# Air Transportation and Multimodal, Collaborative Decision Making during Adverse Events

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**Abstract**

This paper makes the case for multimodal Collaborative Decision Making (CDM) during adverse events. Two case studies, the Asiana Crash in the US, and an hypothetical closure of London Heathrow airport in Europe, demonstrate that multimodal alternatives to reaccommodate passengers impacted by diversions and cancellations, have the potential to significantly decrease passenger delay at effective costs. Based upon additional evidence and interviews conducted a preliminary study sponsored by the EU, a multimodal CDM concept is elaborated, defining milestones and information flows to support harmonized decision-making and passenger treatment, and ensure a faster recovery process from a passenger standpoint.


## I. Introduction

In 2012, 2.9 billion passengers boarded an airplane, whether for business or leisure, across the world [1], and the demand is predicted to keep increasing. In its vision for Europe in 2050, the European Commission [2] sets the goals: 90% of travelers within Europe are able to complete their journey, door-to-door, within 4 hours. Passengers and freight are able to transfer seamlessly between transport modes to reach the final destination smoothly, predictably and on-time. Transportation modes are usually studied separately as if not interacting, although they are intrinsically coupled through passenger transfers. The failure of one mode disrupts the entire passenger journey. Over the past few years, many disruptions, such as snow storms and volcano eruptions, have highlighted the rigid structure of transport infrastructures and the potential for perturbations to snowball across multimodal infrastructures. Such perturbations stress the importance of putting the passenger at the core of the system [2] [3] [4]. There has been extensive research on disturbance propagation in the airspace [5] [6] [7] [8], the impact of airline scheduling of aircraft and crew [9] and the best recovery optimization schemes [10] [11]. Recently, a shift toward passenger-centric metrics in air transportation, as opposed to flight-centric, has been promoted, highlighting the disproportionate impact of airside disruptions on passenger door-to-door journeys [12] [13] [14] [15]. Disrupted passengers, whose journey was interrupted, only account for 3% of the total passengers, but suffer 39% of the total passenger delay. Zhang [16] developed a framework to reduce passenger "disutility" due to delay and missed connections, and to utilize and distribute scarce resources more efficiently and equitably. Real-time intermodality includes the substitution of flights by surface vehicle trips and, when the hub is part of a regional airport system, the use of inter-airport ground transport to enable diversion of flights to alternate hubs. The Collaborative Decision Making Approach is led by Eurocontrol, the Federal Aviation Administration, the European Organisation for Civil Aviation Equipment and the Civil Air Navigation Services Organisation. CDM provides a transparent program to efficiently share data between airport operators, airlines, ground handlers, air traffic control and air traffic management. The objectives are to increase predictability and improve decision making [17]. In Europe, more than ten airports have obtained the A-CDM label. In the US, Surface CDM is centred on the data integration and sharing between stakeholders and systems. Examples include the JFK Ground Management Program, the Collaborative Reroute Process from United Airlines, the ATL Surface Management System. Through several examples, both in the US and in Europe, this paper aims at making the case for Multimodal Collaborative Decision Making and its potential for improving crisis management during adverse events, particularly from a passenger-centric point of view. Section II provides examples and case studies highlighting the need for Multimodal CDM. Section III presents the MetaCDM concept and develops future recommendations. Section IV draws the conclusions of the paper.

## II. Evidence of the need for and opportunities afforded by Multimodal Collaborative Decision Making

### A. Anecdotal Evidence

For Europe, a summary of all major disruptive events is included in the Eurocontrol Network Operations Reports (NOR) [18] and the CODA delay digest [19]. These reports review network activities and disruptive events across Europe by month and by season. The most common disruptive events noted in the NOR are weather, strikes, and disruptions caused by the implementation of new infrastructure. Other disruptive events include accidents, security alerts or attacks, IT systems failures, measures to prevent the spread of infectious diseases, and infrastructure upgrades. Their impacts can vary significantly, e.g. closure of airspace or airports, absent staff or significantly increased process times. Some specific examples from the past few years in the US and in Europe include : snow storms paralyzing flights in Western Europe (December 2010); volcanic ash clouds grounding a vast portion of European traffic for a week (April 2010); a crash at Amsterdam Schipol (February 2009); a radar failure at Athens Airport (September 2012); strikes affecting French airports (April 2012); Hurricane Sandy leading to airport closures all over the East Coast of the United States (October 2012); lightning strike at Baltimore-Washington airport (September 2013); airline reservation system outages (Sabre in August 2013, Amadeus in July 2012); a crash at San Francisco airport (July 2013); a fire evacuation and two-weeks closure of the Chicago En Route Center (ZAU) (September 2014) ; flight data system failure at Swanwick air traffic control center (December 2014). These events were exacerbated by the rigidity and complex nature of transport networks, as well as by the lack of appropriate preparation. During such disruptive events, system-wide ripple effects prevented the use of the air transportation systems for several hours, and subsequent delays prevented passengers from reaching their destinations at least on the same day, even though multimodal passenger routing offer viable alternatives to minimize passenger disruptions.

