDEAS). It can be used in (a) siting fire stations, (b) siting fire lanes, (c) estimating RFF response time, (d) diagnosing problems that could delay or disrupt emergency response, (e) developing safety improvement strategies, (f) identifying alternative methods to implement a strategy, and (g) evaluating safety improvement implementation costs and benefits.

Adaptation included the following:

1. For airport use, the ranges allowed for AMM parameters were adjusted to emphasize the high-speed travel required for an RFF vehicle and to deemphasize the low-speed movement of military convoys.
2. Because an airport, unlike the Army, has unilateral control over airport grounds, technical applications were extended to include impact analysis of changes to the landscape; for example, elimination of obstacles, grading rough areas, filling in ditches, or adding fire lanes.
3. An estimate of all-terrain response is accomplished by calculating travel time from the airport fire station (origin) to all potential destinations. For data presentation, travel time is plotted in contours. In Figure 6, each contour represents an additional 30 sec of travel time.
4. The relationship established between the models by colocation was made airport-specific by superimposition over airport geography, producing a tri-location. The airport was partitioned into 15-foot-square sections. Then, each section had an AMM patch superimposed on it and a T-Model node located at the center point. Partition size was chosen because it is simultaneously proportional to (a) changes in airport features that could affect delivery, (b) size of the RFF vehicle, and (c) aircraft accident conditions.

The following list developed by RSPA/TSC includes commercial and field options for improving airport emergency services.

VEHICLE

- Vary tire pressure,
- Change tire width,
- Use radial tires,
- Use chains and paddles,
- Use additional wheels, and
- Modify suspension system.

ROUTE

- Use emergency routes,
- Plan preposition locations,
- Map airport, and
- Install fire lanes.

ENVIRONMENT

- Study impact of wind,
- Study ground congestion,
- Grade terrain,
- Fill ditches,
- Improve drainage, and
- Mark ground obstacles.

HUMAN

- Train vehicle operator.

The IDEAS method is site-specific. It depends on actual airport topology and weather history, actual RFF vehicle configuration, and airport safety policy. Therefore, a case study is presented as an aid to understanding and to demonstrate IDEAS capability.

Case Study

In 1988, RSPA/TSC completed a case study of IDEAS with the cooperation of the General Mitchell International Airport at Milwaukee, Wisconsin. It investigated one specific approach to reduce arrival time of a payload and considered the costs and benefits of several implementation alternatives.

This aircraft rescue and firefighting (ARFF) Index D airport covers approximately 2,200 acres (6 mi^2). Formerly farmland, the soil contains a high percentage of clay and the terrain is generally flat, with a forested hillock on the approach to Runway 1L.

In 1986, soil samples, aerial maps, and terrain data were gathered by WES and RSPA/TSC with the assistance of air-

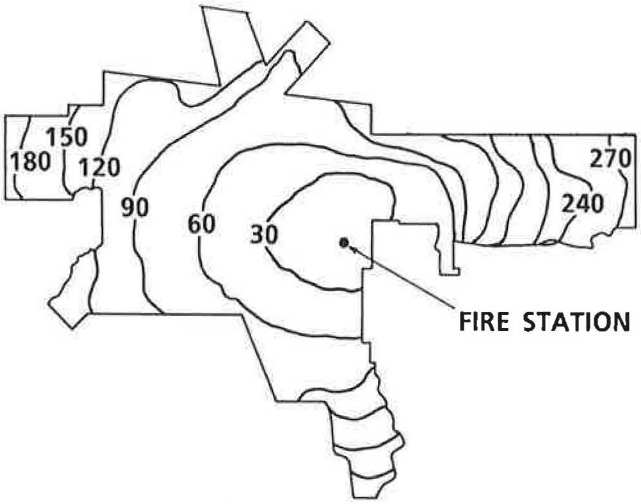

FIGURE 6 Time contour concept, scale 1:36,000.

port personnel. The data were digitized and entered into the ARC/INFO geographic information system data base. The resulting airport data base contains information on approximately 1,422,000 fifteen-foot-square patches of airport terrain with an equal number of center point nodes. Figure 7 is a map of the airport that identifies airport features such as runways, control tower, fire station, railroad, highway, ditches, fences, ponds, parking lots, fire lanes, urban, and wooded areas. The fire station is to the right of the tower, which is located near the center of Figure 7.

