REAL-TIME INTER-MODAL SUBSTITUTION (RTIMS) AS AN AIRPORT CONGESTION MANAGEMENT STRATEGY

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ABSTRACT

We explore the potential for real-time inter-modal substitution to reduce flight traffic and reduce delays in situations where there is a temporary severe shortfall in airport capacity or airport closure. Two schemes are discussed in this paper. One is that airlines cancel short-haul flights and rebook passengers on surface transport modes in cases when the delay savings from reduced flight traffic is greater than the costs and increased travel time associated with the surface mode. We demonstrate an optimization model that chooses which flight to cancel, and which flight to be substituted with ground transportation. As a second scheme, alternative hubs are selected among nearby airports and surface transportation links hub, alternative hub airports, and other spoke airports. Further study is needed to compare these two schemes for a real case.

1. INTRODUCTION

In this paper, we will describe and analyze an approach to air traffic flow management that we will term real-time inter-modal substitution (RTIMS). In this approach, airlines facing a severe airport capacity shortfall or airport closure as a result of adverse weather or other transient events cancel commuter (short-haul) flights and replace them with surface transport in order to increase capacity available for large-jet operations. This can reduce system delay costs and, in some cases, allow short-haul passengers to arrive earlier despite the longer surface transport time. Inter-modal substitution allows airlines to make decisions with more reliable capacity forecasts so as to avoid excess ground delay, airborne delay, or cancellation costs.

Although there are different definitions about inter-modal transportation, a well-accepted one is "the concept of transporting passengers and freight on two or more different modes in such a way that all parts of the transportation process, including the exchange of information, are efficiently connected and coordinated."[1] Passenger inter-modal transportation has lagged in the U.S., compared to the freight transportation or passenger transportation in European Union (EU). This is especially true for inter-modal services involving the aviation mode. The integration of transportation modes requires well designed connection facilities. For example, the European air-rail inter-modal system features intercity rail stations on the lower levels of major airports [2]. In the U.S., lagging infrastructure development holds back the possible coordination between air and rail modes. Since curb access is possible without major facility investment, the cooperation between airlines and coach charter companies, however, is readily conceivable.

Airports are pivots in the national transportation network. When demand at a major U.S. airport starts to reach the airport's capacity, the airport becomes vulnerable to disruptions such as adverse weather, security threats, or other transient events. For hub-and-spoke networks operated by most legacy airlines, capacity shortfalls at hub airports cause passenger misconnections, which contribute to a significant percentage of total passenger delay. Research has shown that passengers whose itineraries were disrupted encounter seven hours delay in average [3]. Delay estimation based on traffic forecast reveals a large difference between average flight delay on normal days and that on days with adverse weather [4]. Delay at an individual airport readily propagates to the whole National Airspace System (NAS). Studies have demonstrated that one minute of delay at a single airport will cause several minutes of delay system-wide [5]. This makes delay reduction one of the most critical issues to solve in the air transportation operation. Volume-related delay (delay caused by excessive demand) can be addressed by controlling demand, either through market mechanisms or administratively. These measures, however, are not appropriate for weather-related delay because limiting schedules to the level that can be accommodated on bad weather days will unnecessarily constrain airline operations on good days. Instead, a real-time congestion relief strategy is needed to solve weather-related delay problem.

In the worst scenario, a security crisis may cause temporary shutdown of airports. For instance, airports in the U.S. were shut down for almost three days right after 9/11. The following was from a passenger's web log describing what happened after he was stuck at Denver airport on that day, "As I approached the ticket counter I heard an announcement informing us that the Denver airport was now closed and everyone needed to evacuate. I was going to be spending the night in Denver…I began calling rental car agencies and Amtrak and Greyhound looking for any kind of ticket out of town. There was neither a car to be rented nor a ticket to be purchased. My sister usually gets results but she came up empty this time. No one at Northwest had any information for her."[6] "The transportation chaos in the aftermath of 9/11 tells Americans that the US is excessively reliant upon a single mode of transportation, inter-modal connectivity is poor in many parts of the country, and intercity commercial passenger transportation alternatives are poor or nonexistent." [7] There are urgent needs to develop an integrated transportation system in the U.S.

To date, there has been little study on the design or feasibility of an air-coach inter-modal substitution system as a real-time airport congestion management strategy. Extensive research on airline scheduling problems under disruptions has focused more on disruptions from unexpected aircraft shortage and crew shortage rather than on disruptions from airport capacity reduction [8,9,10,11,12,13]. The concept of a floating hub as a response to a hub airport facing a capacity reduction has been considered [14]. The study showed that high capital investment is needed to construct necessary ground facilities at the floating hub(s), which may not be justified by the delay savings [15]. The inter-modal strategy considered here has requires considerably less capital investment.

The rest of the paper is organized as follows. In Section 2, the current air traffic flow management system in the U.S. is described, and issues relevant to airport congestion management are discussed. A network traffic assignment problem with node capacity constraint is defined in Section 3. An optimization model is formulated in Section 4 to solve this problem with deterministic airport capacity information. In Section 5, the model is applied to a numerical example, optimizing a feeder airline's operation at a representative U.S. airport. Costs are compared for different strategies: including no cancellations, canceling flights without RTIMS, and canceling flights with RTIMS. In section 6, the second scheme combining inter-modal substitution and alternative hubs are briefly described. Future work is proposed in Section 7.