### B. Research and interviews highlighting the need for Multimodal CDM

As part of the MetaCDM project, our team investigated how information sharing, CDM and multimodality can improve passenger experience during disruptive events [20]. The most comprehensive set of recommendations for airports dealing with disruption is made by the Airport Cooperative Research Program [21]. This report discusses in a US context how airports can best develop, evaluate and update contingency plans for the occurrence of irregular operations (IROPS) as a result of disruptive events. Four types of IROPS impact situations are identified: surge, in which extra aircraft and passengers flow into an airport; capacity, in which the airport terminal becomes full of passengers or ramp space/gates become full of aircraft; after-hours, in which aircraft land and passengers need to deplane at hours when facilities are not functional; and extended stay, in which passengers and aircraft may be immobilized at the airport for an extended period of time. Bolic et al. [22] offer recommendations to better address such large disruptions, stressing the need for better information exchanges between all the stakeholders with, for instance, a central repository of all information related to a given crisis.

The UK Civil Aviation Authority (CAA) [23] conducted an online survey of passengers to assess how passenger welfare could be improved during disruption, in the context of the severe snow perturbation in the UK in 2010. Considerable room for improvement was found; 74% of respondents were dissatisfied with the quality of information they were given, 75% were not informed of their rights, and 60% received no care or assistance from their airline. The accessibility of passenger information was highlighted as a particular problem. Facing inadequate information about whether their flight was operating, many passengers chose to travel to the airport in search of better information; and, once there, many passengers were reluctant to leave for similar reasons. The need for clarity on information about what costs incurred by passengers would be reimbursed by airlines (e.g. hotels, food or onward journeys) was noted. As the aviation system grows, more airports will be operating close to capacity, leading to decreased ability to recover from or mitigate disruption. However, progress on technologies will likely facilitate earlier warnings of disruptive events, better recovery from disruption, increased safety and increased systems robustness. SITA [24] reports that improving passenger experience is the number one driver of Information Technology investment by the majority (59%) of the world's airports. A rapid increase in mobile and social media apps is expected to deliver a more personalized customer experience, such as keeping passengers informed about flight status and wait times. 88% of airports plan to invest in mobile apps by the end of 2015.

Stakeholders also felt that there is not enough information available at a network level, given that disruption at one airport may have impacts at many others. One key example is during the severe winter weather which affected many Northern European airports in December 2010. During this period, CDG was operating close to maximum capacity. CDG was not aware of the closure of Heathrow until shortly beforehand and had to accommodate long-haul flights bound for Heathrow at short notice. Subsequently, CDG also had to close due to a lack of deicing fluids for passenger aircraft. As an airport with an A380-capable runway, Toulouse Blagnac had to accept long-haul flights bound for CDG at very short notice. Although Toulouse Airport was unaffected by snow, it suffered severe disruption because of the large numbers of stranded passengers from the diverted flights and a lack of aircraft parking space. Improving information sharing on a network level is therefore a desirable goal.

### C. Existing stakeholders initiatives

At all airports, contingency planning and risk management are ongoing activities, involving many stakeholders, and, particularly at large airports, plans are subject to regular review. Major airports typically have dedicated crisis centres, recovery plans and a coordinated multi-stakeholder response to crisis events. Airlines may have their own crisis cells in close collaboration with those at the airport, and their own equipment and procedures for dealing with stranded passengers (e.g. camp beds, and arrangements with hotel and bus companies for transport to overnight accommodation). At the highest level, governments will also have oversight of airports classified as national assets, with monitoring meetings between government, airports, civil aviation authorities and other bodies such as Air Navigation Service Providers (ANSPs). One point of confusion is the potentially large number of agencies who may be involved in crisis response at larger airports, meaning that sometimes responsibilities and lines of command are not clear. Revisions may also be made based on lessons learned after disruptive events. Following the December 2010 Winter season, Heathrow adopted a three-tier Bronze, Silver, Gold framework as used by emergency services, representing operational control, tactical command and strategic command to be activated sequentially depending on the severity of the incident. Contingency planning distinguishes between predictable and unpredictable crisis irregularities. A longer notice period means an event is typically easier to deal with. For example, schemes such as Frankfurt Airports Terminal Colour Concept to redirect passengers in terminals require a days notice to set up. One example of a longer notice period here is the role of Heathrow for the 2012 London Olympics, in which significant extra traffic was handled without extra disruption due to the long planning time and extensive training exercises.

