Collaborative project co-funded by the European Commission

Seventh Framework Programme

Aeronautics and Air Transport

FP7-(AAT)-2012-RTD-1

Theme [AAT.2012.7-26]

[Efficient Airports for Europe]

Project MetaCDM

D.3.2 – WP300 Report

MetaCDM Concept of Operation

Isabelle Laplace, Aude Marzuoli, Eric Feron (ENAC)

Lynnette Dray, Roger Gardner (University of Cambridge)

Gunnar Spies, Thomas Günther (BARCO Orthogon GmbH)

Submission date: November 2014

Dissemination level: RE/PU/PP/CO

Change Log

Release	Date	Details of changes
0.1	21/02/2014	First version of the final report
0.2	25/03/2014	Merged work papers and changed structure of document
0.3	02/04/2014	Further elaboration of milestones and description
0.4	07/04/2014	Update document structure
0.5	-	Intermediate versions for editing
0.6	30/04/2014	Merge of contributions and comments
0.7	04/05/2014	Added contributions to chapter 2.1 and 6
0.8	15/05/2014	Extended chapter 2.2 and incorporated content of chapter 2.4 into chapter 2.1
0.9	25/06/2014	Merged contributions, review and comments from partners for final review: incorporated chapter 2.4 into 2.1.2, added content to old chapter 2.5 and to 3.4, moved chapter 4 into chapter 3.6, major rework of old chapter 5 and 6 (now chapter 4), merged old chapters 7 and 8 to new chapter 5 and added content to it
0.10	17/07/2014	Revised whole document for release
1.0	28/08/2014	Final version
2.0	30/11/2014	Addition of section 6 on recommendations to the European Commission and to the other stakeholders

Table of contents

EXECUTIVE SUMMARY

The MetaCDM (Multimodal, Efficient Transportation in Airports – Collaborative Decision Making) project aims to define the future of Airport CDM (A-CDM) – a future where CDM techniques can be used to address major disruptive events, and where the needs of the passenger are the centre of attention.

The passengers' priority is to enjoy a stress-free journey, meaning going through processes that are faster, more convenient and easy to use, even if they are not frequent fliers. The question in a passenger's mind is not only: "when will my plane finally take off?", but rather: "how will my door-to-door journey be affected?". An integrated view of the passenger journey is essential for answering the latter question.

Implementing A-CDM helps to successfully mitigate the effects of delay upon Air Traffic Flow Management (ATFM) slot adherence and although it helps airports, airlines and ground handlers in optimising their resource allocation, but the landside is not within scope of A-CDM. To include the passenger in the CDM process an extension of A-CDM to the landside is needed.

This document describes an operational concept to exchange information on the status of the passenger door-to-door journey under both normal and crisis situations, enabling the transportation service provider(s) to incorporate this information into the planning of the transportation service. In return the concept foresees an earlier and more accurate feedback of flight updates to the passenger. The aims are to improve passenger travel experience, to reduce door-to-door journey time and delays, and to allow transportation service and facility providers to better optimise their use of resources.

There are already tools on the market for the exchange of information between transportation service provider and passengers. But at the time being, these tools are either streamlined to the needs of one transportation service provider, e.g. an airline, or they only provide general information, such as the current location of a flight, from which it can be difficult to tell whether that flight or following departures that depend on it will be on time. A common framework is missing that defines which processes should be monitored and which information and estimates should be exchanged.

To set up a common framework for the information exchange between passenger and transportation service provider, MetaCDM defines Milestones for travel connections that should be used to enable the monitoring of door-to-door journey progress and allow forecasts of arrival times at critical points in the journey. Furthermore, travel and process times to/for these Milestones are defined that should be estimated and exchanged/updated between

transportation service providers and passengers, to allow the passenger to plan their door-to-door travel based upon the best available information. The defined procedures are suitable both for normal and for adverse conditions and will allow the passenger to make more informed decisions concerning their travel, particularly when disruption occurs.

The MetaCDM concept is intended to improve the handling of crisis events in the aviation system and to mitigate their effects. As passengers have better information about when and whether to leave home during disruptive events and the alternative options available to them for travel, airport overcrowding and long delays for passenger re-accommodation should be reduced. Similarly, airlines can use enhanced information on passenger location to inform their decisions and how they allocate resources for passenger assistance during crisis situations.

This report also identifies a number of issues and actions that should be addressed by organisations with policy and network facilitation roles and by stakeholders touched by the passenger's journey experience. Principal amongst these is the need for a more formalised dialogue as the concept of MetaCDM is still very much in its infancy. As a result, there is also a need for improved understanding of current practice, passenger surveys, ways to enable full stakeholder participation through cost benefit analysis and the running of airport trials.

Investigations undertaken through the MetaCDM project suggest that broad application of the concept would make a material contribution to the European Union's goal for a maximum of 4 hour door-to-door journeys within the Union. However, much remains to be understood so knowledge gaps and research needs are identified at the end of this report.

Abbreviations

Abbreviation	Description
A-CDM	Airport Collaborative Decision Making
ACI	Airports Council International
ANSP	Air Navigation Service Provider
ARDT	Actual Ready Time
ATFM	Air Traffic Flow Management
CANSO	Civil Air Traffic Services Organisation
CDM	Collaborative Decision Making
CODA	Central Office for Delay Analysis
COFU	Collaborative Management of Flight Updates
CTOT	Calculated Take-Off Time
DPI	Departure Planning Information
EC	European Commission
FIM	Flight Interruption Manifest
FUM	Flight Update Messages
GDS	Global Distribution System
GHG	Greenhouse Gas
GPS	Global Positioning System
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
IT	Information Technology
KPI/A	Key Performance Indicator/Area
MetaCDM	Multimodal, Efficient Transportation in Airports – Collaborative Decision Making
NAAP	National Association of Airline Passengers
pkm	Passenger-Kilometre
R&D	Research and Development
ROI	Return on Investment
TSAT	Target Start-Up Approval Time
TTOT	Target Take-Off Time
VPTT	Variable Process and Transfer Time

1 Introduction

Recent years have seen a number of major disruptions due to natural elements (ash clouds, heavy snow storms) causing severe delays and cancellations in the European aviation system. The volcanic eruption in Iceland in 2010 resulted in the cancellation of 90% of flights in Northern Europe over six days, costing airlines more than a billion in revenue. In such cases, airlines have little control over cancellations and passengers may be re-accommodated several days later. However, the majority of passengers' journey disruptions can be attributed to everyday delays and cancellations.

Flight delays or cancellation data reflect an aircraft-centric point of view. For a passenger, a disruption corresponds to any change to the itinerary planned or the package purchased. To an airline, "Irregular operations" encompass delays, missed connections and cancellations. They may be due to natural causes (such as bad weather) or air traffic delays, factors that are beyond the airline's control, or strikes or mechanical problems, which the airline may be able to influence. No matter the cause, for a passenger, an irregular operation corresponds to any change to a booked element of their original itinerary. Depending on the purpose of the trip, even a moderate flight delay can be a major disruption to the passenger's overall journey. Although airlines are obligated to provide passenger assistance when major delays occur, passengers are often not aware of their rights and many complain of not being given enough information in these situations. Airlines are required to provide alternative transportation to stranded passengers (nearly always a later flight, often the next day) and/or a refund. Sometimes passengers decide not to use this re-accommodation provided by the airline and find alternate transportation modes on their own. Although they may get to their destination sooner by this method, it requires confidence and access to information which is often hard to obtain in the situations stranded passengers find themselves in. A passenger-centric viewpoint is also key in understanding the passenger's door-to-door journey as a whole, in which airport disruption may be caused by or may impact on disruption to passengers travelling to or from the airport.

The 9th annual SITA survey [1], in partnership with Airports Council International (ACI) and Airline Business, reports that improving passenger experience is the number one driver of Information Technology (IT) investment by the majority (59%) of the world's airports. An example of changes passengers can expect to see in future is a rapid increase in mobile and social media apps to deliver a more personalized customer experience. Keeping passengers informed about their flight status and wait times is the top reason for airports providing mobile apps, with 88% planning to invest in them by the end of 2015. During this period, 78% of airports also plan to invest in social media.

As the number of passengers continues to rise at airports across the world, optimizing the use of the available real estate is a priority and passenger flow management will become more and more important; half of the airports see geolocation as a top priority for reducing passenger congestion. Within the next three years, new way-finding services are set to become commonplace on mobile devices, allowing passengers to navigate easily through the airport. Just 10% of airports provide them today but this figure is set to jump to 70% by 2015. Airports are also investing in business intelligence solutions to deliver an improved passenger experience. Some 86% of airports see it as a priority for sharing information and collaborating with partners; 83% to ensure more accurate service information for passengers; and 76% to reduce flight delays due to ground operational issues [1].

With airports planning to invest in business intelligence, and using it to better collaborate with partners, it is clear that there is a strong desire among operators to work together with stakeholders, including airlines and ground handlers, to create a better passenger journey.
While the growth of personal mobile devices is an opportunity for air transportation providers to decrease fixed asset costs, the delivery of relevant time-critical information has the potential to enhance the situational awareness of travellers and their opportunities to either actively participate in the decision making process regarding the planned travel and/or to re-plan the travel on their own.

The MetaCDM project aims to investigate how A-CDM concepts can be extended to provide more support to passengers, particularly during crisis situations. Based on studies carried out in Work Package 100 and interviews conducted in Work Package 200, this document defines a concept of operations that describes what is operationally needed to allow travellers to participate in the CDM-process to their own benefit. Because there is already an existing standard for A-CDM, the ETSI EN 303 212 V1.1.1 (2010-06)[2], the project partners decided to choose an analogous set-up for describing how MetaCDM should work. This concept of operations focuses on the operational needs and procedures required, but does not go into detail on the functional requirements and on what must be implemented to make MetaCDM a reality. It does, however, suggest a number of actions that would need to be taken by stakeholders to move towards that reality.

The key concept elements for MetaCDM are introduced in chapter 2, “Key Concept Elements”. This chapter provides an overview on the stakeholders, the Functional Groups of MetaCDM, the integration of multimodality and how the traveller could be involved. It concludes with a view on related developments needed from trade associations and non-governmental organisations.

Chapter 3, “MetaCDM Functional Groups”, provides details on the Functional Groups of MetaCDM. These Functional Groups are set up in a way comparable to those in A-CDM, beginning with information sharing and passenger travel milestones whose process times and inter-milestone transfer times can be subject to monitoring and prediction. The applicability of MetaCDM in crisis situations is subject of the last section, 3.6. This section describes the identification of solutions for passengers, the information flows in case of flight cancellation and the MetaCDM crisis milestones.

An overview of the expected benefits and costs to stakeholder of MetaCDM are given in Chapter 4, which also discusses the plausibility and scope of the concept, focussing particularly on the use of alternative modes in crisis situations. This chapter also considers the environmental impacts of the MetaCDM operational procedures.

Chapter 5 gives an outline of how the concept for MetaCDM might be pushed forward by taking a look at the required implementation steps and the future research paths required to bring the concept to reality.

2 MetaCDM Success Factors and Concept Drivers

The key concept for MetaCDM is the expansion of A-CDM ideas to encompass the whole of the passenger door-to-door journey under both normal and crisis situations, with the aim of improving passenger experience and reducing journey time and delays. This chapter introduces the concept drivers for MetaCDM. It begins with a summary of the role and critical involvement of the concerned stakeholders (section 2.1) and deduces in section 2.2 the Functional Groups applicable for MetaCDM from the A-CDM concept elements. How multimodality can be integrated into MetaCDM is described in section 2.3. This chapter concludes with a view on the role of high-level organisations (section 2.4).

2.1 Airside and Landside Stakeholder Involvement

A prerequisite for successful MetaCDM is informed engagement between stakeholders. Evidence drawn from Work Packages 100 and 200 suggests that current practice varies enormously, ranging from patchy or ineffective connections to close coupling of planning and service. A-CDM has already taken substantial steps towards better planning, communication and coordination with resultant benefits to the corporate or institutional airside collaborators.

2.1.1 Links between stakeholders

The points of connection between A-CDM collaborators are strong and mutually beneficial so there is a clear incentive for them to cooperate. On-time performance has immediate effects upon capacity, utilisation, throughput, etc. so all players can see good Return on Investment (ROI). For MetaCDM, however, the stakeholder community needs to be expanded, with involvement from passengers and ground transportation providers amongst others. For a number of these MetaCDM stakeholders, the links are more tenuous and less formalized and the ROI resulting from closer connection is less clear. The common connecting strand is ‘the passenger’ so, in order to achieve effective MetaCDM, it is necessary for MetaCDM stakeholders to make passenger-related performance metrics a priority and for these to be aligned between the players, potentially with the help of passenger organizations such as the International Airline Passengers Association (IAPA).

The pivotal role of the passenger, though obvious, becomes clear when considering the role of the main stakeholders involved in the door-to-door travel experience in normal and disrupted conditions. Only passengers (or their luggage) connect with all stakeholders. Other stakeholders have one or a few connections up or down the line but they do not have an immediate operational reason to be aware of the needs, priorities and issues facing the full run of stakeholders involved in journey process.

Table 1 shows the key stakeholders to be accounted for when determining connections from A-CDM towards MetaCDM development.

Stakeholder	In A-CDM	Role and critical involvement
Passenger		Customer, autonomous or automatic connection
Airlines	✔	The main ‘supplier’
Airports	✔	Facilitation of interface between modes and provider of travel services
Border control		Key gate and pinch point
Police/emergency service		Planning and crisis mitigation engagement
Ground handlers	✔	Facilitation of turnaround
Air Navigation Service Providers (ANSPs) and Network Managers	✔	Traffic coordination and throughput
Local authorities		Planning and crisis mitigation engagement
Ground transport providers		Routine access providers and contingency routing
Information service providers (infrastructure)		Potential agent for solutions
Media		Information dissemination and incident reporting

Table 1: Stakeholders and their roles in MetaCDM

Through interviews, the MetaCDM project has observed numerous obstacles to aligning priorities between these various players, such as:

- Competitive and commercial confidentiality concerns;
- Differing perceptions over hierarchy of control in routine and crisis situations;
- Incompatible information systems.

As a result, some key elements of the MetaCDM concept are to get players to:

- Accept the central goal of a seamless, speedy and well-informed passenger experience as they transit through the system (this may appear obvious, but in reality the passenger focus is often overtaken by business efficiency targets that lose sight of the bigger picture);
- Move towards commonality of, or at least some degree of compatibility between, language, systems and data used at the key interface points in the journey experience;
- Extend the degree of common planning, contingency arrangements, training and monitoring for normal and adverse operational conditions to provide resilience in crisis situations.

In practice, this means establishing either local, regional or international fora, depending upon the focus of the group that is connecting, to achieve the most important basic ingredient that will enable effective MetaCDM: good communication.

Present-day information sharing is partial at best, as noted above. It works well in situations where, for instance, police have daily liaison with airport operations managers and can adjust control and management of flows as a result. Similarly, there may be good connections between airlines and airports that facilitate the number of check-in counters available at any point in time to suit throughput highs and lows. These single connection relationships are relatively easy to manage. A new concept of operations needs to extend this principle to the full run of stakeholders so that there is visibility across the full range of steps involved in the journey. The economic actors involved in ground transportation, hotels and the supply chain would benefit from greater knowledge of fluctuations of demand in ‘normal’ situations and could be that much more responsive if given rapid insight into emerging crisis situations. Equally, those providing border control, check-in, baggage control, etc. would benefit from knowing about highway incidents and public transport disruption. These examples of knowledge sharing illustrate how local operations may be improved. Similar improvements may be obtained at the regional or even international levels.

The scope for achieving better communication can be seen from a top-down or a bottom-up perspective. A number of possibilities exist for enhanced top-down connection:

- Network Managers could act as conduits for the exchange of information between departure and arrival airports, which can then disseminate this information throughout their networks;
- Industry trade associations such as the Airports Council International and IATA could provide alerting services that provide better visibility of network availability;
- The EC could support a regional network ‘dashboard’ that provides dynamic updating of service condition for airports and any major disruptions affecting passenger access.

From a bottom-up perspective, passengers can approve use of cell-phone data, tweets and other data sources to provide real-time updates of their individual situations and be better supported that way, similar to how GPS position data allows planners to guide road travellers through uncertain environments.

At the intermediate level, airports and major transport hubs can provide similar, more localised hubs for knowledge exchange and dissemination between stakeholders. Several airports do this but the network is often too limited in its participation. The key is to gather all the relevant layers of stakeholders together with varying degrees of participation according to their importance in the chain of connections. It is apparent that, in the same way that smaller airports in the MetaCDM interview process tended to favour 'A-CDM Lite', the less connected MetaCDM stakeholders will favour a simple method of engagement and knowledge sharing rather than resource-intensive participation in systems akin to full A-CDM.

The outer edges of the journey network are often the first to hear of problems that may affect journey integrity. For instance, meteorological services warning of major weather events or highways control organisations, ground transport providers and emergency services alerting the network to incidents that can disrupt passenger access or shut down certain aspects of local infrastructure. As a result, it is imperative that all connected stakeholders are part of communication hubs on both a contributory and recipient basis. If they are not all directly connected in a single forum, they should, at least, be indirectly connected through the key players. For instance, the local authority may act as intermediary for a number of highway agencies.

Attention should be given to establishing communication fora for all airports and providing network connectivity at the international level. As noted above, an essential step towards achieving effective alert networks will be to gain a better common understanding of the constraints, priorities, systems, data formats and needs of each stakeholder. There are often knowledge and communication barriers that need to be dismantled before new networks can effectively be built.

2.1.2 Engaging the passenger

Passengers can differ significantly in their travel behaviour, requirements and preferences. The MetaCDM analysis in this document considers two main traveller 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.

Guided travellers: specify a requirement, entrust much of their journey planning and delivery to an agent, 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.

Guided travel might not only be suitable for business trips but for elder travellers too. A good example of guided travel is available from the Air Travel Companion, an Australian company, which provides door-to-door transfer of elderly passengers by a professional nurse. Guided travel is also well suited for travellers who struggle with problems such as language barriers, particularly in case of disturbances and in the absence of clear and visible communication from system players.

Of course, these profiles are the two extremes of a continuous spectrum of passenger profiles. If there is to be effective MetaCDM engagement between the travel service providers and the passenger, the differences between passenger types must be acknowledged so that information support and service are provided according to those differences. An intermediate form of empowered and guided travel might be enabled through significant changes in air booking and ticketing technology aiming at giving more control to passengers. The next step is to direct traveller access to the Global Distribution System (GDS), with no company-approved portal or online booking tool needed. The level of access could likely depend on the traveller's frequent flier status. Top passengers would have the same ability to book, buy and change tickets in the GDS as the top corporate travel agent, without the travel department [3].