2. AIR TRAFFIC FLOW MANAGEMENT IN THE U.S.

Air traffic flow management (ATFM) was developed in the U.S. in the 1980s to facilitate air traffic management (ATM) and airport operations. The objectives of ATFM are to prevent overloading of the airspace system, minimize the economic impact of air traffic congestion, and avoid situations that might compromise safety [16]. Ground delay programs (GDP) are a key component of ATFM. If traffic demand is expected to exceed capacity at airports (or sometimes en route airspace), a GDP is launched to hold an arrival aircraft at its original airport unless there is reasonable assurance that, after departure, it will be able to proceed to its destination with a minimum amount of delay in the air [16]. GDPs reduce the costs and risks of airborne delay.

Centralized ATFM may cause inefficient usage of arrival capacity. Under centralized ATFM, the service provider (in the U.S., the Federal Aviation Administration (FAA)) assigns a ground holding time for each flight. Slots are allocated to airlines based on their original flight schedules and the first-come/first-served principle, which is known as ration-by-schedule (RBS). However, airlines may want to assign slots differently once GDP is in place because some flights are more delay-sensitive and should thus be given higher priority. Furthermore, an airline may cancel a flight. If the airline makes this known to FAA soon enough, the flights after the cancelled one can be moved up and the delay to those flights thereby reduced. However, the airline which cancels the flight may get less benefit than its competitors. Announcing the cancellation too early may also cause competitors to withdraw their intended cancellation to attract passengers from the cancelled flight. Thus, the airline may hold the slot and not inform control centers until it is too late to take advantage of the gap created by the cancellation [16]. As a result, the slot is wasted.

To address these problems, FAA implemented the Collaborative Decision Making (CDM) approach, beginning in 1998. CDM is an effort to improve GDP planning through "information exchange, procedural improvements, tool development, and common situational awareness" [17]. The process of GDP planning under CDM has six steps [16]. First, FAA estimates the arrival capacity. Once the delay is predicted to be severe, a GDP advisory is sent to airlines. Airlines may freely substitute flights among the slots they received via RBS. They transfer their response back to FAA. Finally, a compression program is performed to take advantage of any empty slots and a GDP is implemented if it is still necessary.

In 2003, a new mechanism named as slot credit substitution (SCS) was introduced into CDM [18]. Compared to the compression program, a batch-oriented periodic process, the SCS is a fast-response asynchronous process. The conditional language that airlines used to request slot adjustment in SCS is essentially: "we would like to cancel flight i if flight j can be advanced to slot k." SCS provides a near-real-time response to such request and rearranges the flight sequence if the cancellation is confirmed. The enhanced GDP via CDM yields large savings in flight delay by inducing airlines announce their modifications of the schedule much earlier than before [18, 19]. It also reduces the cost of delay by allowing airlines to allocate delay based on their internal business objectives. At the same time, however, airlines engaged in CDM require more sophisticated decision-support tools to take advantage of its flexibility.

3. NETWORK TRAFFIC ASSIGNMENT PROBLEM WITH NODE CAPACITY CONSTRAINT

By introducing ground transportation modes, the air transportation network is expanded to a network where some of the links are restricted by a node capacity and others are not (See Figure 1).

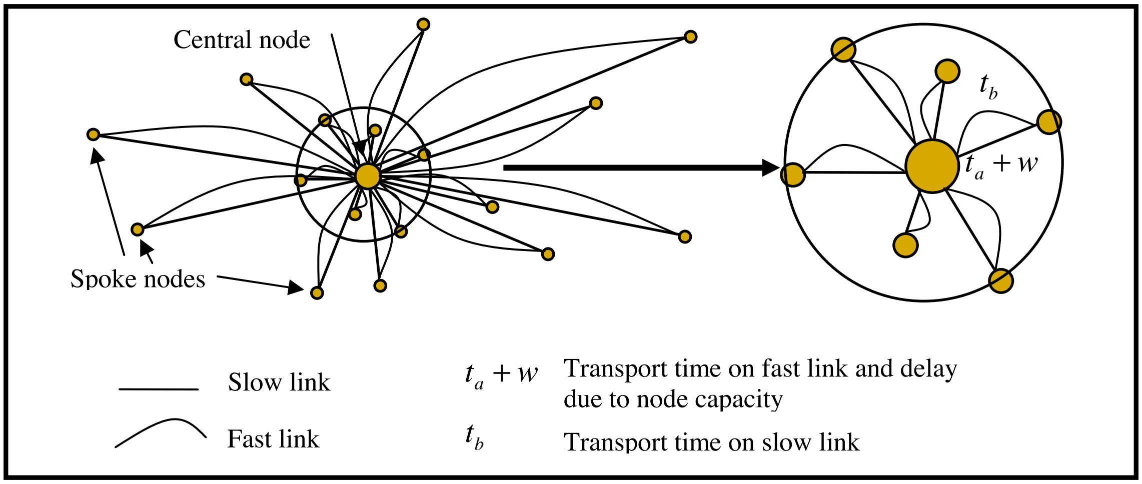

Figure 1 Network with Node Capacity Constraint

The potential benefit of substituting motor coaches for flights is illustrated in Figure 2. In the figure, the abscissa represents the time of the day, and the ordinate is the cumulative number of arrivals at one airport[1] [20]. The solid curve denotes the arrivals according to their scheduled time and the dashed line is the arrival curve restricted by capacity constraints. In the left part of the figure, flight *i* encounters delay t_i if there is no cancellation at all. Given the distance of the city pair that flight *i* serves, an extra time for transporting with a coach, is time t_i'. As shown, the extra transportation time t_i' is shorter than queuing delay t_i. Passengers save t_i-t_i' if they the coach service is provided. The net delay saving of canceling flight *i* to the whole sequence of arrivals is indicated by the shaded area. The benefit from subsituting ground transportation includes delay savings to other flights and delay saving for passengers on the cancelled flight. For flight *j*, in contrast, the extra time of traveling with a coach is longer than the queuing delay. In this sense, the passengers on the cancelled flight sacrifice their time for a net delay saving to subsequent flights.