Currently, CDM does not strongly interact with crisis management. CDM processes are typically not used in a crisis situation and airports switch to face-to-face and/or phone communication for the majority of interactions. At Paris Charles de Gaulle (CDG) airport, there is a dedicated crisis room where stakeholders may be gathered in the event of a crisis to ensure common situational awareness and improved decision processes. Generally, the focus on face-to-face information means that communication in crisis situations can be delayed, particularly to bodies outside the immediate crisis response cell. Similarly, external information is mainly collected via phone calls to different stakeholders. Thus, passengers may not have access information about the situation because it is simply not available.

Multimodality is slowly becoming a reality, at least within the European transportation system. The principal difficulty is not whether it should be done or not - it is widely admitted that flights lasting less than one hour could be advantageously replaced by ground transportation, such as rail. Indeed, finding an economically viable path towards fully integrated multimodal transportation will require leveraging today's resources and investing the profits in system improvement until satisfaction is reached. Such a plan may last several years or decades to be executed and would be highly sensitive to political noise. However, industry today offers interesting leads towards an acceptable implementation plan. Some European airlines already offer origin-destination fares that are using rail transportation for some or all of the passenger journey. Even though the databases and schedules are shared, there is no common optimization between the rail and the airside. Even if there is a TGV station at CDG, passengers have to find their luggage and take it to the train, and the train may not be departing from the train station inside CDG.

### D. Impact of the Asiana Crash and Passenger Multimodal reaccommodation via Bus services

On the US side, our case study focuses on the impact of the Asiana Crash and, in hindsight, how the multimodal reaccommodation of diverted passengers via bus services could have greatly improved their overall journeys. Because the crash happened on a clear weather day, the causality of events is easily assessed.

San Francisco International airport (SFO) is the seventh busiest airport in the United States, with 45 million passengers per year. On July 6th, 2013, the weather was good. At 11:28 a.m, Asiana Airlines Flight 214 crashed just short of runway 28L's threshold. Of the 307 people aboard, 3 died, 181 others were injured. All of the runways were closed for five hours. At 3:30 p.m., the two runways perpendicular to 28L reopened; runway 10L/28R remained closed for more than 24 hours. The accident runway reopened on July 12.

Even after the airport reopened, its capacity was reduced significantly. The crash led to cancellations, diversions and delays at SFO, and impacted the rest of the airspace with ripple effects. This work uses data from the Bureau of Transportation Statistics (BTS) and ETMS data. Over four days, more than 1,200 flights scheduled to depart or arrive at SFO had either been canceled or diverted. On the crash day, cancellations due to the Asiana crash account for more than 85% of all cancellations in the airspace, more than 50% on Sunday and more than 25% on Monday and Tuesday. Over the four days, the Asiana crash led to more than 49% of all cancellations in the US.Diversions, which are tactical operations, mostly occurred on Saturday and on Sunday. 74 domestic arrival flights, i.e. 17% of arrival flights to SFO, and 25 international flights were diverted on Saturday. This corresponds to 9,900 diverted passengers on Saturday, 4,200 on Sunday and 1,400 on Monday and Tuesday. According to the BTS, 0.2% of domestic flights were diverted over year 2013, a steady number since 2004. The major carrier flights were diverted to a number of airports. The other Bay Area airports, Oakland (OAK) and San Jose (SJC) accommodated most flights. Several other airports, as far as Denver (DEN), Los Angeles (LAX) and Las Vegas (LAS), received many diverted flights on the crash day. International flights headed to SFO were diverted to Vancouver (YVR), Seattle (SEA), LAX, LAS, OAK and SJC.

Most stakeholders have access to a partial view of the crisis situation and, in most cases, for only one mode of transport. Following the Asiana crash, if the main stakeholders had had access to real-time data feeds of reliable traffic data via collaborative decision making, the recovery process could have been improved. Our work therefore focuses on optimization of aircraft operations and diverted passenger reaccommodation. At the present stage, only hypotheses can be drawn when it comes to how diverted passengers who landed sometimes several hundred miles from their destination airport actually travelled there. Social Media, such as Twitter, provides pieces of information suggesting that the treatment of passengers and the crisis management varied greatly from airport to airport and airline to airline. Some airlines had not support in the airport where some of their flights were diverted. Depending on the diverted airport, some airlines offered shuttles or buses to transfer passengers to San Francisco, others were asking passengers to wait for rebooking which could take days, some offered hotel accommodation in the meantime. The crash occurred during a holiday week-end, therefore flights were already heavily booked on Sunday, which made it difficult to reaccommodate passengers on later flights.