While information from all involved stakeholders is needed for consolidated decision-making the two main actors involved are the traveller (or their agent) and the service provider of the chosen mode of transportation (flight, train, bus or ferry) or combinations thereof. For the benefit of the empowered and guided travellers alike, service providers must be incentivized to share their information and make it publicly available. In case of a disruptive event, the service provider should provide the traveller with intelligent re-accommodation to enable empowered travelling. Although automated re-accommodation may be effective from the standpoint of the operational staff, it often does not resolve the passenger's travel disruption or address their most relevant needs. A passenger-centric approach entails gathering information about each passenger's preferences and trip purposes so they can choose an adequate alternative. This is also relevant to passengers who did not book their flight directly with the airline.

2.1.3 Stakeholders for empowered travel

In order to convince all stakeholders to provide the necessary information to allow an empowered travel experience, incentives must be elaborated. Such incentives can either be monetary, e.g. premium flight tickets sold at a higher price; performance oriented, e.g. to help the service provider improve efficiency and reduce costs; or, ideally, be more abstract. For example, the incentive could be to increase levels of trust and confidence in the service provided and in the used facilities, and hence build customer loyalty; or to help achieve overall network goals such as the European 4-hour door-to-door journey timeline. Most likely it is the prospect of performance gains that will work for both parties and this inducement could encourage service providers to establish direct means of communication with the passenger (Apps or alerts) that will provide knowledge to the consumer and provider alike (especially if the passenger is willing to provide locational information). Such connections also require better coordination between service providers so that the goal of seamless travel can be achieved. For instance, passenger journey progress information received by airlines would also help security, border control or gate dispatch managers in the same way that knowledge of any disruption in these services would assist the empowered traveller. It is a matter of 'quid pro quo' and the willingness of the service providers to make clear that a better service will be delivered if the passenger is willing to provide certain information.

These links could significantly help travel efficiency in normal operational conditions, when the system performs well within certain tolerances, but they could be especially beneficial in crisis and disruption situations, where some of the congestion and delay effects could be defused. For instance, besides designing and implementing crisis management procedures to deal with massive perturbations and journey disruptions in order to serve their own recovery needs, airlines could include passenger journey contingency planning within their standard service approach. Although some airlines routinely update passengers about any major events affecting the airline's ability to deliver the flight, information is not provided about access to the airport or airport conditions. Such additional information could help both parties but it presumes a willingness on the part of several service providers to share operational status information. Furthermore, it may require a willingness on the part of airlines or ground transport providers to permit exchange of tickets between providers (through some reciprocal arrangements) if the journey objective is to take precedence over the immediate retention of the passenger within the 'control' of the company that has originally contracted to provide the service.

2.1.4 Stakeholders for guided travel

All stakeholders are involved in this form of travel, but the planning interaction takes place mainly between the traveller and a travel agent that interacts on behalf of the traveller with all other stakeholders. Therefore this agent must be able to act as independently from other stakeholders as possible – it should only represent the interests of the traveller. This can be achieved by e.g. the traveller (or their company/organization) being a customer to the travel agent and thus paying some extra amount for their services.

Traditionally, full service travel services, such as holiday packages, may offer this kind of more comprehensive service and possibly book airport access journeys as well as flights. However, they rarely act as comprehensive intermediaries who monitor system performance and unilaterally alert the traveller of delays or changes. The interaction of the travel agency with a full suite of other stakeholders would doubtlessly be very complex and is currently outside the scope of this concept. This might, nonetheless, be a logical progression of the MetaCDM concept.

Of significant interest, therefore, is the interaction of the traveller with the travel agency and how timely and accurate travel information and planning can be exchanged. The guided traveler needs to be able to convey and receive information before and during the journey. In the guided traveller scenario, the main stakeholders are:

- The traveller, who follows the instructions of the travel agency and gives feedback on position and on possible obstacles,
- The travel agency, which is hired by and thus loyal to the traveller.

The travel agent would need to be well connected with a full suite of service providers in order to provide timely information to the guided traveller about the need to adjust or reroute in order to complete the journey successfully. Some of this alerting process might be undertaken through automatic means, where deviations from the norm might be fairly small and contingency algorithms might be established within the bounds of timetables. In crisis situations a dynamic ‘hands-on’ personally managed approach would probably be needed. In either case, there is a need for new fora, protocols and perhaps most importantly, new levels of trust and business approaches to support a concept of operations that delivers real gains to the passenger as well as to service providers.

2.2 Application of Airport-CDM Success Factors

While implementing A-CDM helps airports, airlines and ground handlers in optimising their resource allocation by mitigating the effects of delay upon ATFM slot adherence, the landside is not within the scope of A-CDM.

MetaCDM aims at closing this gap by transferring the successful A-CDM idea onto the landside and thus answering the question: “How can the passenger participate in the CDM-process?” The ways that this might be achieved are discussed in section 2.2.1.

Section 2.2.2 describes the link between A-CDM and MetaCDM and how MetaCDM influences A-CDM and vice versa. In section 2.2.3 the MetaCDM functional groups are discussed, and their links to the existing A-CDM functional groups.

2.2.1 How to adapt the idea of A-CDM to MetaCDM

A-CDM bases its monitoring on the calculation and reachability of the Target Start-Up Approval Time (TSAT) and Target Take-Off Time (TTOT) of an aircraft departure, mainly to check if a regulated flight is able to depart within its ATFM slot. The information on the timeliness of the flight is sent as Departure Planning Information (DPI) to the Network Manager.

Transferred to MetaCDM, the TSAT corresponds to the planned/target time when the traveller starts their journey. Instead of a ATFM slot, there are critical transport services such as long haul flights or long distance trains that must be reached or the travel will be significantly delayed. In this case, the TTOT would be the planned/target time for the traveller to reach a critical milestone of this transport service such as arriving at the gate for the long haul flight or on the platform for a long distance train. Instead of re-allocating a ATFM slot in case of a flight delay, in MetaCDM the travel connection might need to be changed/re-booked in case of a passenger delay (missed connection instead of missed ATFM slot).

Number	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 Transfer 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

Table 2: Functional Groups of A-CDM and equivalents in MetaCDM

The equivalents in MetaCDM to the Functional Groups from A-CDM are given by Table 2 and are detailed in section 2.2.3. The A-CDM concept of Collaborative Pre-Departure Sequencing could have been transferred to MetaCDM as a Collaborative Pre-Travel Sequencing. However, this is not applicable to MetaCDM because the passenger does not need a clearance to leave home and is not subject to a controller. Thus, the predicted/proposed time for leaving home is only a milestone in MetaCDM Functional Group 1, as discussed in section 3.2. Instead, Performance Based Travel Management is included as Functional Group

5 to reflect the importance of the service quality for the traveller. More detail on this is given in section 3.5.

2.2.2 The Link between A-CDM and MetaCDM

The presence or absence (no show) of passengers is a big issue for the airlines especially if the luggage of these passengers is already loaded. This is often a reason for minor flight delays and a better prediction of the passenger reaching certain resources such as security or the gate would help airlines and ground handlers. In return, better knowledge about process and travel time prediction would help the traveller to plan her/his journey.

MetaCDM would be directly linked into the existing A-CDM process via two A-CDM milestones that are directly influenced by passengers. These are A-CDM milestones 11, "boarding starts", and milestone 12, Actual Ready Time ("ARDT"), of the booked flight connection. These link directly to "boarding of booked connection", which is milestone 6 in MetaCDM (see section 3.2).

2.2.3 MetaCDM Functional Groups

As stated in previous sections, the MetaCDM project adopted a similar approach for MetaCDM as given by [2] for A-CDM. Potential MetaCDM equivalents to A-CDM Functional Groups are detailed in chapter 3 and were identified as follows:

1. Information Sharing, see section 3.1:
    - Exchange of specific personal information to identify customers and their needs, e.g. the preferred connection, mode of transportation etc.,
    - Planned and estimated times from service providers / involved stakeholders at milestones, including waiting times in queues, walking time, etc.,
    - Target times from passengers at milestones,
    - Position data of passenger, e.g. Global Positioning System (GPS) data.
2. Passenger Travel Milestone Approach, see section 3.2:
    - Milestones for which monitoring between planned and forecast arrival time should be executed to check if the chosen connection is still reachable or a re-planning of the travel must be done. Examples:
        - Proposed/planned travel start time,
        - Interface with 1st/2nd public transport mode,
        - Arrival at airport, security checkpoint, departure gate etc.

3. Variable Process and Transfer Time Predictions, see section 3.3:
    - Calculation of travel times between milestones,
    - Flexible route durations according to dynamic travel changes,
    - Calculation of queuing/delays at milestones, e.g. at check-in, security, etc.
4. Collaborative Management of Travel Updates, see section 3.4:
    - How and when to exchange data,
    - Quality of data, e.g. accuracy, timeliness, etc.
5. Performance Based Management of Passenger Flows, see section 3.5:
    - The planning of the travel should be based on normed performance parameters that are set by the traveller. This setting should be used by the service provider to select the most fitting travel.
6. MetaCDM in Adverse Conditions, see section 3.6:
    - Action mechanisms for conditions where the destination is not reachable within a reasonable time anymore, e.g. stop at home, reroute at or to a transition point, stop at hotel, return to home etc.,
    - Re-booking, e.g. change of transportation mode,
    - Caretaking, e.g. booking of hotel, compensation etc.

2.3 Integration of Multimodality

MetaCDM aims at streamlining the passenger journey under normal and disruptive conditions. The typical passenger door-to-door journey under normal conditions involves the usage of ground transport modes and hence these modes need to be part of the MetaCDM process. However, the principal benefits of MetaCDM may come under disrupted and/or crisis conditions. When flights are cancelled, many passengers already check the schedules and availability of alternative modes, attempt to find out if using alternative modes could be reimbursed by the airline, assess whether those modes themselves are subject to disruption, and potentially book tickets and rely on them for travel. However, these actions require effort, confidence and sometimes specialised knowledge. Streamlining this process, either by offering passengers the information to make this process much easier (for the empowered traveller, see section 2.1.2) or offering specific alternative ground itineraries with the intervention of a travel agent (for the guided traveller) would allow many more passengers to take advantage of ground transport options when faced with cancelled flights. A travel agent has the opportunity to "pool" passengers and therefore has more weight in negotiations with transportation service providers. The ground transport journey does not need to be all the way to the final destination; passengers could also be offered a ground transport journey to a non-disrupted airport, from which they can take an alternative flight to their destination.

One key idea behind the MetaCDM multimodality concept is that *the passenger journey begins at home, rather than at the airport*. Information on cancelled flights is supplied to passengers (whenever possible) before they leave home. Passengers who are rebooked on ground modes may then travel directly to the access point for that mode (train or coach station, car hire, etc.) instead of travelling to the airport. In practice this means that the airport does not need to be directly connected to the mode of interest, and the passenger does not have to physically pass through the airport to access the alternative journey. It also means that the resources available to stranded passengers are those of the whole city region rather than just those surrounding the airport.

In practical terms, this means that the individual aspects of MetaCDM need to be adjustable to a journey in which the main link is by a ground transportation mode. Data flows from and to ground transport providers are needed for the MetaCDM concept as well as data sharing between airports, airlines and passengers. As discussed in the MetaCDM Work Package 100 and 200 reports, there are many compatibility issues (for example, differing priorities and loyalties, liability issues and database formats) affecting the direct integration of air and ground transport which make widespread through-ticketing and related solutions impractical, at least in the short term. Although smaller-scale integration does take place (for example, air-rail links such as Lufthansa's AIRail, and air-coach links such as Air France's coach service), these would be very difficult to scale to a system-wide level. However, existing information flows to passengers include delay updates for road transport and rail services, schedules, journey times and costs for different public transport options and car hire costs. As well as incorporating these information flows to passengers, MetaCDM can provide information to ground transport providers (for example, that extra demand is anticipated due to flight cancellations), as well as providing links or interfaces to ticket purchase options with the ground transport providers. Likely passenger information requirements under different conditions are summarised in Table 3.

Condition	Empowered Traveller	Guided Traveller
Normal or delayed conditions	Information on disruption/journey times on routes to airport via alternative modes	Information on disruption/journey times on routes to airport via alternative modes and advice on
Cancelled flights	Information on alternative mode schedules, pricing and disruption provided (including whether the airline will reimburse travel)	Choice of alternative mode itineraries, information on disruption in other modes, ticket purchase

Table 3: Alternative mode passenger information requirements under different conditions

Considering ground transportation in MetaCDM leads to the need to include milestones for these stages of the journey. The possibility that a door-to-door journey under disrupted conditions may not pass through the airport or involve a flight means that the MetaCDM milestone approach needs to be more flexible than the corresponding A-CDM process. Similarly, both disrupted and non-disrupted journeys may involve multiple different ground transport legs, either to the final destination, as a means of getting to or from the original airports, or as part of a journey to or from an alternative airport. As a result, each individual journey will have its own set of milestones rather than there being one set of milestones applicable to all journeys. It is possible that the set of milestones may dynamically change during the journey based on updated information from the airline or the passenger. For example, MetaCDM milestones need to be able to cover the following situations equally well:

- A passenger driving to the airport, taking a non-disrupted flight and then a train from the destination airport to their hotel.
- A passenger taking a taxi to a station, catching a train to an interchange station and changing to another train to the airport; while waiting for this train, they receive information about flight cancellations and are offered information including a coach service from a nearby coach station. They take a metro train to the coach station, coach to the city centre of their destination and then another metro service to their hotel.
- A passenger taking a train from their hotel to the airport finds their flight is cancelled at the airport, declines the option of ground transport, spends a night at another hotel and then takes the next flight in the morning.

The milestone approach, including milestones for disrupted journeys, is described further in Section 3.2.

Each ground transport link in the passenger's journey has a scheduled or predicted travel time, which may change depending on conditions (e.g. road congestion). Similarly, interchanges between legs in the passenger's ground journey have predicted transfer times. These interchanges allow the calculation of expected time between different milestones from which collaborative management of passenger flows, analogously to A-CDM, can be carried out (note however that details of the specific tools needed for making predictions are outside the scope of this document). This is described further in Section 3.3.

2.4 High-Level Organisation Involvement

The Meta-CDM concept necessarily involves multiple stakeholders. The systemic nature of aviation means that those stakeholders are international as well as national and local. Logically therefore, to effect meaningful MetaCDM control and cooperation there has to be input from the higher level organisations that can help to prevent, forestall and contain any crises. Similarly, working together, these organisations can enhance the passenger experience in normal as well as disrupted conditions. At the A-CDM level, this is already happening as the largely tripartite relationship between airports, airlines and ANSPs is supported by ANSPs delivering international coordination and promoting roll out of A-CDM. Whilst there is an appetite from stakeholders to engage with the MetaCDM concept they will need the assurance that there is buy-in from the international as well as the national community to support and enable its effective operation. In practice that means international trade bodies, service providers and regulators addressing issues such as establishing protocols, working towards commonality of data and systems and enabling joint working.

Regional and national coordination

It is clear that effective multi-agency working requires coordination. At present, local facilitation is generally undertaken by airports with the support of local municipal authorities. The mobilizing of organisations is therefore through the local hubs based upon mutual recognition of benefit. When the engaging organisations are all based on, and work through, the airport, that is relatively easy. As the network of organisations grows and the geographical spread increases, it becomes harder to secure effective coordination. An example of this might be linking with road and rail networks beyond the immediate surroundings of the airport or gathering and communicating intelligence from upstream and downstream service providers.

The key to delivering effective MetaCDM is communication. Airport networks are generally thought to operate well but their scope can be limited to the first tier collaborators. MetaCDM requires that this is extended to second and third tier organisations and that means introducing:

- Wider local to regional planning and resilience networks that treat transportation as an integrated service and seek to coordinate planning, pool data and facilitate response action when needed;
- A national dialogue of interested parties under the auspices of the relevant government departments. That means the development of a stronger dialogue with governments about the benefits of MetaCDM for national transportation resilience and passenger experience;
- National guidelines and protocols that make it easier for the sharing of knowledge and data and minimize the competitive sensitivities of business by showing that those organisations that engage will see improved operational predictability and reduced disruption costs. The development of such guidance would require further research and the analysis of case studies to illustrate the benefits;

- Simplified communication conduits for intelligence on transport disruption drawing upon security agencies, governmental embassy networks and the media. Early warning is crucial to effective preemptive action and mitigation so the importance of horizon scanning and downstream communication cannot be overstressed.

These actions can be taken forward by regional and national bodies but they need to be supported by the transportation sector and linked organisations, such as hotels. An important element in enabling that dialogue is improved performance on release of operational status data. Companies are reluctant to provide data too early for fear of misreading signs of impending disruption or because they fear loss of competitive position. This is not adequately addressed in current fora looking at preventing disruption and research is needed to understand the way situations unfold, the trigger points for different levels of disruption and when the optimal point for release of operational status information may be. This suggests that trade bodies for airlines, airports and airside operators/baggage handlers, as well as the companies themselves, need to be examining the issues, obstacles and benefits associated with release and sharing of data and best practice comparison. The trade bodies could initiate dialogues in this area.

International coordination

The effectiveness of local, regional and national MetaCDM practice will be enhanced if international organisations show a lead and promote a dialogue. For the underlying obstacles such as lack of trust, competitive concerns or incompatibility of systems and data to be resolved, there has to be serious top-down buy-in and engagement. The recent Icelandic Volcano eruption and the ensuing transport chaos across Europe and beyond clearly illustrated the fragility of the system and the costs associated with not reacting effectively. There is already a recognition of the benefits of extending A-CDM but the case for applying the same principle to wider MetaCDM has yet to be made and accepted.

At the A-CDM level, there is already good engagement and leadership from Eurocontrol and acceptance by a large number of major airports. There is a need to extend the benefits of A-CDM to smaller airports. Many recognize the value of participation but, as structured, CDM places too great a resource burden on smaller airports and that inhibits take-up. Greater attention to concepts such as ‘CDM-Lite’ is needed to deliver the key communication and data benefits without necessarily providing the full coordination service and systems alignment that carries a significant capital and operational cost.

ANSPs could assist the wider airports network in a number of ways and it may be worth considering:

- Protocols that enable levels of filtered alert information to be passed through the network. This would clearly require a significant dialogue with stakeholders about the types, ranking and description of relevant alert information. It would also need to be based upon a clear understanding of the extent of the network of contributors and receivers of information;
- A web 'dashboard' of status information to which stakeholders could contribute. This could be run using a 'traffic light' system to help airports, airlines and others initiate appropriate levels of preventative or mitigation action and when to alert passengers to possible disruption;
- The establishment of intelligence/alert units that can capture non-operational features such as meteorological or security data and make that available to the network.

A major player in promoting and enabling the development and adoption of MetaCDM is the European Commission (EC). It is suggested that the Commission could actively promote a dialogue – given its multi-sectoral interests – between stakeholders in the context of its 4-hour door-to-door journey time ambition. It is in an ideal position to address high-level issues such as who takes responsibility for enabling different aspects of MetaCDM and providing the mechanisms by which the community can get together. Few of the individual sectoral trade bodies or organisations have the reach and influence to simulate interest beyond their own specific interests so the strategic vision that the EC provides is a strong asset in helping to mobilise experts across transport modes, the hotels sector, emergency services and regional representative bodies.