The problem is to determine which flights to cancel or to be replaced by a ground transportation mode (motor coach service), in order to minimize the cost incurred from the transient capacity shortfall. We term this "the network traffic assignment problem with node capacity constraint". Costs in the objective function include airline operating cost, airline cancellation cost, flight delay cost, and contributions of passenger travel time cost and passenger delay cost to the airline's cost.

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[1] It is plotted as a continuous curve. Rigorously, cumulative curve is a step function since vehicles are indivisible. However, a smooth approximation of a given curve is employed generally for using differential calculus as a powerful method of analysis.

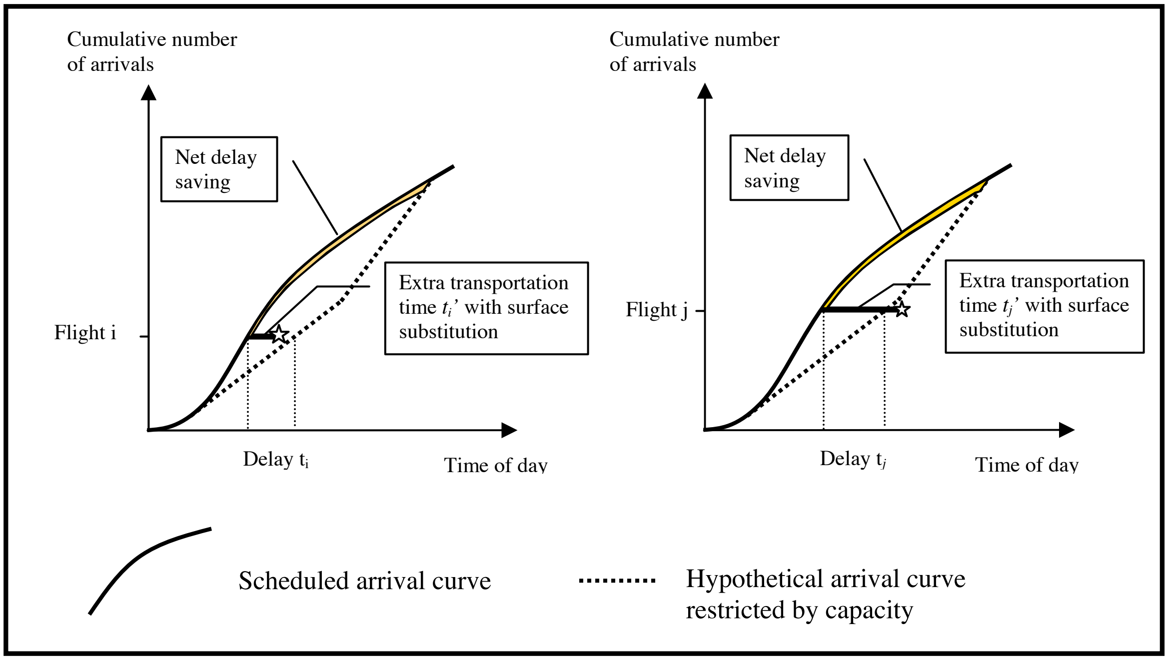

Figure 2 Potential Benefits of Substituting Flight with Surface Transportation

4. THE MATHEMATICAL MODEL

The mathematical model developed for this study is designed to highlight the featured aspects of introducing RTIMS into the airport congestion management, while avoiding an excessive level of detail features about airlines operation. The model is based on the following assumptions.

1. Discrete time periods. The time horizon, T, is fixed and subdivided into discrete, equal sized, contiguous time periods.
2. Deterministic capacity. The capacity available is known and not be updated with time.
3. Deterministic ground transportation time. Ground transportation times between the hub and spoke airports are known[2].
4. Full passenger reassignment. All passengers on a cancelled flight will either be reassigned to the motor coach service or to subsequent flights. If the latter, the resulting passenger delay is treated as a constant, independent of the schedule.

Assumption 1 is typical for traffic flow management and agrees with practice. Assumptions 2 and 3 put the model in the "deterministic" category. Assumption 4 simplifies the model, without greatly affecting the issues that are the focus of this paper.