For this case study, we propose a multimodal reaccommodation scheme [25] that takes advantage of ground transportation (bus services) to reaccommodate diverted passengers. The passenger reaccommodation model proposed aims at assessing the possibility of multimodal substitution as a valuable rerouting option in helping recover from diversions. The optimization problem is defined over pairs of airports: one diverted airport and SFO. It is adaptable to any airport that welcomed several diverted flights initially scheduled to SFO. The objective of the mathematical model is to minimize the cost of reaccommodation of diverted passengers. The input is the actual schedule on July 6th, 2013 (e.g. which flights were diverted or cancelled and which ones could reach SFO), and the model computes the cost-effective rerouting back to SFO. The reaccommodation accounts for the following costs: passengers delay cost while remaining at the diverted airport, the cost of squeezing passengers into remaining seats on flights to the Bay Area, the cost of providing an aircraft to ferry back diverted passengers, the cost of transporting passengers with motor-coaches, either from the diverted airport, or just within the Bay Area. At the end of the chosen time horizon, no diverted passengers must remain in the airport. Consider the reaccomodation of the diverted passengers who landed at McCarran International Airport (LAS). LAS is located more than 550 miles from SFO and absorbed 10% of the diverted flights carrying 572 passengers on July 6. LAS is the 9th busiest airport in the US in terms of passenger movements, and has a high frequency of flights to SFO. The airlines operating at LAS also offer flights to SJC and OAK. On July 6th, there were 9 maintained flights to SFO, 7 to OAK, and 6 to SJC. Let us compare our multimodal passenger reaccommodation scheme with a classic reaccommodation of passengers on remaining seats of later flights. Under hypothesis A, the best case scenario, diverted passengers are reaccommodated in the first seat available on any flight to a Bay Area airport, regardless of the carrier. Under Hypothesis B, a more realistic case scenario, diverted passengers are reaccommodated in the first seat available on any flight to a Bay Area airport operated by their original carrier. Figure 1 shows the cumulative rerouting of diverted passengers in the optimal multimodal rerouting configuration, against a passenger rerouting under hypothesis A. The multimodal rerouting corresponds to a scenario in which airlines have 16 buses and 2 aircraft available (which would probably among the diverted flights aircraft), and 150 passengers fly on remaining seats in later flights. The multimodal scheme would enable passengers to be rerouted within the

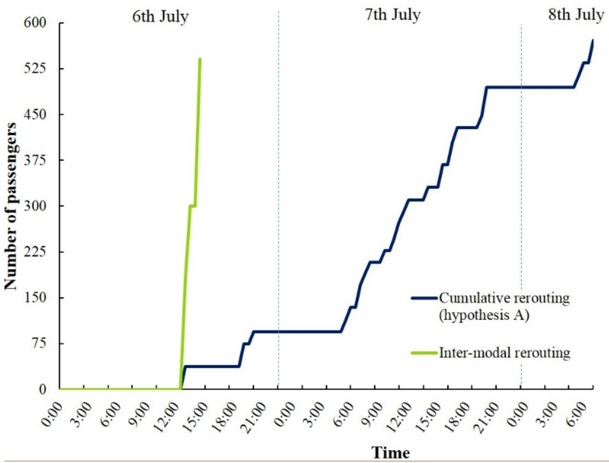


Fig. 1: Comparison of multimodal reaccommodation with reacommodation of passengers on later flights, regardless of their airline.

same day, whilst under Hypothesis A, although it is a best case scenario, some passengers would have to wait more than two days to reach the Bay Area. If we had taken into account the cost of hotels and meals born by the carriers, the cost effectiveness of the multimodal scheme would have been even more striking. Performing the same analysis under hypothesis B, the delays perceived by passengers are greater. All other airlines passengers would have waited until at least Monday July 8th to reach the Bay Area. This case study shows that multimodal reaccommodation provides a cost-effective rerouting for all passengers, and enables them to be reaccommodated on the day of the diversion.