The Commission could consider promoting an international conference, aligned with the 4-hour door-to-door journey time goal that gathers together those who could:

- Expose experience and lessons learned from major disruptive events;
- Identify obstacles to realizing MetaCDM;
- Share research knowledge and current best practice in the sector;
- Outline a policy path towards development of systems and protocols that enable MetaCDM.

With business resilience being a boardroom priority, the influence of the EC in calling for corporate engagement could help to secure the engagement of major transport, travel and logistics players as well as the key trade-bodies. With the research community having now identified many of the main issues and obstacles through a number of FP7-funded projects, the time is right to move the debate on to the beginnings of the strategic planning and delivery phase for Meta-CDM. This would, apart from anything else, help to identify the key issues needing further in-depth research and provide the connections between the research and corporate communities to help make that happen.

In pursuit of its policy ambition to enhance the resilience of the transport network and to apply lessons learned from previous serious disruptive events, the Commission could consider establishing a ‘crisis bank’ that identifies and collates national and international resources that could be mobilized in the event of major events. The Icelandic volcano eruption event and some winter snow events have spurred some sharing of knowledge, resource and equipment. The existence of a register of such capabilities and mitigation support could be a valuable asset and resource to assist transportation service providers and others to deal with crisis events. This could also extend to the development and sharing of core contingency planning approaches and ways to communicate with passengers in the event of disruptive events, including the coordinated usage of media opportunities to alert travellers of disruption and offer advice on actions to ameliorate the worst effects.

With significant attention having already been given to resilience, CDM, multi-modal connectivity, passenger protection and business resilience by the EC, it is ideally placed to take a leadership role in advancing the case for MetaCDM with the global organisations such as the International Civil Aviation Organisation (ICAO). The EC, in conjunction with ICAO member states, could promote a programme of wider international activities, underpinning protocols and international research that would pave the way to some common enablers and practices that would help its own 4-hour door-to-door goal realization and help the aviation and linked systems to become more resilient.

The other group of international organisations that could apply some high-level influence and help towards realizing Meta-CDM is the various international industry trade organisations. In the case of aviation, the most prominent would be the Airports Council International (ACI), the International Air Transport Association (IATA), the Civil Air Traffic Services Organisation (CANSO) and other trade organisations that support subsets of the main parts of the sector. Trade bodies covering rail, road and logistics should also be involved.

Taking the IATA example, the organization offers standards and drives processes to improve airline efficiency and it engages with other trade bodies, but it does not have the power to mandate changes. It already engages with relevant initiatives such as the Flight Interruption Manifest (FIM), a document issued by an airline as a substitute ticket coupon when the passenger's original travel is disrupted by schedule change, overbooking, or cancellation. A FIM is generally issued at a gate, ticket counter or transit desk by an airline agent and will record their original routing and ticket numbers, as well as those of the new routing, therefore making the FIM the new ticket. A FIM is only valid for a specific flight on a new airline that is not necessarily the airline the ticket was originally issued with. For example, a gate agent from Airline 1 could produce a FIM for a flight on Airline 2 and send the data to Airline 2. The FIM would then be accepted as a regular ticket on the specified Airline 2 flight. Flight interruption manifests are perceived by flying passengers and airlines as increasingly impractical, especially with the widespread use of electronic ticketing.

Two recent IATA initiatives are the elimination of the FIM and the Fast Travel Program. Eliminating the FIM means transitioning to electronic re-ticketing, in order to promote a paperless environment and assist airlines in re-accommodating passengers with other carriers. The Fast Travel Program aims at improving the airport and airline experience by implementing self-service capabilities. A self-service environment for flight rebooking and baggage recovery can help all agents to reduce costs while accelerating the average processing time of re-accommodation, which could greatly improve irregular operations. A program of this kind could also be applicable to minor or moderate journey disruptions. IATA has the reach to be able to examine the efficacy of other travel efficiency initiatives for normal operational conditions as well as link with a dialogue on measures to help operator performance and passenger experience.

The importance of the trade bodies being involved is significant as they can help to win hearts and minds towards the benefits of MetaCDM. They can help propagate a discussion amongst the airports and carrier networks and distil from members the attributes that they would like to see involved in MetaCDM and A-CDM-Lite. As repositories of sector knowledge, the trade bodies are also very well placed to gather and then disseminate ‘best practice’ information, such as Frankfurt Airport’s colour coding approach towards disruption management, that can help to improve the efficiency of the sector as a whole. An extension of the accumulation of ‘best practice’ knowledge is the desire to actively share it with those who work daily with the issues in different parts of the sector. Trade bodies could therefore support or offer training to member companies (whether in person or via desktop modules) that communicate A-CDM and MetaCDM practice. It may be rather premature to be thinking in such terms at the present time but it is reasonable to envisage that such training actions will be needed within the foreseeable future as the concept takes hold.

A key first step in moving the MetaCDM dialogue forward is to establish fora that allow for the issues to be discussed. This should be something that the Commission could propose, even if it is practically taken forward by one of the trade bodies. Linked to this step would be the engagement of the trade bodies (international and national) in resilience fora that support the cascading of information.

3 MetaCDM Functional Groups

The Functional Groups of MetaCDM are now introduced as a concrete basis for empowered and guided travel. Any action mechanism to be triggered relies on information sharing, which is described in section 3.1. This differs in quality and quantity for empowered and guided travel.

The action mechanisms are triggered by milestones, e.g. the traveller leaving home. The milestones are described in a similar way to the A-CDM milestones for comprehensiveness in section 3.2. For each milestone, a calculation/prediction is triggered if travellers are able to reach a predefined target in time or if a re-planning of their journey becomes necessary. The variable process and passenger transfer time between milestones deemed important for the chosen service is topic of section 3.3. The exchange of updated information for milestones, process and travel times is described in section 3.4, Collaborative Management of Travel Updates.

An important part of MetaCDM is the performance based management of travel, which should be agreed upon between the service provider or travel agency and the traveller before the beginning of their journey, e.g. ideally before the traveller leaves home. Choosing and evaluating this travel should be based on normed / commonly agreed performance criteria and is described in section 3.5.

Adverse conditions and how these are mitigated constitute critical issues for any travel. Section 3.6 deals with MetaCDM in Adverse Conditions.

3.1 Information Sharing

This chapter describes the overall information sharing process (interaction) between stakeholders (including airport stakeholders, passengers and alternative transport mode providers) in normal operations (e.g. information sharing of estimated on-block times, number of passengers, etc.).

Both forms of travel require some information sharing between the transportation service provider or travel agent and the traveller in order to function properly. If not all information is provided this limits the forecast ability, e.g. if no position data or at least a message for reaching a milestone is provided by the traveller, there is no possibility for the transportation service provider to calculate alternatives. A bigger difficulty would be missing information on schedule changes of the chosen travel connection, as this would disable empowered travelling entirely.

Even though no entity has perfect information, an airport or airline should be able to deliver better and timelier information than third-party flight-tracking websites or mobile applications. In case of disruptions attributable to the airlines, for instance a mechanical issue, use of statistics on past similar events could help to deliver estimates of repair durations. In case of weather or air traffic delays, data-mining techniques could support the identification of patterns using airport capacity, time of day and weather magnitude, which can be translated into estimated departure time and communicated to the passengers. Even though some estimates might be more accurate than others, in most cases this process would yield benefits.

Improving communication between transportation service provider and customer regarding journey disruption relies on four aspects:

- Gathering accurate and timely information about journey disruption,
- Re-accommodating the passenger proactively,
- Communicating with passengers directly and transparently, and
- Offering passengers new booking options through mobile devices, websites or kiosks at airports.

The timeliness and transparency of the communication is critical, especially when third-party apps or social media sometimes provide real-time information from other sources that may not be accurate. It is important that any information provided to the traveller is in their chosen language. Every passenger should receive the following information in a timely manner:

1. Alerts of flight cancellation as soon as it happens with information on the fact that they will be informed soon (with a precise timeline) on the different re-accommodation options they will have.
2. Possible re-accommodation options:
    - Travel cancellation and reimbursement of the travel ticket
    - Transfer to another flight with the corresponding schedules and application of passenger rights (meal, hotel)
    - Alternative transport mode solution to reach the destination, without extra charges, including schedule details (departure and arrival times, successive transport modes, etc.)
3. Once passengers have chosen a specific option, information should be communicated about the process they should follow to:
    - get their tickets reimbursement and collect their luggage,
    - find a meal and/or hotel booking and/or to go to the appropriate terminal area,

- obtain alternative transport mode tickets and/or be at least partly refunded from the original air ticket flight,
- pick up their luggage and to reach the ground transport area (train station, bus station, etc.).

Maps and/or schedules regarding other modes should be provided on screens or available on mobile devices. Table 4 lists what information should be exchanged between the traveller and the service provider or travel agent to enable MetaCDM.

Form of travel	Information needed from traveller	Information provided to traveller
Empowered	Origin of travel, e.g. home address (mandatory), Exit point(s) of desired travel connection(s) (mandatory), Actual position data (GPS - recommended) or At least a message at what time a milestone is reached (mandatory, if GPS data is not provided).	Information about the travel connection, e.g. flight number (mandatory), Milestones (mandatory) with target time at milestones (mandatory) and Estimated transfer time between milestones (recommended).
Guided	Origin of travel, e.g. home address (mandatory), Destination of Travel (address, mandatory), Target time for arrival at destination (recommended), Actual position data (GPS - recommended) or At least a message if a milestone is reached (mandatory, if GPS data is not provided).	Information about the travel connections, e.g. flight number (mandatory), Milestones (mandatory) with target time at milestones (mandatory), Estimated transfer time between milestones (mandatory) and Alternative routes if needed in adverse conditions (mandatory); this includes the important milestones, e.g. a stop at a hotel, change of transportation mode etc.

Table 4: Flow of information from and to the traveller

If possible, the planning of the travel should be based on normed performance parameters that are set by the traveller, see section 3.5. This setting should be used by the transportation service provider to select the most fitting travel.

Sources of information

Information regarding flight departure delay or cancellation should be provided by the airline. It is up to the airline to manage the re-accommodation of passengers and offer them options, even if the delay is not their responsibility. If the passenger opts to continue their journey with another airline or with another mode of transportation, the first airline should provide information to the passenger about the details of the re-accommodation and the second airline should provide the new flight information details.

Information relating to queuing times at airport check-in, baggage drop counters, security check-points, shuttle timetables, availability of information counters, is the responsibility of the airport.

Information regarding the availability of other modes of transportation (bus or train schedules, maps and estimated travel length, taxi waiting time, etc.) is the responsibility of these other modes, but should also be made available by the airport and accessible from other areas than just the train/bus/taxi station.

3.2 Passenger Travel Milestone Approach

This chapter describes the milestones of the passenger travel in order to enable the calculation of process and transfer times as well as the definition of target times.

Milestones are needed to define nodes for the chosen travel within the connection network. These milestones should be monitored before and throughout the journey to check if the chosen connection is still reachable or if a re-planning of the travel must be done.

As discussed in section 2.2.1, all milestones in MetaCDM refer to calculating or predicting the planned or target time when the traveller starts their journey (the A-CDM equivalent is the TSAT) and to reaching a critical transport service such as long haul flights or long distance trains that must be reached or the travel will be significantly delayed (the A-CDM equivalent is the TTOT). The equivalent for the Calculated Take-Off Time (CTOT) is the critical transport service itself which must be changed or re-booked in case of a passenger delay.

3.2.1 Passenger Travel Milestones for Empowered Travel

After booking a travel connection from a transportation service provider, this provider is usually responsible for defining the target time at a resource, such as the time at gate for a flight with an airline, or the time at platform for journey by train with a railway company. In order to empower the traveller to meet this target time, which is also in the interest of the service provider, milestones are defined by MetaCDM, see Figure 1. At these milestones the travel itinerary should be recalculated to check if the traveller is still able to reach the defined target time at the resource. The service provider should provide estimates on travel time between milestones and the traveller is responsible to plan their own “processes”, e.g. the transfer time from park deck to airport entrance, in order to meet the milestones.

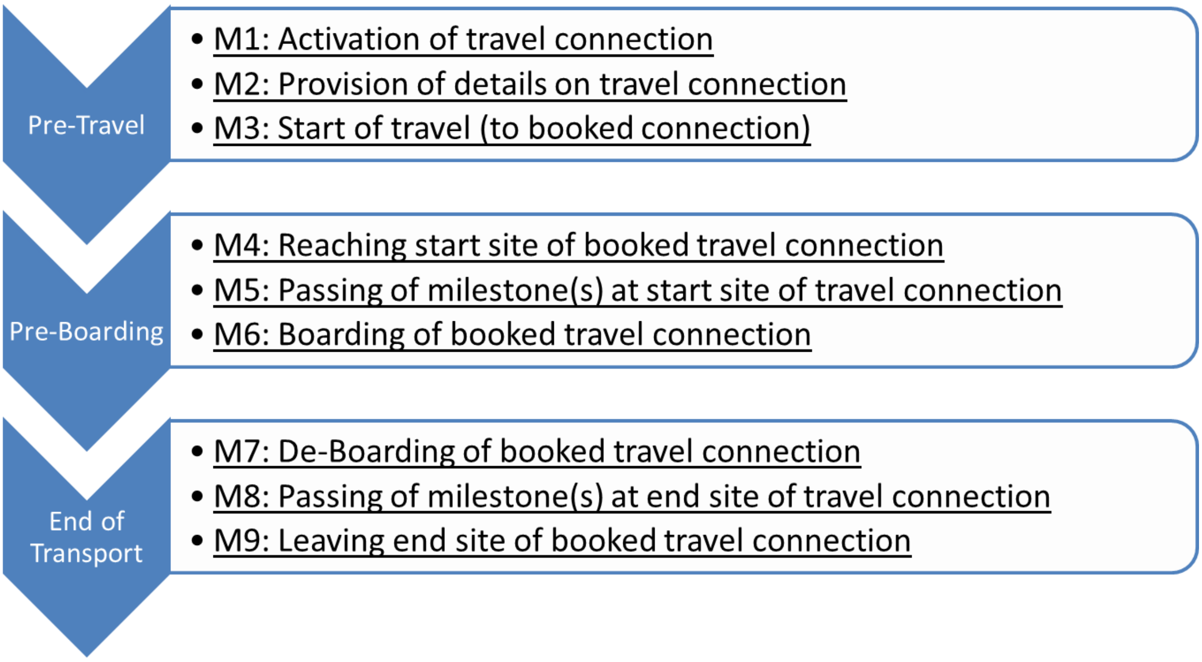

Figure 1: MetaCDM milestones for empowered travel

It is important to notice that travellers can book more than one travel connection from one or more service providers in order to reach their destination. The milestones in Figure 1 describe the nodes that should be used for each of these travel connections. The destination/end of one travel connection is then the initiation (milestone 3) of the next travel connection. For the remaining connection(s), milestones 1 and 2 might be executed before the travel starts or while the traveller is already journeying.

MetaCDM milestones for empowered travel:

1. Activation of travel connection: The traveller books a certain travel connection from a transportation service provider and provides information necessary to enable empowered travel, see section 2.1.2.

    - How and why the connection is chosen is up to the traveller, but the reasoning might be based on their chosen performance parameters, see section 3.5.
    - Travellers are responsible for the remainder of their journey once the service provider has transported them to the end of the booked travel connection.

- Travellers receive a ticket for their chosen travel connections including mandatory and chosen recommended milestones, e.g. their departure time.

2. Provision of details on travel connection: The transportation service provider informs empowered travellers about target times at milestones and estimated transfer time between milestones, see section 3.1. These target times should be updated as needed as described in section 3.4.
3. Start of travel (to booked connection): The empowered traveller either starts their journey (e.g. leaving home), or is at the destination of the previous travel connection and ready to transfer to the following travel connection.
4. Reaching the start site of the booked travel connection: The traveller arrives at the desired entry point to the booked travel connection which might be an airport, a train or bus station or a car rental, for example.
5. Passing of milestone(s) at the start site of the travel connection: This milestone might consist of one or more resources for which times are planned and monitored, such as check-in, baggage drop, border control or security check at an airport. How many resources are separately monitored heavily depends upon the chosen mode of transport and of the possibilities offered by the start site, e.g. check-in at car rental agency.
6. Boarding of the booked travel connection: The traveller boards the booked travel connection and in the case of a flight, is no longer able to influence the arrival time at their destination or next travel connection. The travel connection itself might be subject to a different kind of collaborative decision making, e.g. A-CDM for a flight connection.
7. De-Boarding of the booked travel connection: The traveller disembarks from their chosen transport vehicle and enters the end site of their critical (booked) travel connection.
8. Passing of milestone(s) at the end site of the travel connection: This milestone might consist of one or more resources for which times are planned and monitored, such as border control, baggage claim or toll at an airport. The number of monitored resources heavily depends upon the chosen mode of transport and differs in case of an ongoing connection flight/train/bus with the same transportation service provider, e.g. a connecting flight. In the latter case the next milestone for the follow-up travel connection would be milestone 5.
9. Leaving the end site of the booked travel connection: The traveller leaves the desired exit point from the booked travel connection which might be at an airport, a train station or bus terminal or a car rental location, for example.

The empowered travel ends with the traveller leaving the end site of the booked travel connection as the service provider is not responsible for the further journey. If there is a follow-up travel connection this would again start with milestone 1, which might take place before or during the previous travel connection.

3.2.2 Passenger Travel Milestones for Guided Travel

The traveller sets the initial target time at destination and the service provider is accountable for calculating/planning achievable milestones for the traveller that enable them to arrive at the set target time. For each milestone, the travel agency monitors if the journey can commence as planned and publishes actual estimates on travel times between the milestones and updates for reaching the milestones. If a deviation occurs the travel agency automatically checks for alternatives and provides the traveller with a re-planned route and milestone information.

The MetaCDM milestones for guided travel include:

1. Activation of travel connection: The traveller books a travel at a travel agency and provides information necessary for guided travel, see section 2.1.2.
    - How and why the connection is chosen is up to the traveller, but the reasoning might be based on their chosen performance parameters, see section 3.5.
    - The travel agency is responsible for the entire door-to-door journey from origin to destination and books any needed travel connections for the traveller.
    - The traveller receives ticket(s) for their planned travel connection(s) containing mandatory and chosen recommended milestones from the travel agency.
2. Provision of details on travel connection: The travel agency informs the guided traveller about target times at milestones and estimated travel time between milestones for all needed travel connections, see section 3.2. These target times should be updated if needed as described in section 3.4.
3. Start of travel (to booked connection): The guided traveller starts their journey, e.g. leaves home.
4. Reaching the start site of the booked travel connection: The traveller arrives at the desired entry point to the booked travel connection, which might be an airport, a train or bus station or a car rental for example.
5. Passing of milestone(s) at the start site of the travel connection: This milestone might consist of one or more resources for which times are planned and monitored, such as

check-in, baggage drop, border control or security screening at an airport. The number of monitored resources heavily depends upon the chosen mode of transport.