Notation

Consider a set of flights $\Phi = \{1,...,F\}$ that are scheduled to the central node (hub airport) with scheduled arrival times denoted by SA_f. The time of day is divided into a finite set of time periods of equal duration, and is denoted by the set $\mathrm{K} = \{1,..,K\}$. For instance, K

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[2] They are estimated from historical data according to the time of the day, the weather condition, and road construction information.

might be a set of 480 time periods of 3 minutes each, summing to a planning horizon of 24 hours. Let t_f^a and t_f^b be transport times of flight f on fast link (airborne) and slow link (substituted ground transportation time for flight f), respectively. Both of these are assumed to be deterministic. The number of passengers on each flight is denoted by pax_f . In the initial time period the hub airport capacity drops from its good-weather value c_V to its poor weather value c_I . The capacity remains at the low value for time T_I. Let T_C represents the time when the capacity constrained arrival curve reaches the scheduled arrival curve for uncancelled flights. Evidentally, T_C depends on cancellation decisions. Let w_k denote the delay for flights scheduled to arrive during time period $k-1$ and k , and ω_f the delay for flight f . Finally, let D_k be the cumulative number of uncancelled flights scheduled to arrive through time period k .

Table 1 Notation

Sets	
$\Phi = \{..., f, ...\}$	Set of flights scheduled to arrive at or depart from the hub airport
$K = \{..., k, ...\}$	Set of discrete time periods for the optimization horizon
Inputs	
c_V	Full capacity at the hub airport
c_I	Shortfall capacity at the hub airport
SA_f	Scheduled arrival time of flight f
Pax_f	Number of passengers on flight f
AT_f	Airborne flight time of flight f
BT_f	Coach transportation time for OD pair served by flight f
DT_f	Market-specific average passenger waiting time if flight f is cancelled
$DelC_f$[3]	Delay cost of flight f per hour
$CanC_f$[4]	Cancellation cost of flight f

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[3] Flight delay cost per hour is half of hourly airborne operating cost. The airborne operation cost comes from Reference 21, \$912 per hour for an aircraft with 42 seats, and \$3864 per hour for an aircraft with 159 seats. Other values are gained with interpolation. Other references for setting up the numbers include Reference 22 and 23.

[4] Cancellation cost is \$4000 for a flight with 30 seats and \$10000 for a narrow body aircraft with about 120 seats. There is no literature explicitly giving out flight cancellation cost. Cancellation cost is complicated, depends on initial fleet assignment, crew assignment, etc. We assume that airlines are following strategies that provide short-cycles of fleet assignment and optimal crew assignment so that canceling one single flight will have the least effect on other flights. Michael Irrgang, in his presentation “American Airlines Cost of Diversion” [24], discussed cancellation costs in airlines irregular operation. The cancellation cost in his presentation includes many components (refer Reference 24 for more details). Nevertheless, because we are compared flights being flown and being cancelled, there are common components in both cases can always be deducted from constant revenue that airlines have already obtained by selling tickets. Hence, the cancellation cost used in this paper is much lower than cancellation cost in Irrgang’s slides.

$AopC_f$[5]	Aircraft operating cost per hour of flight f
$BopC_f$[6]	Ground transport cost per hour for a charter (or charters) substituting flight f
$PaxDelC$[7]	Passenger delay cost per hour
$PaxAC$[8]	Passenger time value per hour on flight
$PaxBC$[9]	Passenger time value per hour on flight
α[10]	Percentage of fixed cancellation cost in the total cancellation cost
β	a ratio, reflecting the contribution of passenger cost to the airline's disruption cost
Intermediate variables	
$\Delta_{(f,k)} = 1$ $= 0$	If flight scheduled to arrive at or depart from the hub airport during time period k Otherwise
D_k	Cumulative numbers of flights flying through time period k
w_k	Arrival delay for flights scheduled to arrive through time period k
ω_f	Arrival delay of flight f

Decision Variables

The decision variables in the model are binary variables and simply defined as follows:

$$x_f = \begin{cases} 1 \ \text{ if flight f is flown} \\ \\ 0 \ \text{ if flight f is cancelled.} \end{cases} \qquad f \in \Phi$$

$$y_f = \begin{cases} 1 \ \text{ if cancelled flight is substitued with ground transportation;} \\ \\ 0 \ \text{ otherwise} \end{cases} \qquad f \in \Phi$$

Objective Function

The objective function is to minimize airline's disruption cost with the following expression

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[5] Source: Reference 21.

[6] Coach rental is set as $100 per hour, according to conversation with charter service company.

[7] Source: Reference 21. Passenger delay cost is set as $30 per hour.

[8] Passenger time value on flights is set as $20 per hour.

[9] Passenger time value on coaches is set as $25 per hour.

[10] The percentage of the fixed cancellation cost is set as half of the total cancellation cost, standing for the cost not related to passengers.

$$\begin{aligned} Min \qquad & \sum_{f\in\Phi} x_f \left(\left(DelC_f + \beta \bullet PaxDelC \bullet Pax_f\right)\omega_f + \left(AopC_f + \beta \bullet PaxAC \bullet Pax_f\right)AT_f\right) \\ & + \sum_{f\in\Phi}\left(1-x_f\right)\begin{pmatrix} y_f\left(\alpha \bullet CanC_f + \left(\beta \bullet PaxBC \bullet Pax_f + BopC_f\right)BT_f\right) \\ + \left(1-y_f\right)\left(CanC_f + \beta \bullet PaxDelC \bullet Pax_f \bullet DT_f\right) \end{pmatrix} \end{aligned}$$

The first component of the objective function is the airline cost of flight f in the disruption, once it is completed on a fast link. It includes flight and passenger delay cost, aircraft operating cost and passenger airborne travel time cost. The second part is the cost if flight f is cancelled. If it is cancelled, there are two additional possibilities: either it is substituted with ground transportation or not. The substitution costs include passenger ground travel time cost, and coach operating cost. β is a ratio, reflecting the contribution of passenger cost to the airline's disruption cost.