After reviewing weather data for the past 10 years, two weather conditions were chosen for analysis: best condition—no rainfall (dry ground), which occurs 61 percent of the year, on average; worst condition—excessive rainfall (wet, slippery ground), which occurs 6 percent of the year, on average.

Data for one specific vehicle were then entered into the data base. Typical vehicle data are weight, center of gravity, clearance, number of wheels, power, gear ratio, tire width and pressure, and tread type. The specified vehicle is designed to carry a relatively large payload of 3,000 gal of water, 500 lb of Halon 1211, 360 gal of aqueous film-forming foam (AFFF), 55 gal of fuel, and a crew allowance of 350 lb—a total payload of approximately 31,000 lb.

The case study addressed three scenarios, as follows:

- Scenario 1—Vehicle on dry ground,
- Scenario 2—Vehicle on wet ground, and
- Scenario 3—Modified vehicle on wet ground.

For analysis purposes, each scenario included the vehicle, weather and ground condition, airport features, and one set of soil measurements.

First Estimated Time-of-Arrival Computation

The first step in the analytical sequence was to use the AMM and the airport geographic and vehicle data bases to calculate speed for each patch. Speed per network segment was then set equal to speed per patch; these data were then entered into the T-Model. Travel times from the fire station (origin) to all potential destination nodes were calculated, and plotted as estimated time of arrival (ETA) contours. Figure 8 is an ETA plot for Scenario 1. The less regular contours reflect variations in off-pavement speed caused by grades, rough terrain, and obstacles. Each succeeding contour represents an additional 30 sec of time.

On the basis of a review of larger plots than can be shown here, Figure 8 predicts that the payload can be delivered everywhere on the airport fairly rapidly, coverage is not limited, but speed off of the pavement is slower than speed on the pavement.

Figure 9 is an ETA plot for Scenario 2. In the black areas, speed is zero; the vehicle cannot transport its payload, and deployment cannot occur. Although the vehicle complies completely with current federal emergency response requirements (14 Code of Federal Regulations, Part 139), it cannot perform under these conditions.

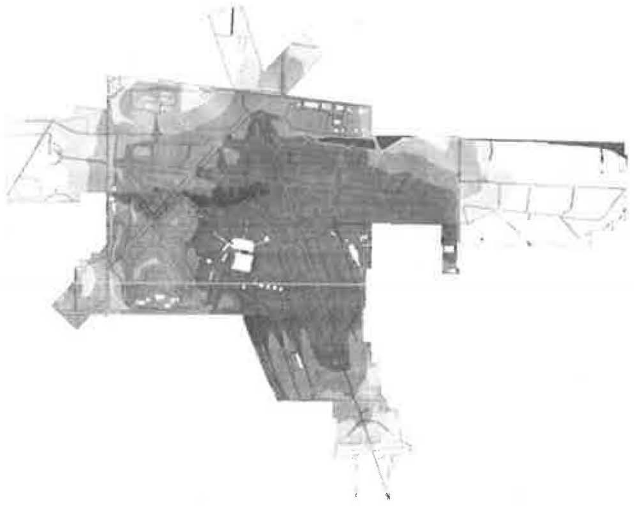

FIGURE 8 Existing Scenario 1—ETA for the vehicle on dry ground, which occurs 61 percent of the year on average, scale 1:36,000.

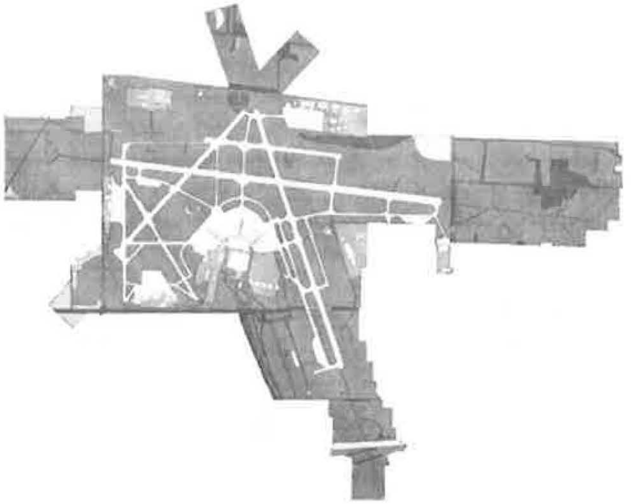

FIGURE 7 General Mitchell International Airport surface feature map, scale 1:36,000.