6. Boarding of the booked travel connection: The traveller boards the booked travel connection and in the case of a flight, is no longer able to influence the arrival time at their destination or next travel connection. The travel connection itself might be subject to a different kind of collaborative decision making, e.g. A-CDM for a flight connection.
7. De-Boarding of the booked travel connection: The traveller disembarks from his/her chosen transport vehicle and enters the end site of their travel connection.
8. Passing of milestone(s) at the end site of the travel connection: This milestone might consist of one or more resources for which times are planned and monitored, such as border control, baggage claim or toll at an airport. The number of monitored resources heavily depends upon the chosen mode of transport and differs if there is a follow up connection with the same mode of transport at the same site, e.g. a connecting flight. In this case the next milestone for the follow-up travel connection would be milestone 5.
9. Leaving the end site of the booked travel connection: The traveller leaves the desired exit point from the booked travel connection, which might be at an airport, a train / bus station or a car rental location for example. If the travel continues with another mode of transportation the next milestone would be milestone 4.
10. Reaching the final destination: The guided travel ends with the traveller arriving at the final destination of their journey, see Figure 2 in section 3.3.

The service provider is responsible for planning and monitoring the whole journey from door to door. This includes finding alternative modes of transportation and re-booking of connections if needed.

3.3 Variable Process and Transfer Time Predictions (VPTT)

This chapter describes the prediction of process times (e.g. waiting time at check-in) and transfer times (e.g. travel time from home to terminal, walking time from check-in to security). Input data and supporting software requirements are also described.

The arrival of the traveller at milestones and planned/monitored resources (milestones 5 and 8) of the chosen travel connection might be subject to changes on short notice. Thus the calculation of transfer times between milestones and planned/monitored resources is an important element of the MetaCDM concept. The (re-)planning of the travel connection should take into account transfer times according to dynamic travel changes and calculation of queuing (process times) at planned/monitored resources, e.g. at check-in, at security etc.

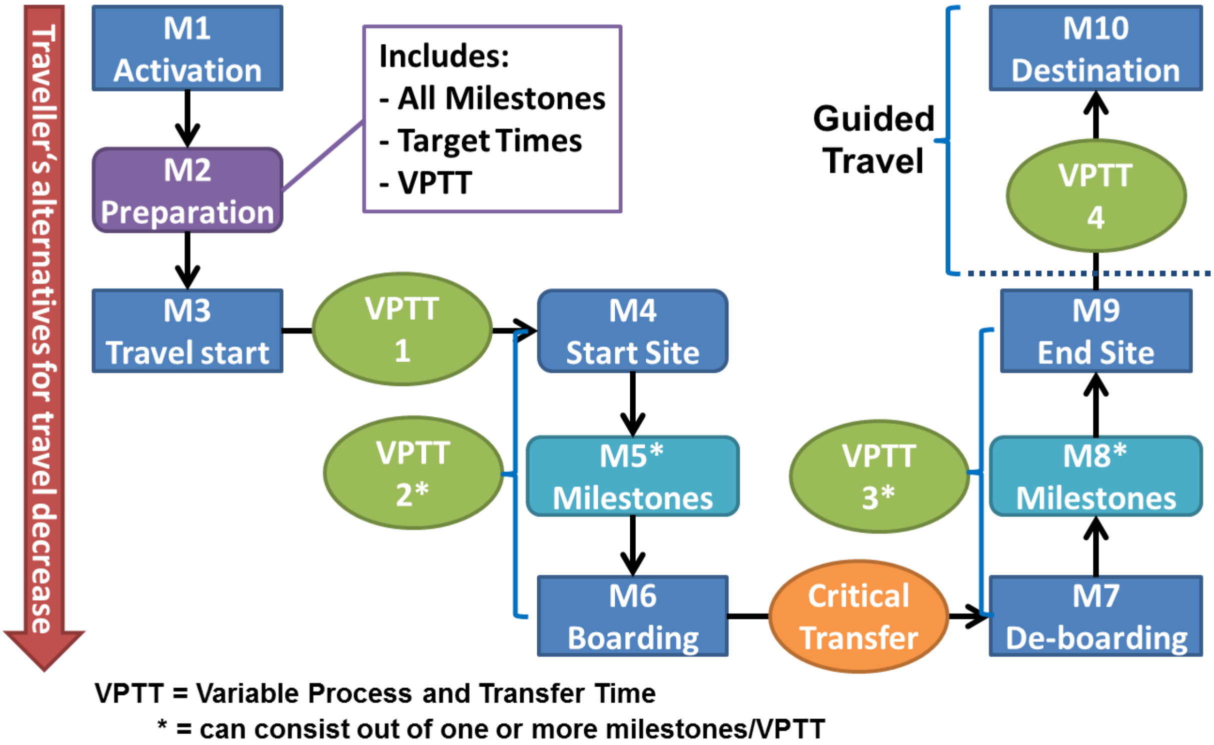

Figure 2: Flowchart on Milestones and VPTT

Predictions of variable process at and variable transfer times between milestones for empowered and guided travel should be calculated for the following durations:

- VPTT(1) between milestones 3 and 4: Transfer time between start of travel (origin) and reaching the start site of the booked travel connection.
  - Transfer time by car/taxi might be predicted using traffic updates from internet, radio (news on congestion) or from traffic advisory tools,
  - Transfer time by public transportation should be updated by the public transportation service provider and made available as a web service or app,
  - Transfer time for bicycle or walk can be predicted by the traveller. Normally an average walking time between adjacent modes of transport is published by a public transportation service provider, e.g. the walking time from a train station to an adjacent bus station or car rental.
- VPTT(2*) between milestones 4 and 6:

    - The number of monitored resources at milestone 5 differs depending upon the size and complexity of the start site. One VPTT for all resources should be sufficient for small train stations and airports; large and complex train stations and especially hub airports might provide more than one VPTT, e.g. Terminal entrance to Check-In, Check-In to Security and Security to Gate.
    - Average transfer times are normally provided by the owner of the start site, e.g. the average walking time from car park to a terminal of an airport is normally published by the airport authority and available on its web site or via its airport app.
    - Process times for monitored resources like check-in and security should be monitored by the operator of the resource and should be published in real time.
- VPTT(3*) between milestones 7 and (resources at) milestone 9:
    - The number of monitored resources at milestone 8 differs depending upon the size and complexity of the end site. One VPTT for all resources should be sufficient for small train stations and airports; large and complex train stations and especially hub airports might provide more than one VPTT, e.g. Gate to Baggage Claim.
- VPTT(4) between milestones 9 and 10 for guided travel: This Transfer Time is added at the end of the overall travel.
    - Transfer time by car/taxi might be predicted using traffic updates from internet, radio (news on congestion) or from traffic advisory tools,
    - Transfer time by public transportation should be updated by the public transportation service provider and made available as a web service or app,
    - Transfer time for bicycle or walk can be predicted by the traveller. Normally an average walking time between adjacent modes of transport is published by a public transportation service provider, e.g. the walking time from a train station to an adjacent bus station or car rental.

3.4 Collaborative Management of Travel Updates

This chapter describes the information sharing with passengers in case of travel updates. Travel updates include both updates triggered by management of disruptive events (e.g. delays, flight cancellations) as well as passenger travel updates (e.g. road traffic jam). The related Functional Group in A-CDM is Collaborative Management of Flight Updates (COFU) and in general it refers to Monitoring / Alerting and the exchange of Flight Update Messages (FUM) and Departure Planning Information (DPI). For MetaCDM this is the information exchange between the Traveller and the Travel Service Provider for empowered travel or the Travel Agent for guided travel.

Which information should be exchanged is described in chapter 3.1. Similarly, another important aspect for any final implementation of MetaCDM is the technical requirements for the data exchange, e.g. a mobile device with GPS functionality is needed to track the location of the traveller in real time. However, the technical and interface requirements for MetaCDM are not within the scope of the initial concept development in this document, so are not detailed here.

3.4.1 Quality of data

3.4.1.1 Accuracy of data

The exchanged data should be of a suitable accuracy to make decisions for empowered and guided travel. While in most cases the data is not very precise a long time before approaching a milestone, the data should become more precise as the traveller nears this milestone and be exact when the traveller reaches a milestone providing actual time and location. If the traveller misses a milestone there might be an agreed buffer time before a recalculation of the travel is executed.

Some sources of delay may affect multiple stages, leading to greater-than-usual journey times throughout the journey. For example, winter weather may cause delays both on ground transport and to flights, and may also affect staff availability leading to longer queues. In the end, each traveller chooses a trade-off between big buffers for Milestones resulting in a higher certainty to reach a critical travel connection and low or no buffers resulting in a lower certainty to reach a critical travel connection.

Each traveller can contribute to the process by predicting the certainty of reaching a critical travel connection by themselves, not as a percentage but on scale of most likely, likely, maybe, unlikely etc. Based on the related estimated travel time the traveller then chooses the appropriate start time for the beginning of travel (Milestone 3). The transportation service provider or travel agent can provide information to support this process, such as estimates based on historical data for the time function buffer versus certainty, for example the needed average buffer in 10 percent steps of certainty. As this is an asymptotic function a certainty of 100 percent cannot be reached. Then it is up to the traveller to decide what degree of risk they want to take. Some travellers might want to take more risk in trade for a shorter overall travel time while other travellers might be more cautious but in return need a longer overall travel time.

3.4.1.2 Timeliness of data

The timeliness of data exchange is very important for empowering the traveller and it also enables the travel service provider to make a good prognosis of the progress of the journey, for example if a milestone is reachable in time. The later information is exchanged, the more limited will be the availability of alternatives and/or countermeasures.

A good example for this is information about a traffic jam on the highway to the airport that would delay travel by car for 30 minutes. If this information is communicated to the traveller 30 minutes before they leave home, they have following possibilities to react:

1. Leave home 30 minutes earlier and take the originally foreseen route (highway),
2. Try an alternative route if possible,
3. Choose another mode of transport if possible, e.g. train.

But if the information is communicated too late, the number of options decreases and, in the worst case, no alternative might be available anymore. If the traveller is already within the traffic jam on the highway, either this delay can be absorbed through journey time buffers, or processes later in the journey could be shortened to allow the traveller to board their critical travel connection in time. If neither of these are possible, the journey would have to be re-planned.

3.4.2 Process and/or Transfer Time Updates

The Variable Process and Transfer Time Predictions (VPTT) should be under continuous monitoring meaning that either in real time or at short time-based intervals (e.g. every 5 minutes) process and transfer time predictions should be recalculated and compared to the previous predictions. If a deviation above a defined tolerance is detected, the new prediction should be published as a process and/or transfer time update. The question "How to define the threshold of this tolerance" is currently out of the scope of this document; it should be answered after a longer field trial in which different thresholds for tolerances are tested and validated. All thresholds of tolerances used in this document are a best guess and should be adjusted if first test results / measurements become available.

<u>Thresholds for sending estimates of reduced VPTT</u>

The threshold for sending a Process and/or Transfer Time Update can be bigger if the updated prediction indicates a shorter process or travel time than before, because this can only positively influence the chance of the traveller to reach the critical connection.

<u>Threshold for sending estimates of increased VPTT</u>

The threshold for sending a Process and/or Travel Update should be small if the updated prediction indicates a longer process or travel time than before, because depending on the buffer this might negatively influence the chance of the traveller to reach the critical connection.

3.4.2.1 Process Time Updates

The process times at milestones are usually predicted and monitored on behalf of the travel service provider. Depending upon the complexity of the start site of travel, e.g. an airport, the prediction might be a rule of thumb based on best guess or historical data or the prediction might be based on monitoring of e.g. the queue length or on measuring the time that a traveller needs from end of queue until being served at the resource.

3.4.2.2 Transfer Time Updates

A Transfer Time Update informs the traveller about deviations of their actual progress from the last transfer time prediction. The source for the prediction of transfer times between milestones will differ: for example, the transfer time within a terminal is normally predicted by the airport and not by the airline. In some cases a Transfer Time Update may be received from a third party, e.g. heard in traffic news. Here the traveller could inform the transportation service provider via a Travel Progress Update.

3.4.2.3 Travel Progress Update

The traveller updates their travel progress between two milestones if they estimate that the foreseen travel or process time is not fitting any more. A Travel Progress Update is not necessary if the following milestone can be reached in time but should be done if the traveller estimates that they will miss the next milestone by more than 5 minutes.

An example would be a delayed train connection (where that information is not already available via the train operator), accident on a highway (where that information is not already available via traffic information providers) or a malfunction of the current transport vehicle. In these cases the traveller should provide the transportation service provider with an estimated arrival time at the next milestone based on the best information they have. This could be done based on best guess or on traffic information if available.

3.4.3 Travel Milestone Update

This section describes reasons and triggers for updating travel milestones to enable empowered and guided travel.

3.4.3.1 Transportation Service Provider updates Milestone(s)

The transportation service provider updates milestone(s) for the travel connection, e.g. because of an expected delay. There are two triggers for milestone updates that are handled differently: changed VPTT and changed availability of resources.

Changed VPTT causes Travel Milestone Update

If the VPTT between two milestones changes, this affects all milestones and VPTT before. Milestones and VPTT after it will remain unaffected unless a new travel connection must be selected. This will be the case if the changed VPTT becomes longer than the sum of buffers before it meaning that the milestone after the changed VPTT cannot be reached any more.

A longer VPTT should be communicated to the traveller immediately to allow them to take countermeasures. Even if the travel plan foresees enough buffers the traveller needs to be aware that the planned buffers have to be reduced in order to make the affected milestone in time. If the traveller, for example, uses the planned buffer time for drinking a cup of coffee before going through security, they will have no problem to simply forgo the coffee to catch up time. But to do this the traveller must be aware of the problem.

A shorter VPTT is usually no problem and smaller deviations might not be communicated. But larger deviations should be communicated to comfort the passenger, and to allow them to make plans if necessary about how to use the increased buffer time.

Changed availability of resource(s) causes Travel Milestone Update

While the unavailability of some resources, like the unavailability of one out of several check-in desks, only influences the process time, other resources such as the unavailability of the critical transport resource (e.g. the aircraft) will severely impact all milestones and might even lead to re-booking onto another travel connection.

3.4.3.2 Traveller updates Milestone(s)

This section deals with milestones that are updated directly or indirectly by the traveller. Directly means that the traveller gives input about reaching/making or missing a milestone while indirectly means that an action carried out by the traveller, such as checking in, triggers an update of their travel status.

Traveller reaches/makes a milestone

The traveller should inform the transportation service provider when they reach a milestone within 5 minutes. This is the actual time for the affected milestone which must not be updated anymore and gives the transportation service provider a better estimate if the traveller will make its journey as planned. This process can be an automated one based on, e.g. GPS data or, if the passenger is unwilling to share location data, it could be done manually (although in this case procedures need to be in place for travellers forgetting to update their information, providing partial data, or incorrectly stating that they have made a milestone when they have not).

Traveller misses a milestone

If the traveller misses a milestone, this should be communicated at once because, depending on the milestone, there might be the need to recalculate the entire travel (re-routing). If the traveller for example misses a train to an airport there is either the possibility to wait for the next train if enough buffer exists to absorb the delay or alternatives have to be chosen like taking a taxi, their own car etc.

If the transportation service provider expects a delay which impacts further connections of the travel this should be communicated at once to enable the traveller to take an alternative. The later the delay is known the fewer alternatives the traveller will have to get the desired connection in time.

Travellers might hesitate to send a travel update in the case of a missed milestone if they see a small chance of still catching the critical travel connection. The transportation service providers should offer incentives for encouraging travel updates in these cases as they might profit from it in some cases, e.g. if the critical travel connection is overbooked or other travellers could be re-booked on this connection.

3.5 Performance Based Travel Management

A passenger-centric approach takes into account loyalty, lifetime value and passenger influence, in addition to direct costs. A passenger's journey disruption may impact brand loyalty and future booking behaviour. Passenger booking behaviour is more influenced by how airlines handle irregular operations than by their on-time performance. They may also influence other passengers' opinions through social media channels. Thus performance-based travel management is important for travellers and transportation service providers / travel agents alike.

Metrics for assessing passenger satisfaction were discussed in the first MetaCDM report. The European Norm EN 13816:2002-07 [4] defines eight quality criteria connected to passenger satisfaction: availability, accessibility, information, time, customer support, comfort, safety and environmental impact. These general areas are echoed by the other sets of quality criteria examined by the project, although some went into greater specificity in individual areas. The overall price for travel is a further performance criterion for MetaCDM because many customers are willing to sacrifice quality in return for cheaper travel.

Ideally, MetaCDM should improve satisfaction with respect to all these criteria. When only some of these criteria can be improved, the improvement should still offset decreased performance according to the remaining criteria, such that overall satisfaction is still improved. For example, under disrupted conditions, some passengers may want to trade off comfort for decreased overall delay (e.g. by taking an overnight coach service to their destination) whilst others may prefer a longer but more comfortable journey. The areas are discussed individually below, along with the principal impact that MetaCDM is envisaged to have. As environmental impact is discussed in section 4.5, it is omitted from the list here.

- **Availability** refers to the extent of the service offered in terms of geography, time, frequency and transport mode. Under normal conditions, MetaCDM should not alter service availability, but under crisis situations, airlines will be able to improve the effective frequency and geographic range of their services compared to the current system, leading to a net positive in this area.
- **Accessibility** can have multiple dimensions, as elaborated in the other passenger satisfaction criteria investigated in the first MetaCDM report. These criteria include ticket accessibility, transport mode accessibility to passengers with reduced mobility, staff accessibility, connections within and between transport modes, and an accessible complaint handling mechanism. MetaCDM aims specifically to improve communication between passengers and transport providers and to streamline the rebooking process when flights are cancelled, so MetaCDM will have positive impacts on many of these areas. Face-to-face staff accessibility may be lowered, however, as passengers in crisis conditions may not be able to pass through the airport. Similarly, accessibility for passengers with reduced mobility and other special needs under crisis conditions must be carefully monitored. Passengers must have the option to specify their requirements and receive tailored alternative itineraries so that they can be sure they will be able to physically navigate all portions of the alternative journey.
- **Information:** MetaCDM specifically aims at improving the provision of information to passengers. In a MetaCDM environment we would expect passengers to have earlier and more reliable information about: flight delays and cancellations; problems getting to/into the airport; available options if their flight is cancelled and their rights in cases of disruption. Therefore MetaCDM should significantly improve passenger satisfaction on information-related criteria.
- **Time:** As with the information criterion, MetaCDM is directly aimed at reducing journey duration, both under non-disrupted conditions (via better information about

journey and process times en-route) and in crisis situations (by offering the use of alternative modes if it reduces the time of arrival at the final destination). MetaCDM should also reduce the amount of time passengers spend planning their journeys by improving information accessibility. Therefore MetaCDM should lead to improvements in time-related criteria for passenger satisfaction.