Constraints

For a first come first serve system, flight delays caused by the node capacity constraint can be approximated by constructing a piece-wise linear function subject to flights original scheduled arrival times and their sequences in the system[11]. Using the continuous approximation, the delay during time period $k-1$ and k is expressed as the following formula.

$$\begin{aligned} w_k &= \min\left(\frac{D_k}{c_I} - t_k, \frac{D_k - c_I T_I}{c_V} - (t_k - T_I)\right) && 0 < t_k \le T_I \\ &= \max\left(0, \frac{D_k - c_I T_I}{c_V} - (t_k - T_I)\right) && t_k > TC \end{aligned}$$

where the cumulative number of uncancelled flights scheduled to arrive through time period k is defined by the following equation.

$$D_k = \sum_{f\in\{f|SA_f < t_k\}} x_i \qquad \forall k \in K$$

Thus, the flight delay is formulated as below.

$$\omega_f = \sum_{k\in K} \Delta_{(f,k)} w_k \qquad \forall f \in \Phi$$

5. NUMERICAL EXAMPLE FOR A FEEDER AIRLINE AND SENSITIVITY ANALYSIS

To demonstrate the proposed model, we apply it to an example and conduct sensitivity analysis with respect to coefficient β . The arrival schedule for San Francisco International Airport (SFO) on a typical day in 2004 is obtained from the Official Airline Guide (OAG). Based on that schedule, we construct a hypothetical short-haul airline (Airline S) serving all segments less than 500 miles. Airline S has 130 flights from 6:00am to 12:00am (18 hours). A severe capacity shortfall at SFO is assumed starting

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[11] This formulation is only suitable for the situation where the demand is keep on saturate for certain time periods but not the one where demand varies slightly around supply.

from 6:00am and ending at 10:00am. The capacity allocated to this feeder airline is two arrivals per hour in the shortfall period and eight arrivals per hour afterwards.

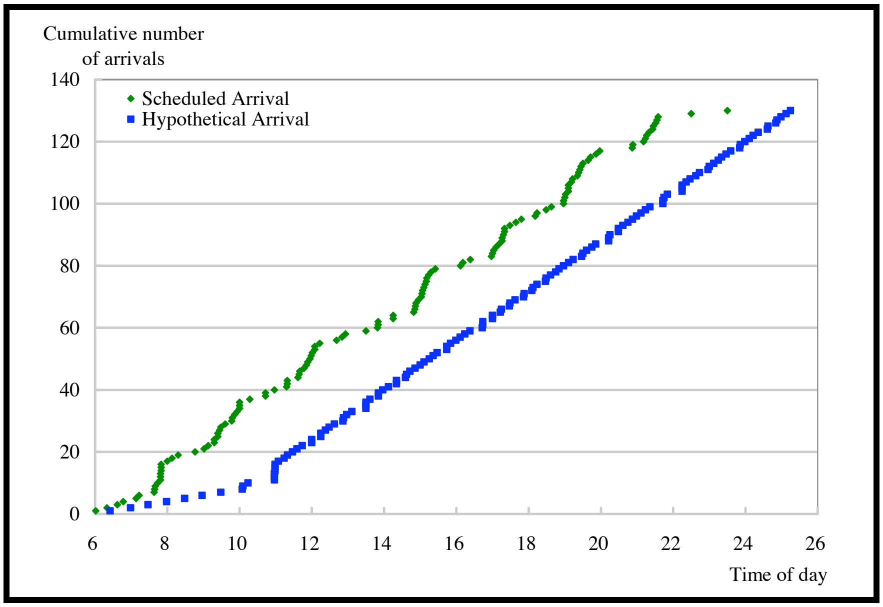

Figure 3 Scheduled and Hypothetical Cumulative Arrivals without Cancellation

Figure 3 depicts the cumulative scheduled arrival curve and capacity-constrained arrival curve assuming no cancellations. The horizontal distance between these two curves is the flight delay resulting from the capacity reduction, and ranges up to four hours.

Binary integer programming is coded in AMPL and MINLP is used to solve this non-linear integer optimization problem for two scenarios, one with RTIMS, and the other without. Costs in these two scenarios are compared with the cost if there is no cancellation at all. Table 2 presents the comparison results for two cases, where β equals to 0.1 and 0.4.

Table 2 Comparison of Different Strategies

	β=0.1			β=0.4		
	w/o cancel	Cancel w/o IMS	Cancel w/ IMS	w/o cancel	Cancel w/o IMS	Cancel w/ IMS
Total cost ($)	696788	371758	318404	1151944	539229	493480
Cancellation		22	26		23	24
Substitution			26			22

Results show that with RTIMS, slightly more flights will be cancelled; however, the airline can reduce its disruption cost significantly. Compared to the cost with no cancellation, the cost with RTIMS is more than 50 percent less. Compared to cancellations without IMS, the use of IMS results in cost savings of 14 percent and eight percent, respectively, for β equal to 0.1 and 0.4. Figure 4 shows the costs for the three cases for a range of assumed β values. The costs without cancellation linearly increase with β. The cost differences between cancellation with RTIMS and without are from eight percent to 15 percent. The largest difference occurs when β equals 0.3.