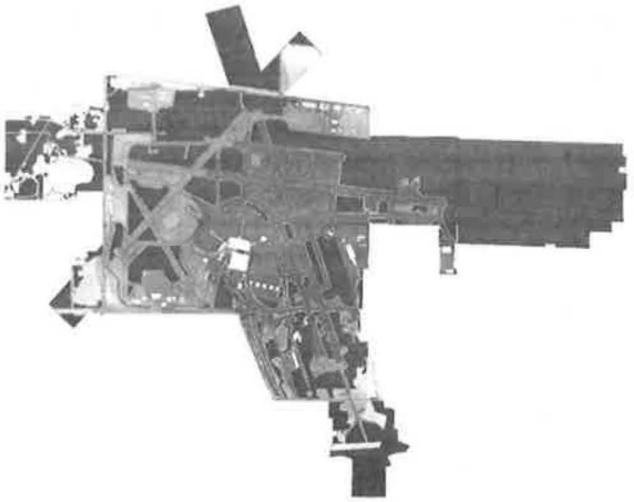

FIGURE 9 Scenario 2—ETA for the vehicle on wet ground, which occurs 6 percent of the year on average, scale 1:36,000.

Scenario 1 Diagnostic

Figure 10 is a plot of the major factors per patch diagnosed by the AMM as the major reason speed is limited in Scenario 1. Most of the light-grey patches refer to speed reductions caused by poor ride quality. Ride quality forces are measured in terms of continuous absorbed power, that is, vibration in the vertical direction. Results of Army field tests indicate that for short periods of time under high stress human tolerance can be as high as 15 Watts of vertical absorbed power. The AMM uses this information to predict operator loss of control because of excessive vibration. It reacts to poor ride quality by reducing vehicle speed until the cab vibration is reduced to tolerable levels.

Airport Evaluation

On reviewing this plot, the airport fire chief and ground maintenance manager indicated that some areas at the airport retained furrows from previous farming activity. Describing the physical problem led almost immediately to suggestions for a better suspension system and better landscaping. There was universal appreciation that these improvements could improve timeliness of arrival.

Scenario 2 Diagnostic

The major AMM speed-limiting factor for Scenario 2 is shown in Figure 11. Most areas, especially those at the ends of runways, are impassable, because the vehicle sinks into the muddy clay soil. This problem had another somewhat more complex solution.

Second ETA Computation

Although Figure 11 shows that arrival time is adversely affected by weather-related ground conditions, to change the soil is not feasible or economical. Instead, an increase in the vehicle's footprint was investigated in the hope that distributing the vehicle's weight (more than 60,000 lb) over a larger area would decrease the tendency to sink.

The large-footprint approach was modeled by changing the computer's data base of vehicle parameters, all other factors being held constant. AMM calculations for average speed per patch were made using the new data. T-Model predictions were also recalculated. After several possible alternatives were tried, Scenario 3 was created and the ETA contours shown in Figure 12 were plotted. Figure 12 shows that many areas (black), formerly predicted by the models as inaccessible, could now be reached by the vehicle. This result shows that the proposed strategy will indeed reduce arrival time and extend emergency response coverage.

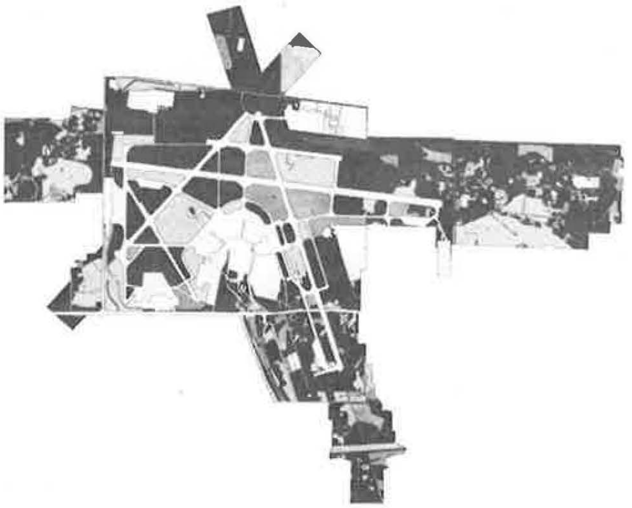

FIGURE 11 Scenario 2—diagnostic plot for the vehicle on wet ground, which occurs 6 percent of the year on average, scale 1:36,000.