### *E. Hypothetical Closure of London Heathrow Airport and Multimodal reaccomodation via bus and rail alternatives*

Analysis in Marzuoli et al. [26] shows that the concept of providing ground transportation options to stranded passengers is feasible in terms of journey times and available ground transportation services. For passenger journeys between the top 50 airports in Europe by passenger traffic in 2012 [27], 85% have the alternative of a city-city rail connection, 96% have the alternative of city-city road/ferry connections, and all have a feasible ground transport route to another airport. The number of stranded passengers for whom taking a ground transportation option would be faster than waiting for the next non-cancelled flight depends on how long the anticipated wait is. Using data on air schedules and air, rail and road journey times from OAG [28], ETISplus [29] and online journey planners (e.g. Deutsche Bahn [30]; TravelMath [31]; MapQuest [32]), around 50% of passengers on these routes could arrive at their destination sooner by taking ground transportation if a 10-hour wait time is anticipated. This rises to 70% for a 15-hour wait time [26]. However, there are a number of further considerations which must be addressed to prove that the concept is feasible. Passenger preferences and confidence with ground transport options may affect which passengers are interested in these choices. The solution also requires computer or smartphone use with internet connectivity, and so may be subject to battery life and/or data roaming constraints. Onward passenger connections, visa requirements for ground transport through an en-route countries, baggage transport and legal liability issues may also cause problems. From an airline perspective, one key hurdle is the cost involved. Realistically, the proposed solution has to provide benefits to both airlines and passengers to achieve adoption. For airlines, a feasible concept should also include a reduction in the cost burden associated with re-accommodating stranded passengers.

To test this, we use year-2012 data for the set of 50 European airports described above to simulate a hypothetical disruptive event, and optimise for airline costs. We will concentrate on outbound passengers from London Heathrow under an hypothetical disruption lasting between 30 minutes and 4 hours. The simulated event occurs on a midweek day at 8 a.m. During the disrupted period, all flights are cancelled; afterwards, normal operation is resumed. For simplicity, we do not model delays to non-cancelled services (e.g. from aircraft being out of place). Hard and soft costs associated with passenger delays are taken from Cook et al. [33]. Air ticket costs for legacy and low-cost carriers are taken from European modelling in the AIM aviation systems model [34], and rail ticket costs from the ETISplus database [29]. For road transportation, we follow Zhang and Hansen [16] in assuming airlines will provide coach service. Coach costs for coach size categories from 8-49 seats are modeled as a linear function of road journey time, using a survey of available quotes for coach hire between representative airports in the 50-airport set. To model the stock of available seats for each mode and the times available, information on schedules and seats available is also needed for ground transportation. Typical rail capacity and load factors are taken from Andersson et al. [35], and an even distribution of rail services throughout the day, excluding the 1am-5am period, is assumed. The total capacity of coaches to take passengers will depend on the stock of coaches that are available for short-notice hire in the local region. For Europe, data is available on the total stock of coaches by region [36]. However, the vast majority of these coaches will be in use or not available for hire. We assume as a baseline that 2% of coaches will be available; for the results shown here, this limit is never met. A four-hour time buffer for these coaches to be available at the airport is assumed [16]. Similarly, a time buffer of 1.5 hours is assumed for passengers to begin rail journeys, and a 2-hour time buffer for passengers using ground transport to alternative airports between ground transport arrival and takeoff.

The goal is to minimise the total cost to all airlines of passenger delay of the disruption. The objective function is defined as the sum of airline costs across all cancelled flights. Airline costs consist of six terms. These are the cost of reimbursing passengers who choose not to fly or be returned to their point of origin, i.e., the average fare paid for the cancelled flight, and the cost associated with five possible options for re-accommodating the disrupted passengers. The options considered are:

- a later flight to the destination;
- a train to the destination city;
- a coach to the destination city;
- a train to an alternative airport followed by a flight to the final destination;
- a coach to an alternative airport followed by a flight to the final destination.

The cost of re-accommodating passengers on each of the options includes the cost associated with the passenger delay relative to their scheduled arrival time on the delayed flight, and the cost of the alternate transport option itself. Decision variables include the number of passengers that are re-accommodated on each option, and the number of coaches hired for the two re-accommodation options that use coaches.

Six constraints are included in the optimization. The first equates the cost of the flights to either zero, if the flight is operated by an aligned airline, or to the average fare paid for the flight, if the flight is not operated by an aligned airline. The second constraint ensures that the total number of passengers on the cancelled flights that choose to be re-accommodated equals the total number of passengers re-accommodated on each re-accommodation option. The third, fourth and fifth constraints ensure that the number of passengers re-accommodated on each re-accommodation option is less than or equal to the number of seats available on that option. The sixth and final constraint ensures that the number of coaches of each size hired is less than or equal to the total number of coaches of that size available for hire.

