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ASSESSMENT OF THE BENEFITS FOR IMPROVED TERMINAL WEATHER INFORMATION*

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An important part of the FAA Aviation Weather Development Program [Sankey and Hansen, 1993] is a system, the Integrated Terminal Weather System (ITWS), that will acquire data from the various FAA and National Weather Service (NWS) sensors and combine these with products from other systems (e.g., NWS Weather Forecast Offices and the FAA Aviation Weather Products Generator) [Evans, 1991]. This wide variety of input data and products will enable the ITWS to provide a unified set of weather products for safety and planning/capacity improvement for use in the terminal area by pilots, controllers, terminal area traffic managers, airlines, airports, and terminal automation systems (e.g., Terminal Air Traffic Control Automation (TATCA) Center Tracon Advisory System (CTAS) [Andrews and Welch, 1989] and wake vortex advisory systems[Evans and Welch, 1991]).

The assessment of benefits from the ITWS, particularly in the area of reducing delay and other aviation system operations costs, has been an important element of the ITWS initial development phase. At the last Aviation Weather Conference, initial results were reported on delays associated with various types of weather based on use of climatology and FAA National Airspace Performance Reporting System (NAPRS) statistics for O'Hare airport [Weber, et al., 1991]. This paper extends the earlier results to consider a broader range of terminal weather impacts on aviation and discuss how the ability of the ITWS to reduce the impact will be quantified.

Weather-related impact on airline operations has been estimated using airline internal data on delays and other impacts at several major hub airports. These results show that the earlier results seriously underestimated the delays that arise when weather impacts an airport. This underestimation arose because air traffic flow control procedures now attempt to hold planes on the ground at the departure airport when the destination airport is impacted by weather, and the NAPRS statistics did not associate delay times resulting from traffic management gate and runway holds at the departure airport with the destination airport impacted by weather.

However, by using airline internal data for carefully chosen weather events, one can assess the relative magnitudes of the delay associated with an airport impacted by weather. Table 1 summarizes internal airline delay data from several major airlines at O'Hare (ORD), Minneapolis-St. Paul (MSP), and Stapleton (DEN) international airports. We see that typically the NAPRS data underestimated the actual total direct delay by approximately 50-100% for thunderstorms and 200-300% for heavy fog.

There are a number of other significant airline costs such as fuel tankering, cancellation, diversions, and costs associated with rescheduling aircraft and flight crews that have not been considered in the aviation weather cost/benefits analyses to date. Table 2 shows the diversions and cancellations for major air carrier O-1 in table 1 during a number of weather incidents at O'Hare. These results should be compared to those cited in [Hartman, 1993] in which it is argued that there is a constant ratio between diversions, cancellations and delays (1:3:100 hours of delays on flights to/from the affected airport] for low-visibility events.

Another very important element of weather impact assessment is the "delay ripple" effect. If an aircraft is delayed on one leg of a flight (e.g., due to adverse weather at the airport), then there is a probability that

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the delay will carry over, or "ripple," onto the next leg (and subsequent legs) flown by that aircraft that day. In cases where the subsequent leg(s) are not impacted by weather, the delay on the subsequent legs may not be attributed to terminal weather. DeArmon states that "delay ripple is in general pretty strong" and persists over a number of successive legs [DeArmon, 1992]. Hartman cites a case where the number of passengers delayed (down-line impact) due to delay ripple was 27 times greater than the initial number delayed [Hartman, 1993a] and has suggested that typically the initial delay at an airport impacted by low visibility is multiplied by a factor of 3-5 due to delay ripple [Hartman, 1993b].

Table 1.
Average Daily Airline Operations and Delay Minutes on Sample Days of Varying Weather Type

Airline	Airport	Weather Day Type [# Days]	Operations Arriv./Depart.	Avg. Daily Delay Minutes Arrival	Avg. Daily Delay Minutes Departure	Delay Min. per Oper. Arrival	Delay Min. per Oper. Departure
0-1	ORD	Baseline Clear [1]*	381 / 393	229 (94%)	15 (6%)	0.6	<0.1
0-2	ORD	Baseline Clear [1]*	315/316	1035 (43%)	1398 (57%)	3.3	4.4
D-1	DEN	Baseline Clear [2]	194 / 195	88 (51%)	86 (49%)	0.5	0.4
M-1	MSP	Baseline Clear [1]	257 / 259	1195 (50%)	1187 (50%)	4.6	4.6
0-1	ORD	Thunderstorm [4]*	392 / 387	3395 (63%)	1958 (37%)	8.7	5.1
0-2	ORD	Thunderstorm [4]*	311 / 314	2570 (47%)	2915 (53%)	8.3	9.3
D-1	DEN	Thunderstorm [5]	193 / 193	1180 (76%)	380 (24%)	6.1	2.0
M-1	MSP	Thunderstorm [5]	273 / 272	4591 (51%)	4430 (49%)	16.8	16.3
0-1	ORD	Heavy Fog [4]*	359 / 356	4676 (80%)	1196 (20%)	13.0	3.4
0-2	ORD	Heavy Fog [4]*	296 / 297	3970 (54%)	3345 (46%)	13.4	11.3

* These data subsets from two separate airlines represent operations and delays for a common set of weather days at ORD.

Table 2.
Cancellations and Diversions on Weather-Impacted Days for a Major Airline at O'Hare Airport

Weather Type (Number of Days)	Total Operations	Diverted	Canceled	Secondary Cancellation*
Clear (1)	779	0	0	0
Thunderstorms (4)	3116	41	19	67
Fog (4)	2830	25	89	82

* Secondary cancellations are flights that were canceled because equipment was not available due to a weather cancellation.

Delay ripple is clearly a very important issue in weather benefits assessment that has not been considered in recent weather system studies. One useful tool for assessing the delay ripple effect as a function of airport weather impact severity and duration will be the National Airspace System Performance Analysis Capability (NASPAC) [Frolow, et al., 1989]. Experimental validation of delay ripple estimates by following specific aircraft throughout a day is also desirable.

The ITWS can reduce the adverse impact of weather by three methods:

1. Increasing the effective capacity of the terminal routes and airport runways during adverse weather (e.g., by providing information for planning routes around hazardous cells, winds information for terminal automation and wake vortex advisory services) [Evans, 1991, Evans and Welch, 1991],
2. Avoiding unnecessary changes in terminal and airport configuration (e.g., by short-term forecasts of runway winds, ceiling and visibility), and
3. Anticipating weather events which will increase or decrease airport capacity so that air traffic management systems can optimize the flow of traffic to the terminal area.

Estimation of the reductions in delay and other impacts of terminal weather that would be achieved by the ITWS is being accomplished by a combination of airport-specific weather studies, analysis of ITWS operational demonstrations at major airports, analytical studies, and discussions with aviation system experts. Results to date and near-term plans for ITWS benefits estimation will be presented in the full paper.

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