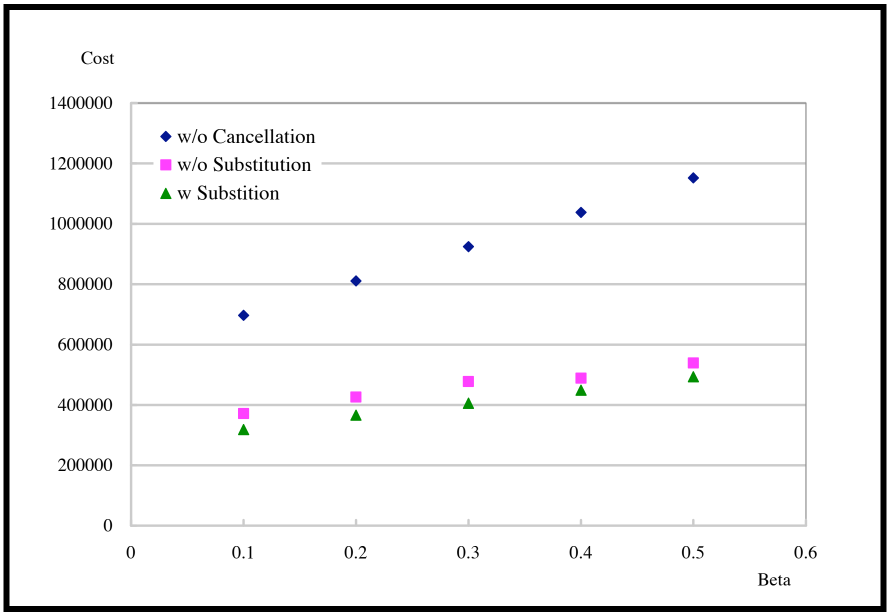

Figure 4 Comparisons of Costs with Different Strategies

6. REAL-TIME INTER-MODAL WITH ALTERNATIVE HUB AIRPORTS

In above sections, airlines make decisions of cancellation and/or substitution according to capacity forecast one day early assuming that the hub airport has been cleared and there is no flights in the air. It is possible that decisions have to be made when there are airborne arrivals that have departed before the capacity reduction or closure is predicted. What airlines usually do is to slow the flights if the duration of low or no capacity is predicted as short or diverge the arrivals to nearby airports. Since there is no preparation for diversion, flights can only be dumped at alternative airports where the fuel consumptions of the extra flying distances do not exceed the fuel reservation. Flights keep on the ground afterwards until clearance is received from Air Traffic Control after the hub has opened up again. Michael Irrgang gives out the delay estimations of flight diversion in normal cases and the cases with "Dump Plan"[12]. Combine those estimations, the total time factor of diversion in the above case will include the following components and last 85 minutes -- 2 hours plus hub closure time.

- 10 - 20 minutes extra flying time to deviate from flight path to land at alternate
- Hub closure time, (30-75minutes refuel at alternate is included in this time)
- 30-60 minutes: Wait for new departure clearance to original destination.
- 45minutes: Fly to original destination

Nevertheless, the demand at the hub airport is not reduced due to the diversions because after capacity recovery, the diverted flights continue flying from the alternative destination airports back to the hub airport. This will push later demand further in the day

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[12] Dump plan is a strategy to preplan the flight diversions by selecting alternative airports and fueling appropriately so that flights do not hold in the vicinity of the affected airport but fly directly to the alternative airports following ATC instruction. Please refer reference 25 for more details.

and cause enormous delays. Applying the inter-modal substitution strategy, the hypothetical arrival curve has to be shift to further right reflecting the consumption of hub capacity for diverted flights. More delay is observed and more cancellation will be executed to achieve minimum disruption cost. The situation gets more severe if the capacity of hub airports are affected for longer duration or the capacity reduction or airport closure happens in the early of the day.

A new strategy to handle this problem is to extend the real-time inter-modal substitution concept by selecting alternative hubs from nearby spoke airports and expand ground transportation links between the alternative hubs with other spoke airports. The selecting criteria of alternative hub airports are as following. First, there should be no capacity reduction due to the same reason as what happens at the hub airport. Second, the airports have to be within reasonable driving distance from the hub for implementing ground transportation modes. Third, flow patterns of the hub airport should be taken into consideration to achieve geographic balance so as to save flying time for diverted flights. Third, if possible, select airports so that the combined excess capacity could be sufficient for handling dumped flights.

After following the above criteria, a network with alternative hubs is depicted in Figure 5. Flights with hub as their initial destination are dumped to the alternative hubs. Solid lines represent flights from spoke airports to the alternative hub airports. Dotted lines stand for ground transportation. Transfer passengers travel between different alternative hubs to catch their connecting flights. Ground transportation links are also established between alternative hubs and nearby spoke airports to reduce the total demand at alternative hubs. Hence, the total arrival demands at alternative hub airports are less than the initial demand at hub airports. The reduction magnitude will be close to the percentage of flights between the hub and those ground linked spoke airports.