- **Customer Support:** Two support levels are envisaged under MetaCDM, as discussed in Section 2.1. Empowered Travellers receive more and clearer information about their journey but make their own decisions about how to use that information. This option is intended for travellers who prefer a lower and/or less intrusive level of support. Guided Travellers would receive extra support, for example with the selection and booking of alternative itineraries using ground transport, with the help of a travel agent. However, it both cases it is envisaged that communication will primarily be performed via electronic means. For passengers who prefer face-to-face support MetaCDM could be less preferable than current disruption handling methods. Thus it is possible that these passengers ignore MetaCDM communications in the case of cancelled flights and travel to the airport in the hope of getting face-to-face support. To avoid these behaviours, it is essential that all MetaCDM participants exercise good faith for passengers to build long-term trust in the system.
- **Comfort** under non-disrupted and/or delayed conditions: MetaCDM estimates of journey and arrival times should lead to passengers being able to spend more time at their desired place (e.g. at home) and decrease uncertainty, which should increase satisfaction on comfort-related criteria. Taking all or part of the journey via alternative modes in the case of flight cancellation may decrease passenger satisfaction (potentially significantly) if it is non-voluntary, for example if passengers are required to take a 10-hour coach journey. However, many passengers prefer to trade off comfort for an earlier arrival, so lower-comfort options should still be offered to passengers if these fit with their stated preferences. Ideally passengers should always be given the option of disruption handling as it is done currently, e.g. a night in a hotel and accommodation on the next flight to their destination with seats available.
- **Safety,** and passenger perception of safety, should not change much under MetaCDM in non-disrupted or delayed conditions. Under crisis situations there are some options which could make passengers feel less safe: for example, taking an overnight bus or train journey, or ground travel through a country they do not speak the language of. As with the comfort criterion, some passengers will prefer to trade off reduced delay for a travel environment in which they feel less safe. Passenger preferences need to be taken into account and the option of a hotel stay and flight once the disruption has passed should always be given. MetaCDM should however reduce passenger congestion and long/overnight passenger waits in airports, leading in turn to improvements in safety and comfort criteria.

- The **overall travel fare** will act in many cases as a limitation for the types of connection that can be chosen. As is discussed in Section 4, the hard cost of providing food and hotel rooms for passengers on a cancelled flight can be relatively low, as many passengers currently do not take advantage of their full rights. Acceptable solutions for the passenger and the airline will likely depend on the airline's business model, the passenger's rights under EC regulations, the passenger's ticket class and frequent flier status, the anticipated length of delay, and the preferences and status of other passengers on the cancelled flight, amongst others.

In order to provide the most fitting service to passengers, particularly in cases of disruption, ticket purchase would be accompanied by a selection of performance parameters by the passenger indicating their needs and preferences. This could include the above areas, and others that are specific to MetaCDM. For example, passengers might indicate that they would prefer an earlier journey start over a risk of missing their flight, that they would prefer to be re-accommodated onto the fastest method of getting to their destination regardless of comfort levels, or that they need a greater level of accessibility (e.g. mobility assistance). To set the desired performance parameters, a simple interface should be offered to the traveller. Ideally the performance of the available services is already rated according to European standards [5]. In this case the traveller setting the performance parameters allows the transportation service provider or travel agency to select the most fitting service.

3.6 MetaCDM in adverse conditions

We define a crisis event as an episode of major disruption that results in many cancellations at one or more airports. The circumstances leading up to these events were discussed more fully in the MetaCDM Work Package 100 report, but could include, for example, major snow events, volcanic ash, aircraft accidents, strikes, technical failures, fires or terrorism. In this section we focus on the specific issues for MetaCDM in crisis situations where large numbers of passengers face a cancellation of their connection. Often their chosen mode of transportation is simply not usable anymore, e.g. air transport due to an ash cloud, or train transport due to frozen overhead lines in extreme winter weather.

Such situations differ from disruptive events which lead primarily to delays. A crisis situation interrupts all MetaCDM successive milestones for empowered or guided passengers. Their connection no longer exists and as a consequence transfer times between milestones cannot be updated.

The first step to address such a crisis situation is to identify potential solutions to be provided to each passenger. This requires a Collaborative Management of Travel Updates.

Once the solution is chosen, the MetaCDM Functional Groups are activated with:

- New Passenger Travel Milestones,
- New information sharing and
- New Transfer Time predictions.

3.6.1 Identification of a solution for passengers

In case of flight cancellation, solutions to be proposed to the passengers can be grouped in four main categories:

- 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.

In other words, the range of possible solutions strongly depends on two main criteria:

1. The characteristic of the cancelled flight for the passenger: outward flight, inward flight or connecting flight, and
2. The length of the cancelled flight: short-haul flight (less than 3 hours) vs. medium or long-haul flight (more than 3 hours).

Table 5 summarises the possible solutions according to these two criteria.

<table>
<tr><th>Options according to cancelled flight characteristics</th><th>Outward flight</th><th>Inward flight</th><th>Connecting flight</th></tr>
<tr><td>Short-haul flight</td><td>• Reimbursement
• Transfer to another mode
• Other flight from same airport
• Other flight from another airport</td><td colspan="2">• Transfer to another mode
• Other flight from same airport
• Other flight from another airport</td></tr>
<tr><td>Medium/long-haul flights</td><td>• Reimbursement
• Other flight from same airport
• Other flight from another airport</td><td colspan="2">• Other flight from same airport
• Other flight from another airport</td></tr>
</table>

Table 5: Potential solutions for the air traveller according to the cancelled flight features

Once the first identification of possible solutions from the flight characteristics is completed, the second step consists of refining them according to the state of alternative transport modes:

- they face the same disruptive events (as often happens in case of bad weather conditions, such as heavy snowfalls),
- they do not face any disruptive event and continue operating close to normal.

No disruptive event for the alternative transport modes				Same disruptive event for alternative transport modes			
Options according to cancelled flight characteristics	**Outward flight**	**Inward flight**	**Connecting flight**	**Options according to cancelled flight characteristics**	**Outward flight**	**Inward flight**	**Connecting flight**
Short-haul flight	• Reimbursement • Transfer to other mode • Other flight from same airport • Other flight from other airport	• Transfer to other mode • Other flight from same airport • Other flight from other airport		**Short-haul flight**	• Reimbursement • ~~Transfer to other mode~~ • Other flight from same airport • ~~Other flight from other airport~~	• ~~Transfer to other mode~~ • Other flight from same airport • ~~Other flight from other airport~~	
Medium/long-haul flights	• Reimbursement • Other flight from same airport • Other flight from other airport	• Other flight from same airport • Other flight from other airport		**Medium/long-haul flights**	• Reimbursement • Other flight from same airport • ~~Other flight from other airport~~	• Other flight from same airport • ~~Other flight from other airport~~	

Table 6: Refinement of possible solutions for the passenger in case of same disruptive event affecting the other transport modes

Table 6 illustrates the refinement in the list of solutions for the passengers resulting from the non-availability of the alternative transport modes solution when they also face the same disruptive event. In that situation, only air ticket reimbursement and transfer to another flight from the same airport platform are worth considering since the two other options require the availability of other transport modes.

Then a third step of refinement is necessary to take into consideration the airport(s) affected by the disrupted event:

- only the departure airport is affected,
- only the arrival airport is affected,
- both departure and arrival airports are affected.

Table 7, Table 8 and Table 9 illustrate the possible solutions to be proposed to the passengers according to the airport(s) affected by the disruptive event.

	No disruptive event for the alternative transport modes				Same disruptive event for alternative transport modes			
	Options according to cancelled flight characteristics	Outward flight	Inward flight	Connecting flight	Options according to cancelled flight characteristics	Outward flight	Inward flight	Connecting flight
Only departing airport affected by the disruptive event	Short-haul flight	• Reimbursement • Transfer to other mode • Other flight from same airport to the initial destination airport • Other flight from other airport to the initial destination airport	• Transfer to other mode • Other flight from same airport to the initial destination airport • Other flight from other airport to the initial destination airport		Short-haul flight	• Reimbursement • ~~Transfer to other mode~~ • Other flight from same airport to the initial destination airport • ~~Other flight from other airport~~	• ~~Transfer to other mode~~ • Other flight from same airport to the initial destination airport • ~~Other flight from other airport~~	
	Medium/long-haul flights	• Reimbursement • Other flight from same airport to the initial destination airport • Other flight from other airport to the initial destination airport	• Other flight from same airport to the initial destination airport • Other flight from other airport to the initial destination airport		Medium/long-haul flights	• Reimbursement • Other flight from same airport to the initial destination airport • ~~Other flight from other airport~~	• Other flight from same airport to the initial destination airport • ~~Other flight from other airport~~	

Table 7: Possible solutions for passengers when only the departing airport is affected by the disruptive event

	No disruptive event for the alternative transport modes				Same disruptive event for alternative transport modes			
	Options according to cancelled flight characteristics	**Outward flight**	**Inward flight**	**Connecting flight**	**Options according to cancelled flight characteristics**	**Outward flight**	**Inward flight**	**Connecting flight**
Only arrival airport affected by the disruptive event	**Short-haul flight**	• Reimbursement • Transfer to other mode • Other flight from same airport to a different airport than the initial one • ~~Other flight from other airport~~	• Transfer to other mode • Other flight from same airport to a different airport than the initial one • ~~Other flight from other airport~~		**Short-haul flight**	• Reimbursement • ~~Transfer to other mode~~ • Other flight from same airport to a different airport than the initial one • ~~Other flight from other airport~~	• ~~Transfer to other mode~~ • Other flight from same airport to a different airport than the initial one • ~~Other flight from other airport~~	
	Medium/long-haul flights	• Reimbursement • Other flight from same airport to a different airport than the initial one • ~~Other flight from other airport~~	• Other flight from same airport to a different airport than the initial one • ~~Other flight from other airport~~		**Medium/long-haul flights**	• Reimbursement • Other flight from same airport to a different airport than the initial one • ~~Other flight from other airport~~	• Other flight from same airport to a different airport than the initial one • ~~Other flight from other airport~~	

Table 8: Possible solutions for passengers when only the arrival airport is affected by the disruptive event

	No disruptive event for the alternative transport modes				Same disruptive event for alternative transport modes			
	Options according to cancelled flight characteristics	**Outward flight**	**Inward flight**	**Connecting flight**	**Options according to cancelled flight characteristics**	**Outward flight**	**Inward flight**	**Connecting flight**
Both departing and arrival airports affected by the disruptive event	**Short-haul flight**	• Reimbursement • Transfer to other mode • Other flight from same airport to the initial destination airport or a different one • Other flight from other airport to the initial destination airport or a different one	• Transfer to other mode • Other flight from same airport to the initial destination airport or a different one • Other flight from other airport to the initial destination airport or a different one		**Short-haul flight**	• Reimbursement • ~~Transfer to other mode~~ • Other flight from same airport to the initial destination airport or a different one • ~~Other flight from other airport~~	• ~~Transfer to other mode~~ • Other flight from same airport to the initial destination airport or a different one • ~~Other flight from other airport~~	
	Medium/long-haul flights	• Reimbursement • Other flight from same airport to the initial destination airport or a different one • Other flight from other airport to the initial destination airport or a different one	• Other flight from same airport to the initial destination airport or a different one • Other flight from other airport to the initial destination airport or a different one		**Medium/long-haul flights**	• Reimbursement • Other flight from same airport to the initial destination airport or a different one • ~~Other flight from other airport~~	• Other flight from same airport to to the initial destination airport or a different one • ~~Other flight from other airport~~	

Table 9: Possible solutions for passengers when both departing and arrival airports are affected by the disruptive event

3.6.2 Information flows in case of flight cancellation

If the most relevant solutions that can be proposed to the passengers can be identified by the process of identification of possible solutions presented in section 3.6.1, their validation and implementation require communication flows between different stakeholders.

Although the exact details will differ between guided and empowered travellers, every passenger should expect to receive the following information in a timely manner:

1. Alerts of flight cancellation as soon as it happens with information on the fact that they will be informed soon (with a precise timeline) on the different options they will have. This alert may happen when the passenger is still at home, when they are travelling to the airport, or after they have arrived.
2. Possible re-accommodation options:
    - Travel cancellation and reimbursement of the travel ticket
    - Transfer to another flight from the same airport platform with the corresponding schedules and application of passenger rights as required (meal, hotel)
    - Transfer to another flight from another airport platform with the corresponding schedules, details of airport transfer and application of passenger rights as required (meal, hotel)
    - Alternative transport mode solution to reach the destination without extra charge and with schedule details (departure and arrival times, successive transport modes, etc.)
3. Once the passenger has chosen a specific option, information should be communicated on the process to follow:
    - to get their ticket reimbursement and collect their luggage (if luggage has already been dropped off),
    - to find a meal and/or hotel booking and/or to go to the appropriate terminal area,
    - to obtain alternative transport mode tickets and/or be at least partly refunded from the original air ticket flight, to pick up luggage (if required) and to reach the ground transport area (train station, bus station, etc.). Maps and/or schedules regarding other modes should be provided on screens or made available on mobile devices.

Four successive flows can be identified as illustrated in Figure 3. Blue boxes represent stakeholders while green boxes represent the transferred information.

- 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 passenger's 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. For instance, if the initial door-to-door journey booked by the travel agency included an urban train connection from the arrival airport to the traveller's final destination (home, hotel, etc.), and if after a cancellation the traveller has been rebooked by the airline on another flight, the travel agency will provide to the traveller new train schedules from the arrival airport to their final destination.

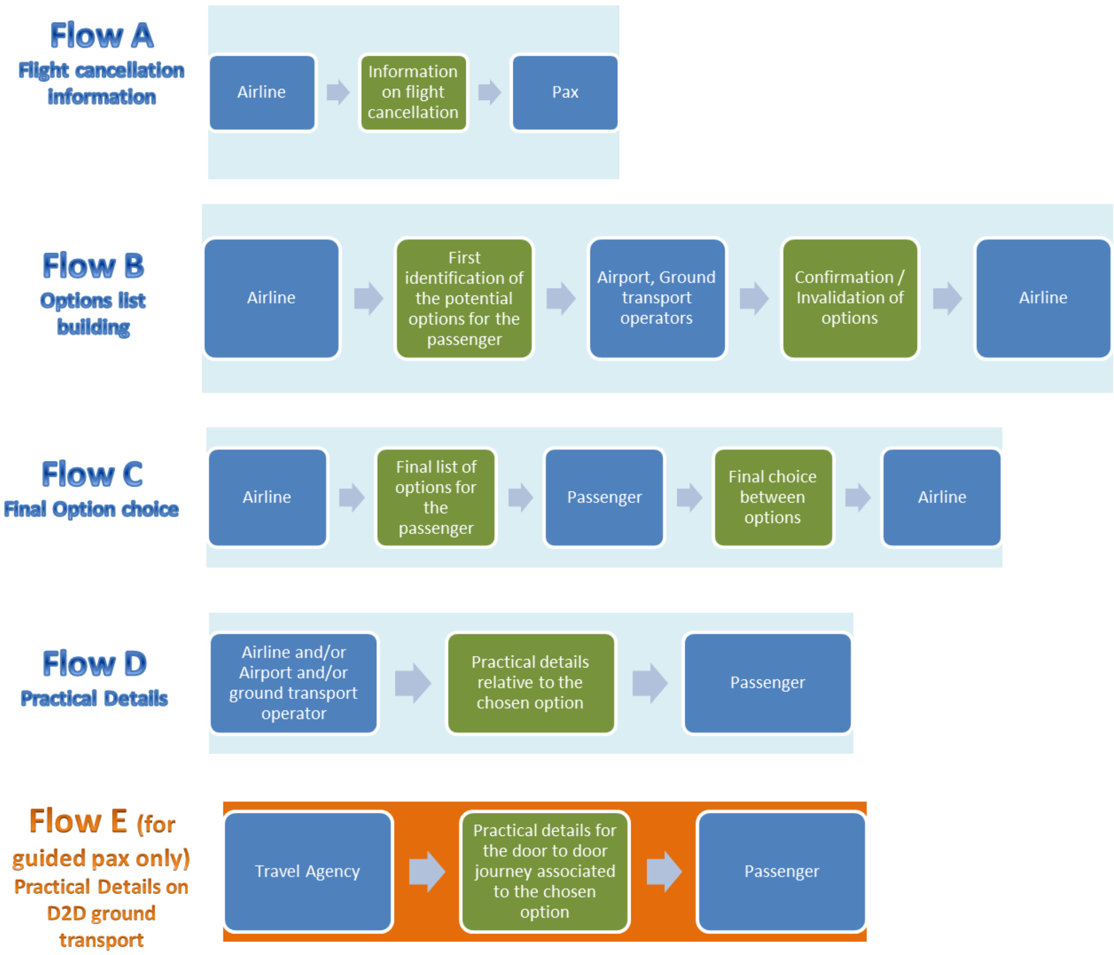

Figure 3: Successive flows of information in case of flight cancellation

The practical details of Flow D differ according to the chosen option as shown in Figure 4.

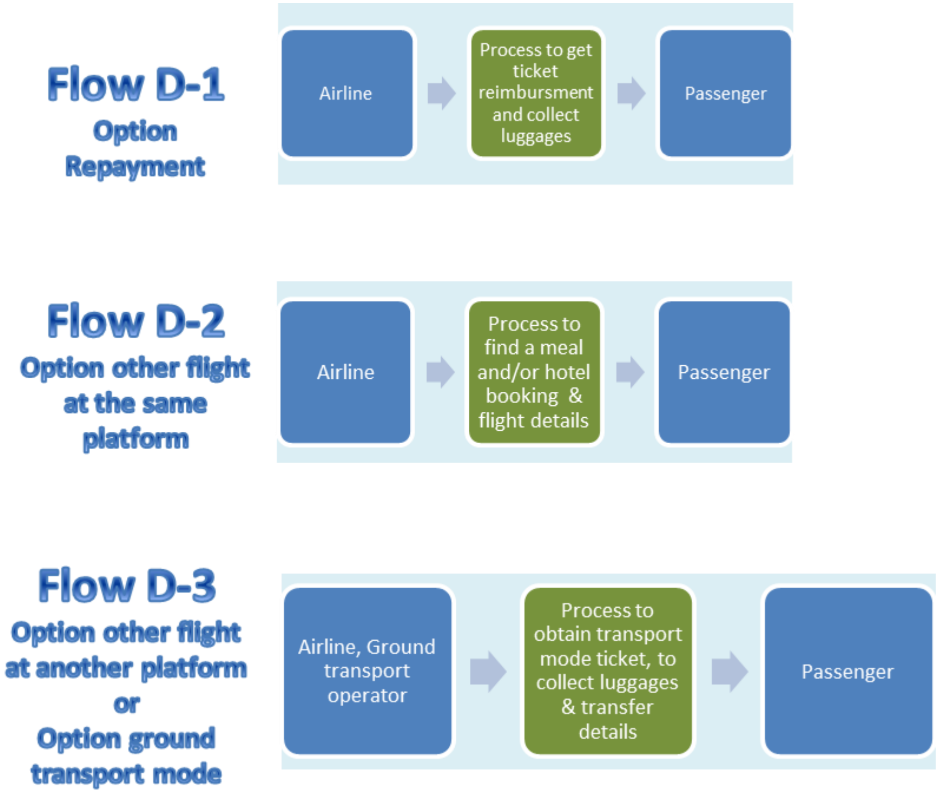

Figure 4: Possibilities for Flow D

3.6.3 MetaCDM Crisis milestones for passengers

In case of flight cancellation, the succession of MetaCDM milestones presented in 3.2 is stopped somewhere between milestone 1 and milestone 9. As in the MetaCDM concept an alternative has to be provided to the passenger, specific crisis milestones arise.