A summary of results is given in Figure 2, in comparison to a baseline where passengers are re-accommodated only on later flights from their own airline or one in the same alliance. For relatively short disruption periods, the majority of passengers are re-accommodated on flights by their own airline and the mean passenger delay is dependent on the specific characteristics of the relatively small number of cancelled flights. Closure periods above an hour are less dependent on the characteristics of individual flights. Here, if alternatives are included, only around 15% of passengers make use of them. For shorter closure periods the most commonly-used option is to use a flight from an alternative airline departing from the same airport, but as the closure period becomes longer a varied assortment of ground transport methods are also employed and the number of alternative airline flight options decreases as those airlines start having passengers of their own to re-accommodate. We do not find a dominant ground transport method; rather, the choice of coach to the final destination, train to the final destination, coach to an alternative airport or train to an alternative airport depends on the specific route, the flights offered by alternative airports (most notably London Gatwick in this example) and the number of stranded passengers. Cost savings are around 15% for closure periods under an hour, falling to around 2% for a 3-hour closure. However, the effect on mean passenger delay is greater. As can be seen from the distribution of delay by number of passengers shown in Figure 3, this arises mainly from a reduction in a small number of very long passenger delays, where airlines have an extra incentive to provide faster ground transportation to avoid having to provide overnight accommodation for passengers. For these passengers, a multimodal solution may represent a significant improvement on the status quo.

## III. METACDM PROCESSES AND CONCEPTS

It is built upon the fact that passenger journeys should be considered on a door-to-door basis, and that ground transportation is a feasible alternative for many stranded passengers. In this concept, the passenger participates in the information exchange process during disrupted conditions and is provided with information about ground transportation. For such a system to be widely adopted and useful for crisis situations it needs to prove useful in nominal situations. The MetaCDM concept is adaptable to both types of situations.

Passengers can differ significantly in their travel behaviour, requirements and preferences. The MetaCDM analysis considers two main traveller profiles that are the two extremes of a continuous spectrum of passenger profiles:

- Empowered travellers take control of their travel strategies, want access to information at their discretion, plan and often book their own individual journey elements, take control of and responsibility for timings and connections and react to and adjust plans according to circumstance. In the North-East corridor of the US, under heavy snow, an empowered traveller would head to the nearest Amtrak station in Washington, D.C. to return home to Boston.
- Guided travellers specify a requirement, entrust much of their journey planning and delivery to an

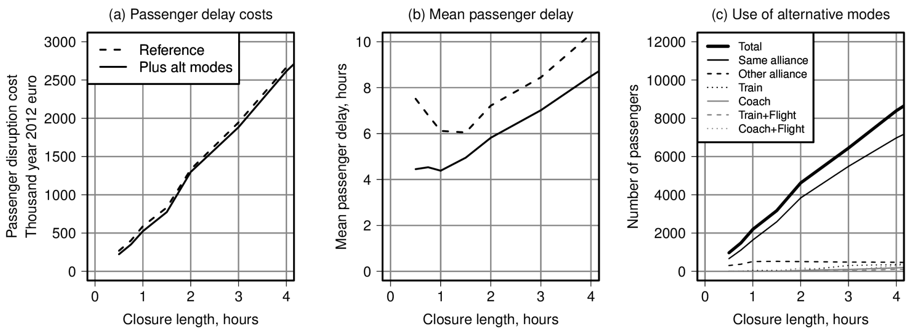


Fig. 2: Costs, mean passenger delay at destination airport, and use of alternative modes by length of cancellation period, for the hypothetical disruptive events modelled here.

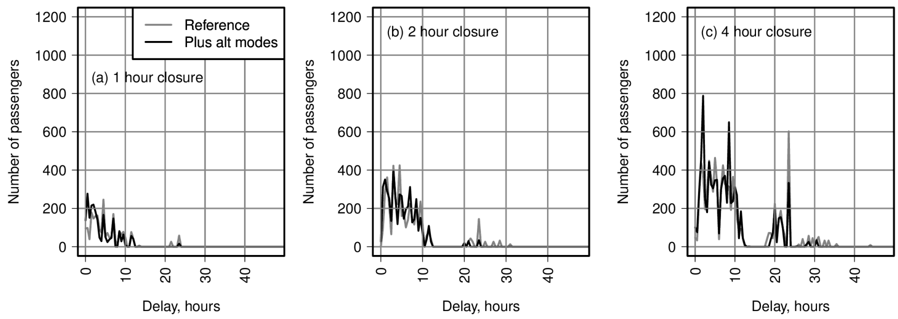


Fig. 3: Distribution of passenger delay for a 1-hour, 2-hour and 4-hour airport closure period.

agent, and rely upon their agent to address and solve problems and adjust or reroute the journey plan as necessary to achieve the original purpose of the trip.