It is easy to know (without any further calculation) that the longest passenger delay in this case is the longest ground transportation time in the center of the network or airport closure duration. Compare the number of affected flights: with alternative hubs, the number of affected flights is at most the arrivals who supposed to land during airport closure duration minus the arrivals from spoke hubs within the central network during the same duration; without alternative hubs, the number of affected flights is much higher, especially for the case when airport closure happens in the early of the day. Strategy with alternative hubs reduces flight cancellation and recoveries airline operation back to regular schedule right after the duration of airport closure.

Major concern of floating hub concept is the high capital investment for ground facilities and labors [15]. The runway characteristics at nearby spoke airports are critical for its ability to become a floating or alternative hub. Nevertheless, the demand at alternative hubs is reduced because of the inter-modal substitution. Ground connections spare gates and other terminal facilities which can be used to accommodate diverted flights and passengers as well. Passengers with alternative hubs as their destinations benefit the most from this strategy. The time saving is at least the connecting time plus flying time from hub to the alternative hub, which can be up to 3 hours. Furthermore, labor shortage at alternative hubs can be solved by transferring station crews from the hub airport to alternative hubs during hub closure via ground transportation.

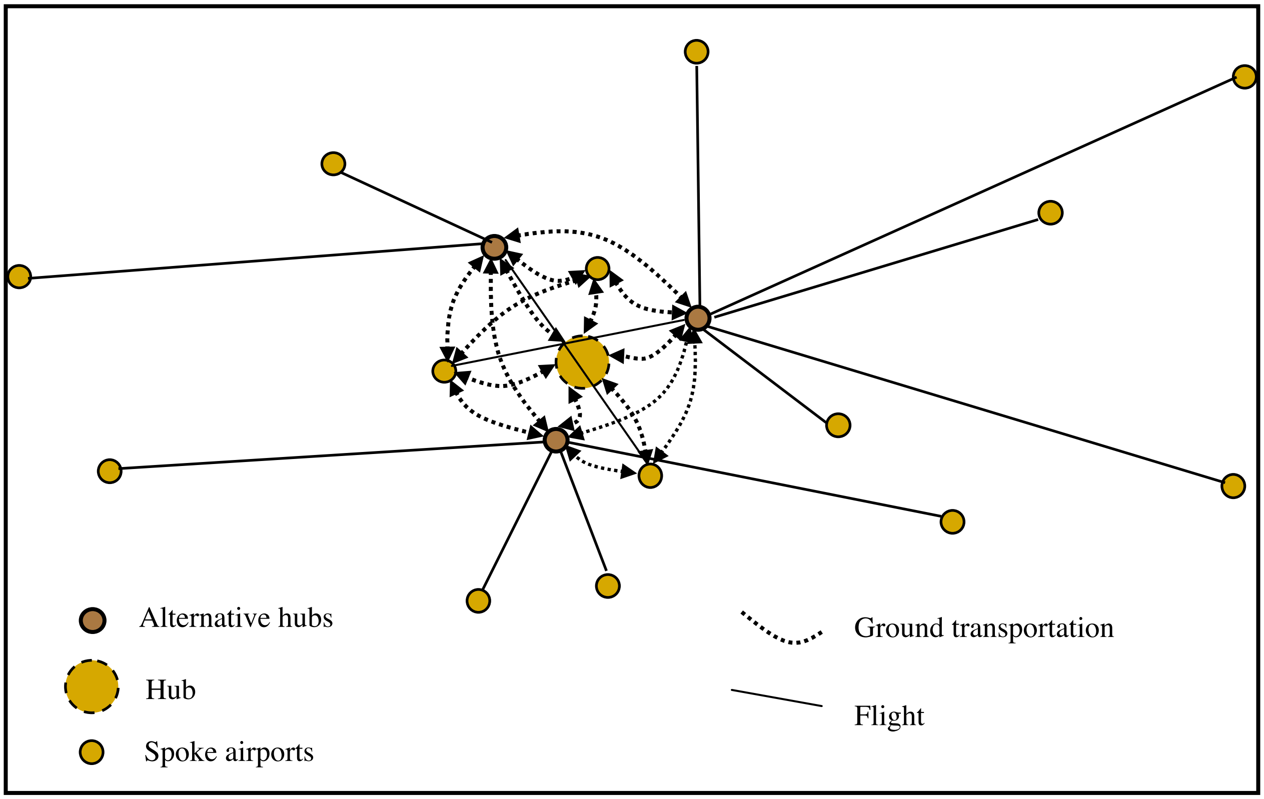

Figure 5 Network for Real-Time Inter-Modal Substitution and Alternative Hubs

7. SUMMARY AND DISCUSSIONS

In this study, we proposed an optimization model to determine flight cancellations and inter-modal substitutions in the case when a hub airport encounters a relatively severe capacity shortfall. The model takes into account the net delay saving of canceling one particular flight to other flights in the schedule. Results show that real-time inter-modal substitution (RTIMS) can save about eight percent to 14 percent of the disruption cost compared to the model without RTIMS. Subsequently, operational concept of expanded RTIMS with alternative hubs is briefly described.

RTIMS is potentially a useful strategy to alleviate the terminal congestions in the U.S. There are several issues that need further consideration. First, variability and uncertainty of the ground transportation times is a potentially important issue. Second, a more complete model of passenger re-accommodation on subsequent flights is required. Third, the potential to combine RTIMS with flight re-ordering should be considered. Third, operational issues of the expanded RTIMS need to be resolved before compared the two schemes on a real-world case. The use of RTIMS is a promising topic for future research to alleviate airlines disruption cost, reduce passenger delay, and improve NAS performance.