MetaCDM crisis milestones in case of flight cancellation are milestones A, B, C, D and E (where E only applies to guided travellers):

A. Information on flight cancellation provided by the air transport operator

B. Information on the list of options for alternative solutions provided by the air transport operator

C. Choice between options to be given by the passenger to the air transport operator

D. Information on practical details relative to the chosen option provided by the air transport operator

E. Information on practical details for door-to-door ground transport (for guided traveller only).

Once these milestones are complete, the following milestone is milestone 2 from the MetaCDM milestone set under nominal conditions, unless the passenger has chosen the option not to travel, in which case the milestone process stops. Figure 5 illustrates the milestone chain in the situation of flight cancellation, when this cancellation arises somewhere between milestone 3 and milestone 7. The nominal MetaCDM milestones stop as soon as the flight is cancelled since this flight no longer exists. In such an exceptional situation, new milestones adapted to the crisis situation are activated until the final provision of details on the alternative solution to the passenger (Milestone D for the empowered traveller or Milestone E for the guided traveller). Then a new journey is begun and the nominal milestones of this new journey are activated.

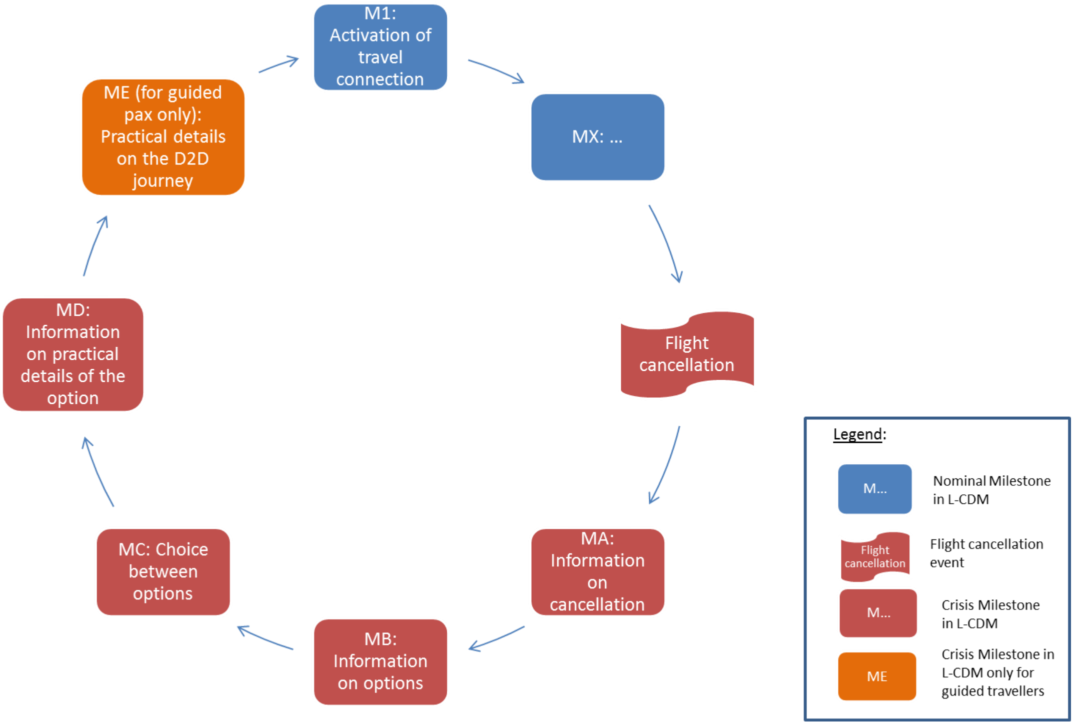

Figure 5: Illustration of MetaCDM milestones chain in a situation of flight cancellation

3.6.4 Variable Process and Transfer Time Predictions

In case of flight cancellation, the (re-)planning of the travel connection should factor in flexible route durations according to dynamic travel changes and calculation of queuing at milestones and planned/monitored resources.

For an Empowered passenger, the reaction times (RT) between milestones that should be calculated in the situation of flight cancellation are:

- RT between Flight cancellation and Milestone A: The time between the decision of flight cancellation and the provision of the corresponding information to the passenger,
- RT between Milestone A and Milestone B: The time between the information of the flight cancellation and the provision of options to the passenger,
- RT between Milestone B and Milestone C: Time between the provision of options to the passenger and the choice between options made by the passenger,
- RT between Milestone C and Milestone D: Time between the option choice of the passenger and the provision of practical details relative to this choice,
- RT between Milestone D and Milestone 1: Time between the provision of practical details relative to the chosen option and the activation of the new travel connection,

Then, nominal transfer times between the following milestones have to be calculated as explained in section 3.3.

Figure 6 illustrates the MetaCDM Reaction Times (RT) for an empowered traveller in a situation of flight cancellation appearing somewhere between milestone 3 and milestone 9. Once crisis milestones are activated, the times between milestones are no longer Variable Transfer Times (as in nominal MetaCDM) but become Reaction Times. They correspond to the time of reaction of the different stakeholders between the crisis milestones.

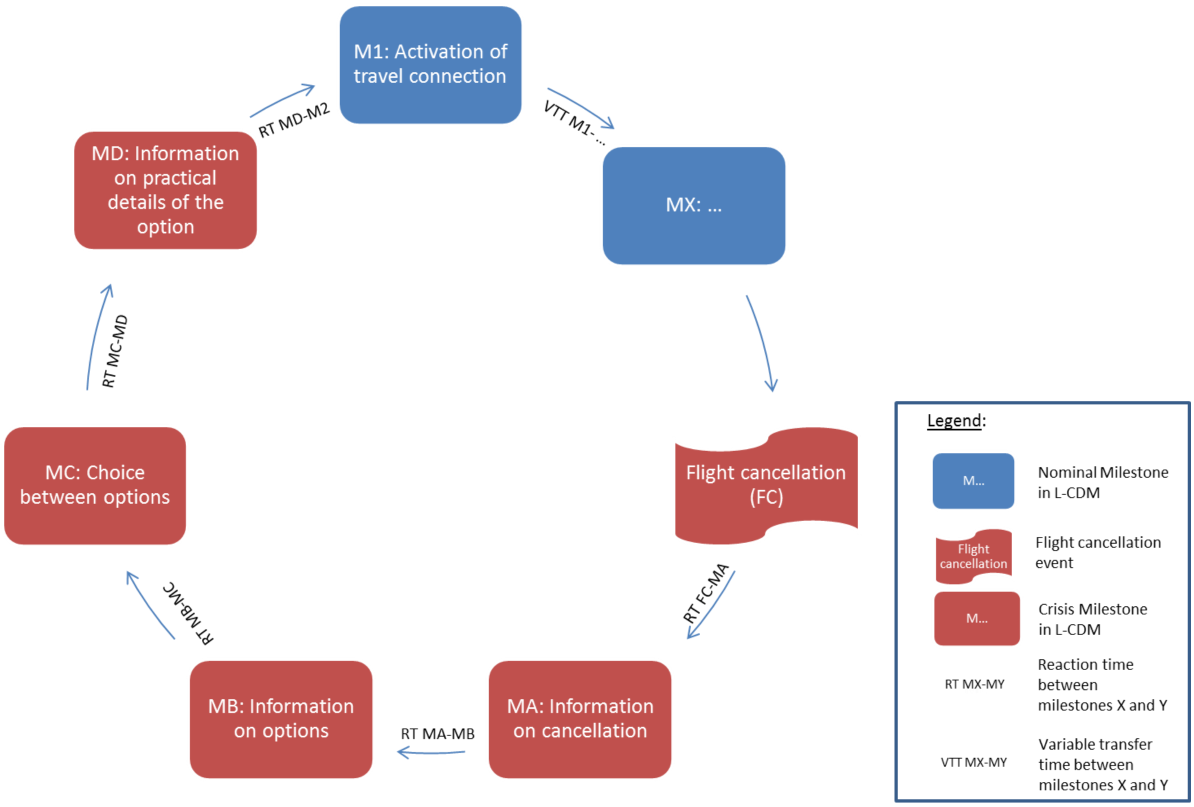

Figure 6: MetaCDM Reaction times in a situation of flight cancellation for empowered travellers

For guided travellers, the Reaction Times (RT) between milestones that should be calculated in the situation of flight cancellation are the same as those for empowered passengers. The only difference is the addition of a reaction time between Milestone E and Milestone 1. An illustration of MetaCDM Reaction times in a situation of flight cancellation for guided travellers is given by Figure 7.

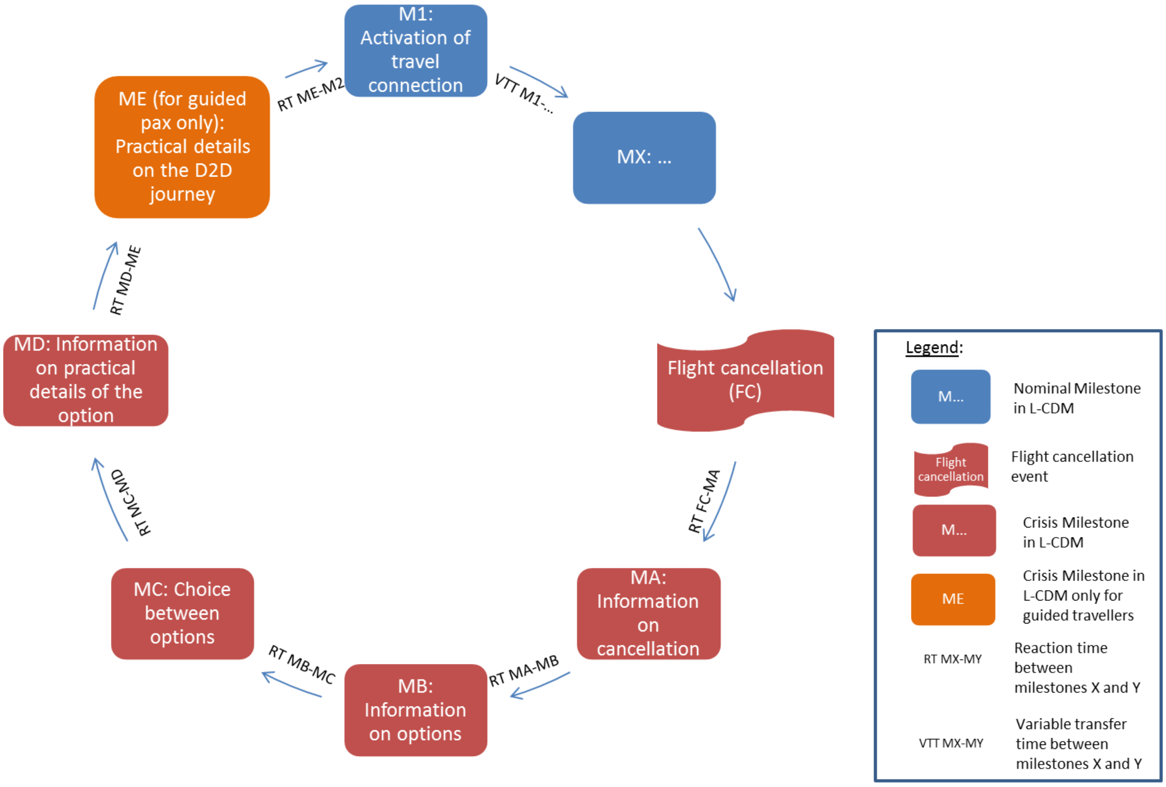

Figure 7: MetaCDM Reaction times in situation of flight cancellation for guided travellers

4 Benefits, Plausibility and Scope for using Alternative Modes

In order for the MetaCDM concept to be adopted, it needs to provide demonstrable benefits. As discussed at the second MetaCDM workshop, ideally this needs to be a win-win situation for all stakeholders involved, including airlines, airports and ground transportation service providers. Above all, there need to be clear and demonstrable benefits for the passenger or adoption will not occur.

In this section, we discuss the likely impacts of the MetaCDM concept. Section 4.1 considers the impacts by major stakeholder; Section 4.2 focuses on passenger impacts and passenger-centric metrics; Section 4.3 considers the feasibility and costs of MetaCDM; Section 4.4 considers the capacity and ability of other transport modes to take stranded air passengers in crisis situations; and Section 4.5 considers environmental impacts.

4.1 Benefits by major stakeholder

As discussed above, ideally MetaCDM needs to provide benefits for all major stakeholders. There are several A-CDM elements which can be used as a template for the expected MetaCDM benefits. Analagously to the A-CDM benefits covered in the A-CDM Implementation Manual [2], MetaCDM benefits should include:

- Reducing congestion in airport terminals, both under normal conditions (as passengers spend less unnecessary time in the terminal) and in crisis situations;
- Improving passenger satisfaction by reducing door-to-door travel time, reducing uncertainty, and improving information provision;
- Helping airlines to better maintain schedules by reducing the uncertainty associated with late passenger arrival at the gate; and
- Allowing stakeholders to optimize resource allocation (for example, improving prediction of how many immigration desks will need to be open at a given time in a given airport).

More specifically, the benefits and costs associated with MetaCDM will vary by stakeholder. Table 10 gives the expected benefits and costs of the MetaCDM concept by major stakeholder group.

Stakeholder	Expected Benefits	Expected Costs/Disbenefits
Passengers	Shorter journey times under disrupted conditions; improved experience of delay (e.g. at home rather than in queues); reduction in uncertainty	Reduced accessibility to travellers without smartphones; passengers may have to transport own baggage; data provision may cause privacy concerns
Airlines	Reduction in passenger accommodation costs, complaints and uncertainty over passenger location in disrupted conditions	Cost of funding travel via alternative mode; staff and infrastructure costs for information provision
Airports	Reduction in terminal crowding under disruption; reduction in uncertainty over passenger location	Staff and infrastructure costs for information provision; Passengers may spend less long in shopping areas
Ground Handlers	Minimal impact (with the exception of terminal-based services, e.g. ground handlers providing counter service will benefit from smaller numbers of passengers arriving at the disrupted airport)	Minimal impact
ANSPs/Network Managers	Minimal impact	Minimal impact
Federal Police	Decreased uncertainty about passenger location (so can e.g. plan staffing levels to reduce queues at immigration)	Potential infrastructure/information handling costs
Local Authorities	Reduction in congestion associated with disrupted airports	Infrastructure costs for information provision (e.g. if motorway dot matrix signs are used)
Ground Transportation Service Providers	Greater knowledge about where and when extra demand from stranded air passengers will arise, allowing better capacity/schedule planning; increased passenger revenue	Potential for overcrowding and complaints from existing passengers; issues of duty of care/legal liability for air passenger transportation
Information Service	New business opportunity (service providers); more, better and faster	Startup/infrastructure costs

Providers/Media	information (media)	
Travel Agents	New business opportunity; opens up potential new market (services to independent travellers)	Startup/infrastructure costs

Table 10: Expected benefits and costs per stakeholder

4.2 Passenger focus and impact on passenger-centric metrics

Although benefits to other stakeholders are necessary to gain acceptance, the main aim of MetaCDM is to improve the passenger experience. This in turn can provide additional benefits for other stakeholders. For example:

- Passengers who have a great airport experience are more relaxed, spend more and want to come back.
- Airports increasingly compete with each other and also with alternative transport modes for passengers; a better passenger experience improves customer loyalty.
- A good passenger experience makes a good impression / enhances the reputation of the city/state/country, given that the airport is the first and last thing a visitor sees. Therefore from a tourism, business and economic point of view it can make sense to invest in the airport experience.
- A good passenger experience makes it very difficult for governments/regulators to argue that the airport is doing a bad job – the airport is clearly serving the community.
- Focusing on the customer binds an organisation together. It gives all staff a clear goal and a clear understanding of the aims of the airport – for example, what types of behaviour are acceptable and to be encouraged.
- Staff who are committed to providing a great passenger experience tend to help their colleagues more making the airport more efficient and effective.
- Staff, passengers and the local community who are proud of their airport look after it better, want to be associated with it and are less likely to litter or accept a shabby ambience.
- A good passenger experience keeps media onside and helps marketing/publicity for the airport. Passengers often prejudge an airport based on its media profile. Given that media tend to publish negative issues more than positive ones, this can be a problem.

As discussed in [6], current performance metrics concentrate on airline- and airport-specific quantities, often at the expense of neglecting the passenger experience. For example, small aircraft delays could result in much greater door-to-door delays to passengers if they miss connecting flights as a result. Cancellations can result in large and highly variable levels of passenger delay, as analysed further in Section 4.3. Similarly, airport- and airline-specific metrics can omit less easily quantifiable aspects of the passenger journey, such as comfort or perceived safety.

As covered in Section 3.5, the European Norm EN 13816:2002-07 [4] defines eight quality criteria connected to passenger satisfaction: availability, accessibility, information, time, customer support, comfort, safety and environmental impact. These criteria are broadly representative of those in other metric sets surveyed by MetaCDM which look specifically at passenger experience. A summary of the expected MetaCDM impacts for each of these areas is given below.

- **Availability** refers to the extent of the service offered in terms of geography, time, frequency and transport mode. This should be unchanged under normal situations but may be improved under crisis situations.
- **Accessibility** can have multiple dimensions. MetaCDM aims to improve communication between passengers and transportation service providers and should increase the accessibility to passengers of using alternative modes when faced with disruption by removing information barriers. However, face-to-face staff accessibility may be lowered.
- **Information:** MetaCDM specifically aims at improving the provision of information to passengers, and should improve satisfaction in this area significantly.
- **Time:** Similarly, reducing door-to-door journey time is a key aim of MetaCDM, both under normal conditions (via better information about when passengers should leave home) and under disrupted conditions.
- **Customer Support:** In MetaCDM it is envisaged that passengers will choose the support level (guided or empowered) that they are most comfortable with. However, face-to-face support may be reduced as in both cases it is envisaged that support will be provided electronically (e.g. via smartphone apps). Some customers may therefore be less satisfied in this area.
- **Comfort:** MetaCDM should allow passengers on delayed flights to spend more time at home rather than at the airport, increasing comfort levels. Under disrupted conditions passengers may be given the option to trade off comfort for arrival delay (e.g. by taking a less comfortable mode of transport to get to their journey sooner) depending on their personal preferences. In these conditions comfort may worsen but overall satisfaction should increase.
- **Safety** should generally not be much changed by MetaCDM. As with comfort, some passengers may choose under disrupted conditions to trade off reduced journey time

for travel conditions in which they feel less safe (e.g. changing trains in a country where they do not speak the language).