To construct the MetaCDM concept of operation, we use the successful and widely-adopted A-CDM standard as a template. However, the fact that passengers are not aircraft (e.g. the passenger at home does not interact with a controller) leads to key differences in MetaCDM. In the MetaCDM concept, the equivalent time to the TSAT (Target Startup Approval Time) would be the start of the passengers door-to-door journey, and the TTOT (Target Take-Off Time) would be arrival time at a critical journey milestone, e.g. arriving at the gate for their flight. The CFMU slot would be equivalent to a critical transport link that must be reached or the journey will be significantly delayed.

Figure 4 compares the different functional groups between the A-CDM and the MetaCDM concept. The information sharing is a key element of both concepts, but passengers and ground transport operators are included in the MetaCDM information sharing

| # | A-CDM Functional Group | MetaCDM Functional Group |
|---|---|---|
| 1 | Information Sharing | Information Sharing |
| 2 | Collaborative Turn-Round Process | Passenger Travel Milestones |
| 3 | Variable Taxi Time Calculation | Variable Process and Travel Time Prediction |
| 4 | Collaborative Management of Flight Updates | Collaborative Management of Travel Updates |
| 5 | Collaborative Pre-Departure Sequence | Performance Based Travel Management |
| 6 | CDM in Adverse Conditions | MetaCDM in Adverse Conditions |

Fig. 4: MetaCDM functional groups.

process. This information exchange could cover customer needs, planned and estimated times at milestones, target times from passengers at milestones, and potentially GPS position data. For each passenger travel milestone, planned and forecast arrival times are tracked to check if the chosen travel connection is still feasible or if the journey needs to be re-planned. Travel times between milestones need to be calculated flexibly, in response to dynamic changes in

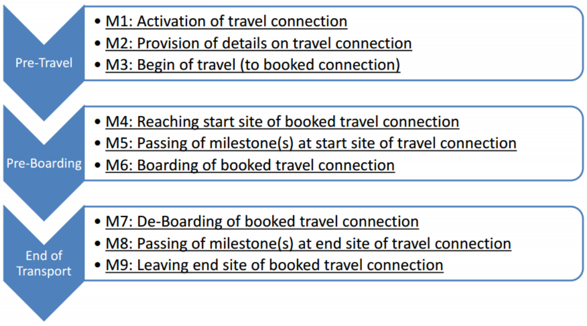


Fig. 5: MetaCDM Milestones.

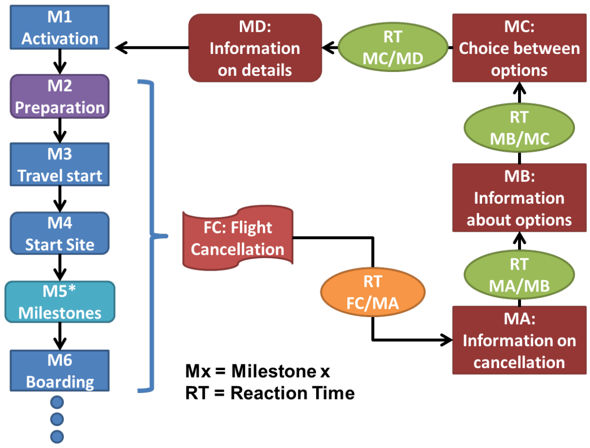


Fig. 6: Illustration of MetaCDM milestones chain in a situation of flight cancellation