REFERENCES

1. Muller, Gerhardt (1999), “Intermodal Freight Transportation”, 4th Edition. Transportation Foundation and Intermodal Association of North America, Washington D.C., 1999, pp. 1.
2. Goetz, A. R., and Vowles, T. M., “Progress in Intermodal Passenger Transportation: Private Sector Initiatives”, accessed on April 29, 2006, http://www.ie.msstate.edu/ncit/RESEARCH.html
3. Barnhart, C., and Bratu, S., (2004), “Airline Passenger Delays”, Sloan Industry Centers Annual Conference, April 19-21, 2004 Atlanta, GA.
4. Knorr, D., “Factors which affect the NAS on-time percentage”, INFORMS, WB 18, San Francisco, November 13-16 2005.
5. Hansen, M.M., and Zhang, Y., “Operational Consequences of Alternative Airport Demand Management Policies: Case of LaGuardia Airport in New York”, Transportation Research Record 1915, pp. 95-104, 2005, Washington D.C.
6. Zywiec, R., “Flying Scared on 9/11”, accessed on April 29, 2006, http://angelingo.usc.edu/issue03/places/a_flying.php,
7. National Center for Intermodal Transportation. “A New Agenda for America: in the Aftermath of 11 September 2001”. November 2001.
8. Teodorovic, D., and Guberinic, S., (1984), “Optimal Dispatching Strategy on an Airline Network after a Schedule Perturbation”, Europe Journal of Operational Research, Vol. 15, pp178-182,1984,
9. Teodorovic, D., and Stojkovic, G., (1990), “Model for Operational Daily Airline Scheduling”, Transportation Planning and Technology, Vol. 14, pp273-285,1990,
10. Jarrah, A. et al. (1993). “A Decision Support Framework for Airline Flight Cancellation and Delays”, Transportation Science Vol. 27, No. 3, pp266-280, 1993,
11. Yan, S., and Yang, D.-H., (1996), “A Decision Support Framework for Handling Schedule Perturbation”, Transportation Research, Part B, Vol. 30, No. 6, pp405-419, 1996,
12. Cao, J.-M., and Kanafani, A., (1997a), “Real-Time Decision Support for Integration of Airline Flight Cancellation and Delays Part I: Mathematical Formulation”, Transportation Planning and Technology, Vol. 20, pp183-199, 1997.
13. Cao, J.-M., and Kanafani, A., (1997b). “Real-Time Decision Support for Integration of Airline Flight Cancellation and Delays, Part II: Algorithm and Computational Experiments”, Transportation Planning and Technology, Vol. 20, pp201-217,1997
14. NBAA Press Releases, 2005. “NBAA Strongly Supports Funding of Minneapolis Reliever Airports”, http://web.nbaa.org/public/news/pr/2003/20030515-026.php, accessed on January 27,2005
15. Meyer, E. et al. (1997), “Evaluating the Feasibility of Reliever and Floating Hub Concepts when a Primary Airline Hub Experiences Excessive Delays”, Research Report SWUTC/96/467503, Southwest Region University Transportation Center, Center for Transportation Research, The University of Texas at Austin, August 1997
16. de Neufville R., and Odoni, Amedeo, (2003), “Airport Systems: planning, design, and management”, McGraw-Hill Company, Inc., 2003
17. Ball, M., Hoffman R., Knorr, D., Wetherly, J., and Wambsganns, M. (2000), “Assessing the Benefits of Collaborative Decision Making in Air Traffic

Management", Third USA/Europe Air Traffic Management R&D Seminar, Naples, Italy. June 13-16. 2000

18. Ball, Michael O., Hoffman, R., Lovell, David J., and Mukherjee, Avijit, (2005), "Response Mechanisms for Dynamic Air Traffic Flow Management", 6th USA/Europe Air Traffic Management Research and Development Seminar, Baltimore, MD, June 27-30, 2005.
19. Ball, M., Hall, W., Hoffman, R., and Rifkin, R. 1998. "Collaborative Decision Making in Air Traffic Management: a preliminary assessment", National Center of Excellence in Aviation Operations Research (NEXTOR), University of Maryland, College Park, MD.
20. Carlos F. Daganzo, Fundamentals of Transportation and Traffic Operations, Amsterdam ; New York : Pergamon, c1997.
21. APO, "Economic Values for Evaluation of FAA Investment and Regulatory Programs-Updated Executive Summary April 2002", Economic Information for Investment Analysis: Data Package, ASD, System Architecture and Investment Analysis, April 4, 2003
22. Barnett, A., Shumsky, R., Hansen, M.M., Odoni, A., and Gosling, G., "Safe at Home? An Experiment in Domestic Airline Security", Operations Research, Vol. 49, No. 2, Mar.-Apr. 2001, pp. 181-195.
23. Hansen, M.M., Gillen, D., and Djafarian-Tehrani, R., "Aviation Infrastructure Performance and Airline Cost: a Statistical Cost Estimation Approach", Transportation Research Part E, Vol. 37, 2001, pp. 1-23.
24. Michael Irrgang, American Airlines Cost of Diversion, American Airlines and Flight Dynamics Inc. Feb-May 1992.
25. Michael Irrgang, Airline Irregular Operations, the Handbook of Airline Economics, Aviation Week Group, 1995.