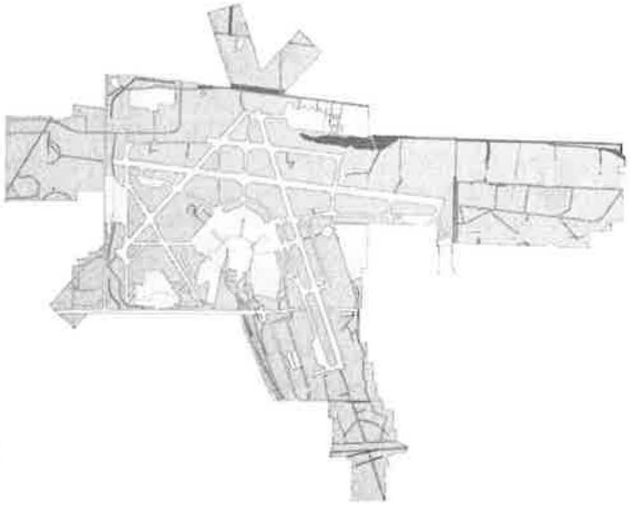

FIGURE 10 Scenario 1—diagnostic plot for the vehicle on dry ground, which occurs 61 percent of the year on average, scale 1:36,000.

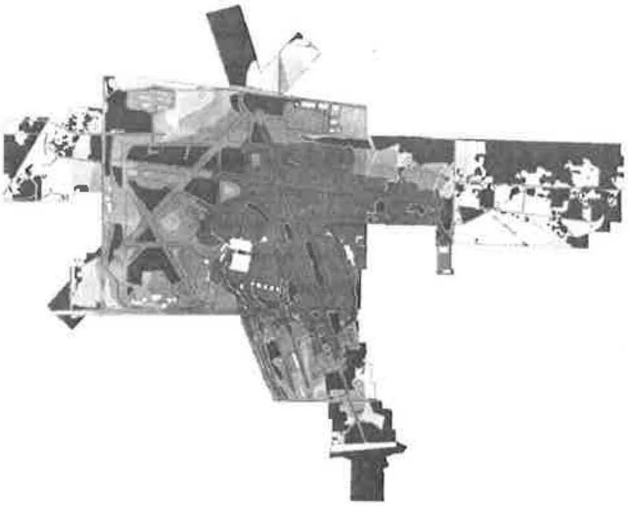

FIGURE 12 Scenario 3—ETA for the modified vehicle on wet ground, which occurs 6 percent of the year on average, scale 1:36,000.

Working from the list of proposed safety options and from tire experts' recommendations, three large-footprint implementation alternatives were identified:

1. Reduce tire pressure manually. This option is not recommended. However, when all else fails this approach might help.
2. Install tires rated for low pressure operation and add a bead retention system to clamp the tires to the rims. This option is recommended for consideration because of its low initial cost, relative ease of maintenance, and reliability. Driver training is also recommended because a large footprint alters the vehicle's handling characteristics.
3. Install tires rated for low-pressure operation and an automatic inflation-deflation system. This option is also recommended for consideration. Because the vehicle operator can adjust tire pressure according to situational requirements (e.g., full inflation when on pavement and lower inflation off the pavement), this solution could provide the best overall response capability. Retrofitting the specified vehicle is feasible, but more complex and expensive than the other alternatives.

CONCLUSIONS

On the basis of the work reported, IDEAS is a useful adaptation of the models developed by WES. The case study demonstrates that airport-specific methodology can be used to assess and improve delivery of emergency services. In addition, combining the two models with a specific geography creates a situation in which it is possible to quickly investigate travel time sensitivity to changes in factors such as weight, gear ratio, and tire pressure. This experience indicates that properly applied geographic colocation could lead to integration of transportation models with models from other fields.

ACKNOWLEDGMENTS

The authors would like to express their sincere gratitude to Bertrand Ruggles, FAA, Office of Airport Standards, Safety and Criteria Division, for funding and contributing his expertise to this work. Thanks are also extended to the General Mitchell International Airport staff for their cooperation and to the WES Mobility Systems Division staff for their technical contributions.