travel conditions, leading to the variable process and transfer time element, with calculation of queuing at milestones, e.g. at check-in. Collaborative management of travel updates covers how and when to exchange data and the accuracy and timeliness of that data, e.g Heathrow shutdown. Performance based travel management covers travel planning that is carried out in response to performance parameters set by the traveler (e.g. are they willing to trade off comfort for journey time in the event of disruption). Finally, MetaCDM in adverse conditions covers the action mechanisms for situations where the destination is not reachable within a reasonable time any more , including providing information and alternative options to the passenger. The Milestone approach under nominal conditions is illustrated in Figure 5. In the Pre-Travel phase, the passenger books his/her full door-to-door itinerary, the provisional details on the different connection of this door-to-door itinerary to the beginning of the travel are sent. Consider a traveller who booked a flight as well as the different ground transport connections to reach and leaves the airport. He/she chooses to reach the airport by using successively a bus and a train. Once the booking is confirmed, he/she receives all the travel details (bus, train and air travel schedules), which can be updated if necessary once the journey starts. The Pre-Boarding phase includes all the milestones to the different connection sites up to the boarding in the aircraft. The End of Transport phase includes all the milestones to the different connection sites from the aircraft de-boarding to the arrival to the final destination (i.e. to the hotel). Different operators are responsible for providing information on different target times. For each transport connection, the provider defines a target time for boarding; any passenger journey may include one or more travel connections from one or more service providers. Other milestones are defined to aid the passenger in meeting these target times (e.g. when to leave home). Other service providers will provide information on the travel times between milestones (e.g. the length of a train journey to the airport).

We define a crisis event as an episode of major disruption that results in many cancellations at one or more airports, see Section II.B for examples.

A crisis situation interrupts all MetaCDM successive milestones. Their connection no longer exists and as a consequence transfer times between milestones cannot be updated. Passengers could receive information about their flight cancellation whilst still at home, whilst they are travelling to the airport, or whilst they are waiting at the gate. As soon as information on cancellation is available, the normal milestone process is interrupted and a crisis milestone process begins instead. Passengers are given information on the cancellation and on the options that are available to them (refund, transfer to another mode, take an alternative flight). This information is tailored to passengers stated preferences. Once passengers have made a choice between options, they are given practical information on how to proceed. If the passenger chooses to travel (either by an alternative flight or ground transportation) then the nominal milestone process is restarted for the new journey. Figure **??** illustrates the milestone chain with needed reaction times. MetaCDM crisis milestones are:

- MA: Information on flight cancellation provided by the air transport operator,
- MB: Information on the list of options for alternative solutions,
- MC: Choice between options to be given by the passenger,
- MD: Information on practical details relative to the chosen option.

RT MX/MY is the reaction time between milestones X and Y i.e the time of reaction of the different stakeholders, between the crisis milestones, to provide flows of information. Stakeholders involved in each successive flow of information are Airlines, passengers, airports and ground transport operators. The flows are broken down as follows:

- Flow A, Flight cancellation information: this information flow is the first information provided by the airline to the passenger to alert them about their flight cancellation and about the fact that solutions will be proposed to them shortly,
- Flow B, Options list building: this information flow is between the airline, the airport and the ground transport operators so as to identify the possible options to be proposed to the passenger,
- Flow C, Final option choice: this information flow is between the airline and the passenger, informing the passenger about the option(s) that the airline can propose to them and getting the passengers final decision between these options,
- Flow D, Practical details: this information flow is between the airline and the passenger and aims at providing to the passenger the practical details of their chosen option,
- Flow E, Practical details on door-to-door ground transport (for guided traveller only) This information flow is provided by the travel agency to the guided traveller and consists in providing more detailed guidance on the urban ground transport connections to reach the final traveller destination.

According to these criteria all or only some of the following options will be proposed to the traveller:

- Air ticket reimbursement without offering an alternative solution: this solution will be favoured more in case of an outward flight for the passenger,
- Transfer to an alternative transport mode: this solution relating to ground transport modes (e.g rail or coach services) will be favoured more in case of cancellation of short-haul flights (flight duration less than 3 hours),
- Transfer to another flight from the same airport platform: in this solution the transfer can be to the initial destination airport or to another airport in the same region.
- Transfer to another flight from another airport platform: in this solution a ground transport mode (often a bus transport mode) is necessary to reach the other platform. Moreover, the flight operated from the other airport can be to the initial destination airport (as booked by the passenger) or to another airport in the destination region.

## IV. Conclusion

The strong evidence for the need of multimodal, passenger-centric CDM during adverse events and justifies the development of a corresponding concept of operation. Through two case studies, the Asiana Crash in the US, and an hypothetical closure of London Heathrow in Europe, we show that there are significant opportunities for improved passenger reaccommodation. Several events over the past few years and interviews conducted during the Meta-CDM project support the claim that multimodal CDM could provide an answer to several needs and concerns of the industry. A multimodal CDM concept is elaborated, defining milestones and information flows to support harmonized decision-making and passenger treatment, and ensure a faster recovery process from a passenger standpoint. Future work aims at developing additional multimodal case reports, establishing more detailed models, determining the limits of performance, validating and refining the MetaCDM concept against these case studies.

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