- **Environmental impact** is discussed in Section 4.5. In general, environmental impacts will change only minimally (under normal conditions) or should be lower than in the non-disrupted case (under disrupted conditions).

In terms of more easily quantifiable metrics, the Passenger-Oriented Enhanced Metrics (POEM) project [7] examines classical and enhanced metrics of aviation system performance from a passenger-centric viewpoint. The core metric list from the POEM project (slightly adapted to exclude metrics which are effective duplicates in the MetaCDM context) is given in Table 11, along with the likely impact in each case of MetaCDM.

Metric (unit)	Definition	Expected MetaCDM impact
Flight departure/arrival delay (minutes/flight)	Delay from/at the gate relative to schedule	Small reduction under normal conditions due to better information about passenger location
Departure delay of departure-delayed flights (minutes/flight)	Delay from the gate relative to schedule	Small reduction under normal conditions due to better information about passenger location
Passenger departure/arrival delay (minutes/passenger)	Delay from/at the gate relative to schedule	Small reduction under normal conditions; potential large reduction under disrupted conditions; see numerical analysis in Section 4.3
Departure delay of departure-delayed passengers (minutes/passenger)	Delay from the gate relative to schedule	Small reduction under normal conditions due to better information about passenger location; note that passengers may not pass through the gate under disrupted conditions.
Arrival delay of arrival-delayed passengers (minutes/passenger)	Delay at the gate relative to schedule	Small reduction under normal conditions; potential large reduction under disrupted conditions; see numerical analysis in Section 4.3 (though note that, as passengers may not pass through the gate under disrupted conditions a better measure is arrival delay at final destination)
Passenger hard cost (euros/passenger)	Hard costs (see Annex 2) averaged per passenger	Significant reduction in hotel/food costs for stranded passengers; however, extra costs associated with providing alternative transport (see numerical analysis in Section 4.3)
Passenger soft cost (euros/passenger)	Soft costs (see Annex 2) averaged per	Some reduction under crisis situations; depends strongly on assumptions (see Annex 2 and Section 4.3)

	passenger	
Non-passenger costs (euros/flight)	Fuel, crew and maintenance costs averaged per flight	Minimal change
Total flight cost (euros/flight)	Passenger plus non-passenger costs per minute of departure delay	Small reduction under normal conditions; reduction under disrupted conditions depends on cost of alternative transport.
Total flight cost per minute of departure delay (euros/min)	Passenger plus non-passenger costs per minute of departure delay	Depends on assumptions; likely minimal change.
Reactionary delay ratio	Reactionary delay/flight departure delay	Likely minimal change.
Arrival-delayed passenger/flight ratio	Arrival delay of arrival-delayed passengers/arrival-delayed flights	Likely minimal change under normal conditions (not applicable to cancelled flights).

Table 11: Metrics and MetaCDM likely impact

4.3 Feasability and cost analysis

Any MetaCDM concept has to provide plausible benefits for a large enough percentage of travellers to make implementation worthwhile. In the case that flights are delayed, the benefit of having better information about when to arrive at the airport will apply to all affected travellers. Similarly, better information about cancelled flights will straightforwardly benefit all passengers who choose to take a later flight or not travel. However, providing information to passengers to allow them to switch modes relies on suitable infrastructure being in place to allow those passengers to reach their destinations via those modes sooner than they would by taking a later flight. The situation here will differ by route and airport connections. Some passengers will not be able to take advantage of this part of the concept at all (e.g. those travelling from or to airports on remote islands; those who do not have the correct visa for all countries the ground journey passes through; those on long-haul flights if a nearby alternate airport is not available). For others, the alternative ground journey may be an improvement on taking the next available flight only in the most disrupted circumstances (e.g. for travellers using airports with only low-speed and/or multiple-connection ground transport options to the destination city). Other travellers may not want to take advantage of ground transport options even if they offer a reduction in journey time.

Infrastructure development works on long timescales. In addition, ground transport schedules are optimised for the original customers of that mode and it is difficult to significantly alter them to accommodate stranded air passengers due to capacity and stock constraints. This means that the ground transport infrastructure and scheduling MetaCDM will have to work with will be similar to that currently in place. If switching to ground transport is not widely feasible under present-day conditions (assuming suitable information is provided) then this part of the MetaCDM concept will not work.

To estimate to what extent this concept is feasible, we examine the top 50 airports by passenger traffic in Europe for 2012 [8]. A list of these airports is given in Annex 1. According to EC data on passenger movements [9], traffic between these airports accounted for just over half of intra-European passengers and flights in 2012; however, they are likely to account for substantially over half the system delays and cancellations since the list of airports contains all of the top 20 airports for arrival delay in 2012 as calculated by Eurocontrol's Central Office for Delay Analysis (CODA) delay monitoring program [10]. Eurocontrol's Network Operations Report for 2012 [11] summarises the locations of disruptive events in 2012, which are dominated by airports on this list.

The Eurostat movement data covers 223 million passenger departures and 228 million passenger arrivals between the top 50 European airports in 2012 (excluding Russia, Ukraine and flights between Turkish airports). The distribution of these is shown in Figure 8; note that data on domestic flights in Turkey is not available. Airports in the top 20 for arrival delay are highlighted in red. The flight network for 2012 is very dense and well-connected, with large numbers of small flows as well as a smaller number of more heavily-used routes.

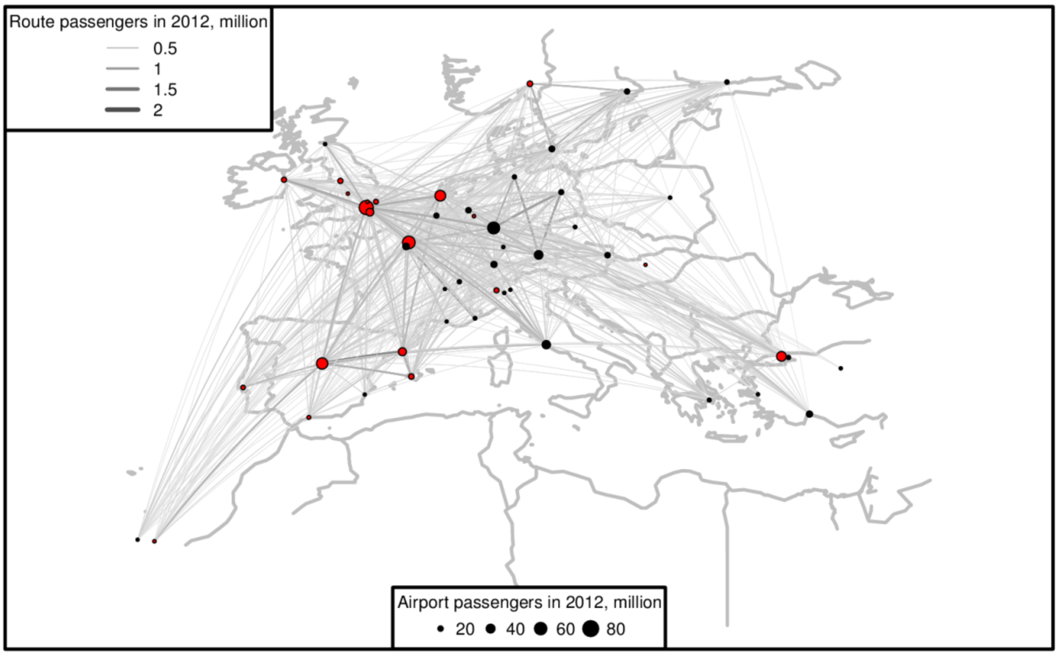

Figure 8: Flight connections between the top 50 European airports in 2012

Whilst most of the airports are in mainland Europe and hence have a wide range of ground travel alternatives available, several are on islands with ferry or train access (the UK, Ireland, Mallorca) or are otherwise difficult to access without a ferry journey (Finland). In general, however, most are linked in to European road and rail networks; the main exceptions are the airports on the islands of Tenerife and La Palma. As detailed by the MODAIR project [12], seven airports (Brussels, Paris Charles de Gaulle, Lyon St-Exupéry, Düsseldorf, Frankfurt, Cologne/Bonn and Amsterdam Schiphol) currently have High-Speed Rail (HSR) links directly to the airport. A further four (Paris Orly, Stuttgart, Madrid and Barcelona) have planned HSR links. Of the 82 airports in the TEN-T urban node network, approximately half (39) have links to commuter trains, underground or light trains, 19 have an air/rail connection via mainline services and 10 are served via airport express trains. Since one of the central ideas of the MetaCDM concept is that passengers are informed of flight cancellations and available alternatives before reaching the airport, however, it is not necessary that the alternative transport modes are directly connected to the airport – instead, the traveller should ideally be able to travel directly from their home to the access point of the alternative mode. This means that it is possible to utilise transport links associated with the airport city rather than only the airport itself.

The distribution of rail lines between the 50 airports is shown in Figure 9, indicating high- and low-speed links. Only main lines between the cities considered are shown; rail lines with constraints which would render them straightforwardly unsuitable for the MetaCDM concept (e.g. sections going through Russia and related visa problems) are omitted. This network is significantly sparser than the air network, due to the constraints of providing infrastructure.

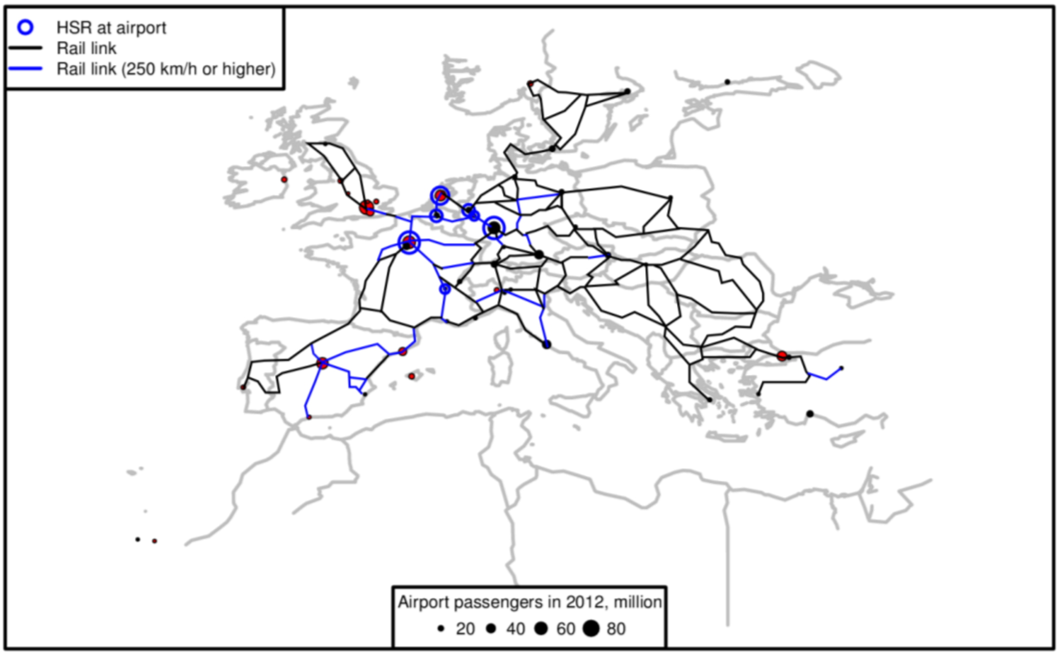

Figure 9: Rail links between the top 50 European airports in 2012.

The availability of ground transport links for the journeys taken in 2012 between the 50-airport set is summarised in Table 12.

As can be seen, putting passengers on airport-airport HSR links has limited applicability – under three percent of journeys in 2012 could be substituted in this way. However, using city-city links instead would make 30% of journeys substitutable. As discussed below, favourable connections can have a greater impact on journey time than considering only the speed of the various links. As such, it is not necessary that the entire route is covered by high-speed rail. If low-speed rail is allowed for all or part of the journey, over 80% of journeys are substitutable, and if road and ferry journeys are also considered, 96% of journeys are substitutable. If the option of ground transportation to an alternative airport is available, assuming that airport is not also disrupted, then all journeys made in 2012 between the 50-airport set could be substituted by a combination of ground transport and alternative flights in case of disruption.

	Arrivals	Departures
2012 total passengers (million)	228	223
On routes with current HSR airport-airport connections	2.7%	2.6%
On routes with current or planned HSR airport-airport connections	8.7%	8.5%
On routes with city-city HSR connections	30.3%	30.0%
On routes with city-city rail connections (any type)	86.0%	83.8%
On routes with road airport-airport connections (excluding ferry/train)	62.8%	62.7%
On routes with road airport-airport connections (including ferry/train)	96.0%	96.0%
On routes with ground access to alternative origin/destination airport	100.0%	100.0%

Table 12: Ground transport availability for passenger journeys taken in 2012 between the top 50 European airports.

This suggests that the general idea of substituting ground transport for all or part of a journey to get air passengers to their destination in cases of disruption is broadly feasible, although the mix of modes for each airport is likely to be different. However, the ground journey has to provide greater passenger satisfaction (or at least, less passenger dissatisfaction) than simply waiting for the next non-disrupted flight would. Passengers should arrive at their destination sooner than they would by waiting for the next non-disrupted flight, and they should do so in a way that is safe, comfortable and accessible. For example, passengers may be reluctant to take overnight train journeys (on non-sleeper trains) when the alternative is a night in a hotel and a flight the next morning. Similarly, passengers may be reluctant to negotiate multiple train changes in unfamiliar countries, particularly if they have heavy luggage.

To look at the feasibility of ground transport modes, we compare journey times by each mode. For air journeys, we use yearly average scheduled flight durations by airport-pair from 2005 [13] and assume that these have remained broadly constant to 2012. Where data from 2005 is not available, we use a linear regression between distance and journey time from the 2005 data to estimate flight duration. For road and rail journeys, we use data from online journey planning software [14], [15] and [16]. In the case of rail journeys, journey time and the number of connections can depend strongly on the date and time of day. We assume substitution for a flight on a Wednesday morning in April, and prioritise routes with fewer connections and avoiding overnight train journeys when choosing from the offered schedules. Figure 10 compares journey times by mode and distance between the European airports.

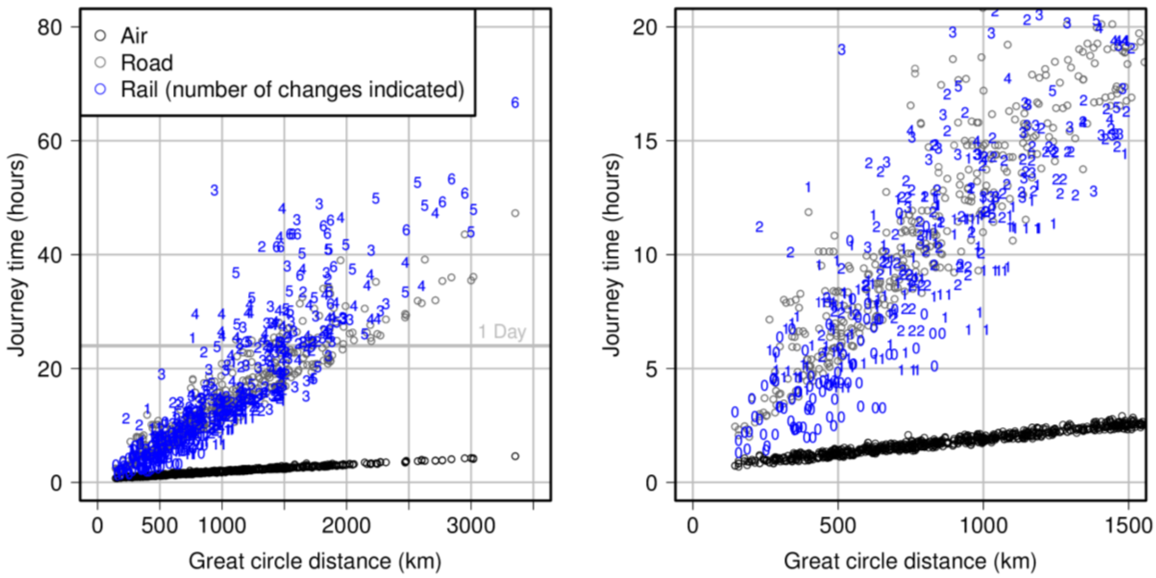

Figure 10: Journey times by mode and distance between the European airports. Left: full data set; right: shorter journeys only.

This analysis includes only scheduled journey times and does not include the following times: check-in/waiting time at the airport; schedule delay (i.e. the gap between the desired air/road/rail departure time and the first available connection); transfer time from home to the airport, station, car hire or other first alternative transportation service provider, and transfer time from the last transportation service provider to the final destination. If the passenger is first informed at home in advance of their flight that cancellations are expected, then a ground transport journey will include transfer time to the alternative provider plus schedule delay, whereas the original flight would have involved transfer time to the airport plus check-in/waiting time. On routes with relatively frequent ground transport connections it is plausible that these timescales may be similar.

However, with this considered it is obvious that the benefits of rail are highly variable depending on the route that needs to be substituted and if suitable rail network links and schedules are available. As shown in [12], the connectivity of different regions varies strongly and is a function of geography, e.g. the locations of mountain ranges and bays, in a way that air connectivity is largely unaffected by. Suitable routes and schedules can make more of a difference than the route being entirely high-speed; for example, Paris-Manchester train times are significantly lower than driving times despite a long section of low-speed line. In general, trains are a better option on shorter-distance journeys where few or no connections are needed, and road travel (assumed to be by the passenger's own vehicle, hire car, or coach if a suitable service is available, though in principle an airline could also hire coaches if a large number of passengers need to be transported, similarly to the use of rail replacement buses for train services) is a better option on longer journeys.

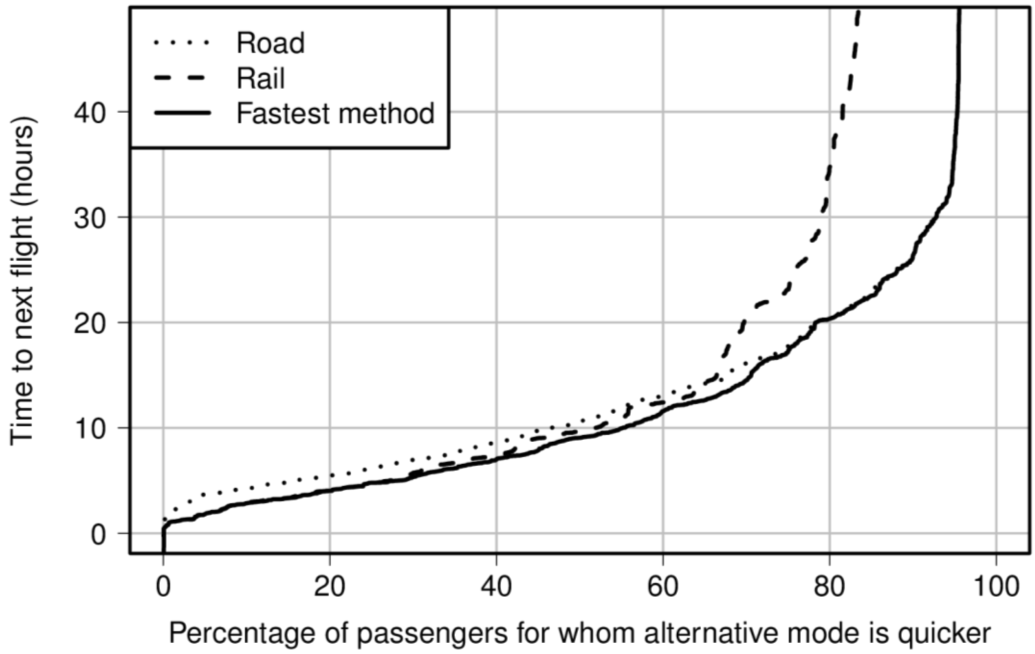

Figure 11: Percentage of passengers who could reach their destination sooner by taking an alternative mode than by waiting for the next flight, by time to next flight.

Figure 11 shows the percentage of system passengers in 2012 (travelling between the top 50 airports) who could reach their destination sooner by taking a ground transportation alternative rather than by waiting for the next flight, compared to time to next flight. Under the assumptions used here, for a 10-hour wait to next flight around 50% of passengers could make use of ground modes and this rises to around 70% for a 15-hour wait. Major disruptive events can and frequently do last for days; for example, many of the events listed in Eurocontrol's Network Operations Report for 2012 [11] are strikes with duration typically a day or more. These numbers will be lower if the cancelled flight is in the evening, as fewer train services run overnight and many passengers will not be willing to take an overnight land journey; however, waits to the next flight may also be longer for cancelled evening flights due to overnight curfews at airports. Similarly, they will be lower if the ground modes are also subject to delays (for example, in the case of snow events). However, in many cases road and rail transfer times are similar, providing a backup option in case of disruption in one mode. In general, this analysis points to ground transport substitution being a plausible option for many passengers on cancelled flights, but only if an individual and flexible plan for each airport is used which is responsive to information on ground transport disruption (for example, directing passengers to road modes when trains are not running, or to rail when there is major congestion on the roads). Ideally, the MetaCDM process here should facilitate the process that many passengers follow already in major disruptive events – checking availability, schedules, and disruption on alternative modes, checking if the airline will reimburse costs, booking tickets according to individual passenger requirements and preferences and using online information sources to guide them through the journey – allowing more passengers to use this method.

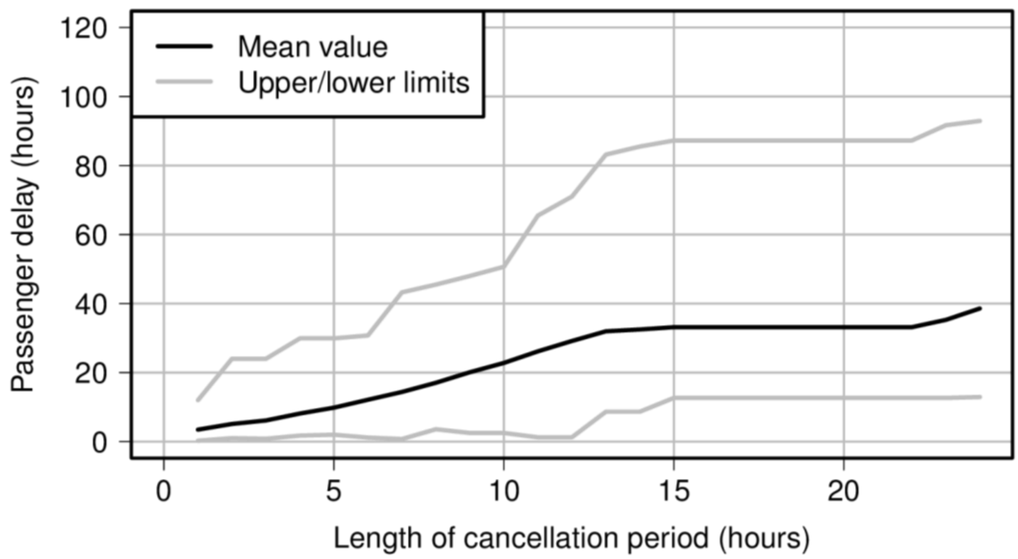

Figure 12: Passenger delay as a function of cancellation period

The above analysis can be extended by looking at real-life aircraft schedules. Using data on year-2012 aircraft load factors from [9], and schedule data for 2012 from [17], it is possible to simulate the impact of a period of closure on the airports modelled above. If an airport is closed for 10 hours and all flights during that period are cancelled, the average passenger delay in reaching their final destination can be significantly more than 10 hours. Figure 10 shows the impact on passenger delay distribution for a block of cancellations at Heathrow, assumed to start at 8 a.m. on a midweek day in May. Passengers are assumed to be re-accommodated on flights with the same carrier, depending on the number of seats available at typical load factors. Under these assumptions, a 5-hour cancellation period results in around a 10-hour mean passenger delay, and a 10-hour cancellation period results in a mean passenger delay of nearly a day; the maximum passenger delay in this case (typically from routes with low frequency and/or high load factors) is over two days. These calculations assume that 10% of passengers on cancelled flights choose not to travel, and do not consider the impact of additional delays associated with the cancellation period, or reactionary delay.

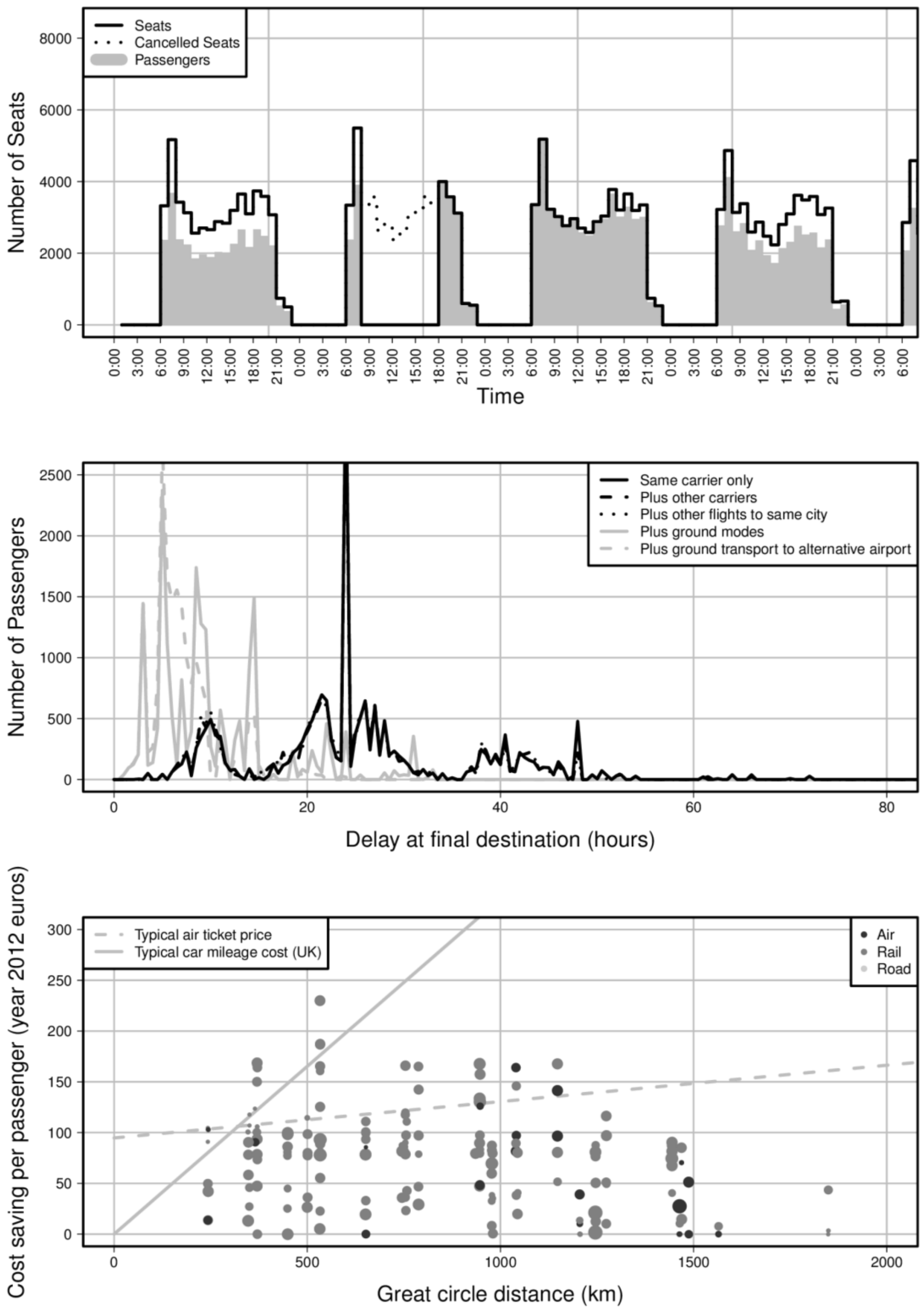

Figure 13: Schedule, passenger delay distribution and passenger costs of delay by distance for the example of a hypothetical 10-hour closure of London Heathrow Airport.

What impact could the MetaCDM concept have on these delay distributions? In Figure 13, we take the specific example of a hypothetical 10-hour cancellation block at Heathrow, starting at 8 a.m. on a May weekday. The top panel shows the schedule in the case discussed above in which all passengers are re-accommodated onto flights by the same carrier. As passengers are re-accommodated, after the cancellation event, load factors approach 100% for the following day and remain higher than usual the day after that. The middle panel shows the passenger delay distribution under various assumptions about how passengers are re-accommodated. It is assumed that 10% of passengers on cancelled flights choose to be reimbursed and not travel at all, and a further 10% choose to be reimbursed and returned to their point of origin. Small reductions in delay are possible by allowing passengers to be re-accommodated on flights with other airlines travelling to the same destination (assuming that these airlines have already found seats for all their own stranded passengers), and by additionally allowing passengers on flights which go to a different airport in their destination city[1].

Significantly greater reductions in delay can be gained by using ground transport to the final destination, and/or ground transport to nearby airports which have alternative flights to the final destination. In these scenarios, we assume a buffer time of two hours between the cancellation and the time the passenger accesses a suitable ground transport service to account for decision time, transfer time to the access point of the ground transportation service, and schedule delay. For access to flights at alternative airports, it is assumed that the passenger additionally needs to arrive at the airport two hours before flight departure. In reality, the distribution of access times to use alternative modes of transport is likely to be wide. For example, in the case that a passenger is already at an airport with an associated train station and is informed of the cancellation in advance, they may be able to access rail services before the official departure time of their cancelled flight. We do not consider the available capacity on ground transport modes in this step; this is discussed in Section 4.4 below.

Although the reductions in passenger delay associated with ground transport use are substantial, they may not be attractive to airlines if they are not associated with reductions in cost. The bottom panel of Figure 13 shows the estimated change in passenger cost of delay to airlines with journey distance, comparing the case where passengers are given the option of ground transportation with the next best case. The cost estimations are based on [7] and are discussed in detail in Annex 2. It is assumed non-passenger costs of delay (for example, associated with aircraft being in the wrong places) are unchanged by MetaCDM. As discussed in Annex 2, estimates of passenger costs are subject to a high level of uncertainty and are dependent on a number of assumptions about passenger behaviour. Therefore these numbers should be taken with caution. However, they suggest that cost savings of 50-100 euros per

[1] Note however that this is an unattractive option for passengers who have connecting flights.

passenger are typical for most routes, with some routes having greater benefits and some having nearly no benefit. These numbers can be compared with the cost of travelling similar distances by different modes. Overlaid on Figure 13 are indications of the typical European air ticket price by distance (from [7]) and typical UK car mileage costs (from [18]). Rail ticket prices for same-day travel vary significantly based on the country and time of day, amongst other factors. In general, these prices are above the 50-100 euro price range indicated. However, advance tickets on long-distance train and coach services are frequently within or below this price range. This suggests that the costs are feasible if airlines can make arrangements as part of the MetaCDM setup process with ground transportation companies to charge advance-level ticket prices to stranded air passengers, but are not feasible if passengers have to pay the full walk-up fare. This is similar to the situation with airport hotel provision to stranded passengers (see e.g. [7]) where airline costs are relatively low due to pre-arranged deals with hotels.

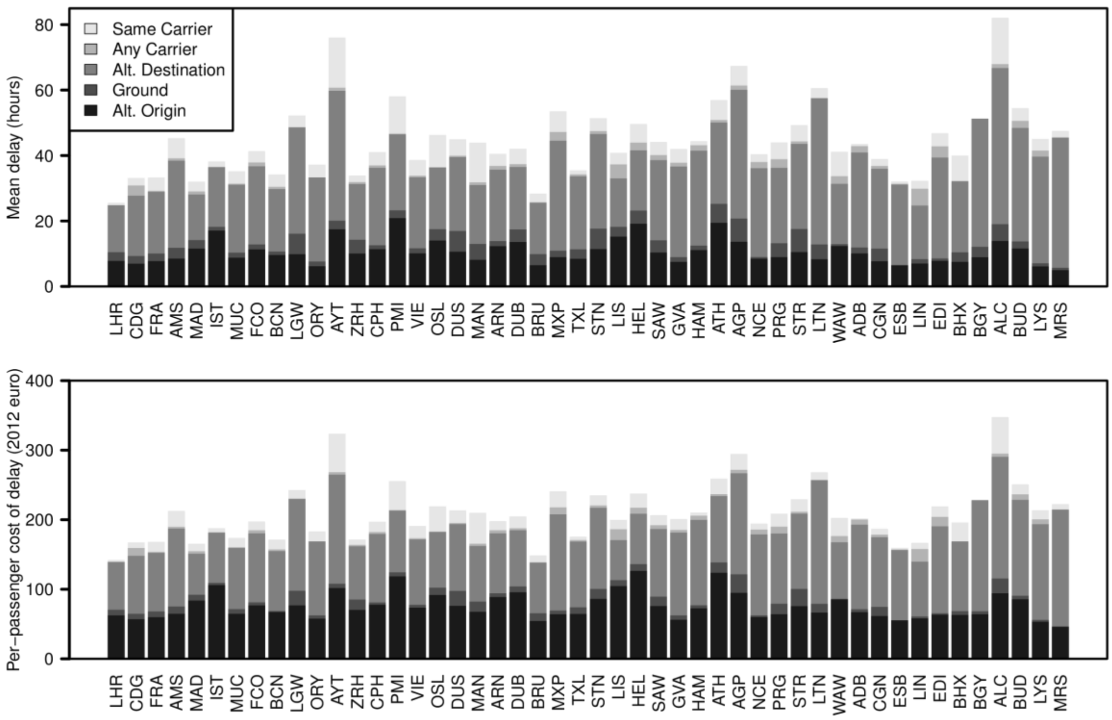

Figure 14: Benefits by airport and passenger reaccommodation scenario.

These conclusions apply similarly to most airports. In Figure 14, we repeat the hypothetical 10-hour closure scenario for the other airports modelled in this analysis, by passenger reaccommodation scenario. The two Canary Island airports modelled (LPA and TFS) are omitted from Figure 14 as unrealistically high delays were produced due to their location and high passenger load factors; in this scenario it is likely that airlines would provide extra flights to get stranded passengers home. Typically, the greatest benefit in terms of reduction in mean passenger delay is from allowing passengers to use ground transport. Smaller but still useful delay reductions can be obtained by allowing passengers to take flights with other carriers, flights to other airports in their destination city, and by allowing passengers to take ground transportation to an alternative origin airport. The mean cost savings per passenger for each airport from allowing ground transport vary, but are typically in the 50-150 euro range. As with the analysis for Heathrow, this suggests that costs for putting passengers onto ground transportation are feasible but only if airlines have pre-arranged deals with ground transport companies.

There remain several further constraints which may reduce the applicability to passengers. Access (or lack thereof) to passengers with reduced mobility or with heavy luggage needs to be established for the ground mode options and may prevent some travellers using these options. Passengers who are trying to connect from the destination airport onwards may have their own time constraints and preferences based on the time of the next available connection at that airport. Passengers also need to have the right to travel between all the countries on the ground route. For EU citizens this is straightforward as nearly all ground transport routes examined stay within the EU28 countries[2]. Non-EU citizens may need to wait for the next flight if they do not have appropriate visas. However, if they have the right of entry to the country of the origin airport they may still be able to transfer via ground modes to another airport in that country for an alternative flight to their destination.

4.4 Capacity of other transport modes

As discussed above, the capacity of other air services to provide spare seats for passengers from cancelled flights is a key factor affecting recovery from crisis events. In normal operations, airlines try to maximise their load factors. In crisis events, however, faster recovery is aided by lower load factors on subsequent flights so that there is more space to reallocate passengers. Therefore an airline that has performed better at optimising its services under normal conditions may have more trouble in crisis recovery. The same situation is true of ground transport modes. Putting passengers on ground transport is feasible only if there are sufficient seats at suitable times for them. In previous crises, there have been cases of passenger demand for ground transport exceeding the seats available; for example, seats on Eurostar sold out rapidly after the start of the 2010 volcanic ash crisis [6]. In the analysis above, we assumed (in the absence of detailed ground transport schedule data) that sufficient

[2]Whilst a small number of road routes between the countries examined here exit the European Union, these routes are multi-day trips and hence likely infeasible in any case.

capacity would be available for passengers on ground transportation. This section investigates the limitations of that assumption.

One of the key concepts of MetaCDM is that passengers are informed of flight cancellations as soon as possible, ideally before they start their journey to the airport. In the case that the passenger opts for an alternative mode, they do not have to pass through the airport at all. The alternative mode options that are offered can then take advantage of the resources available to the local city area rather than just the local airport area, allowing much greater capacity in hotel rooms, rental cars, seats on coach and train services etc. to be utilised. This means that some of the problems associated with past disruptive events, such as passengers sleeping in airport terminals because all local hotels are full, can hopefully be more easily avoided. However, there may still be capacity bottlenecks. A key example, as mentioned above, is Eurostar services. The necessity of travelling through the Channel Tunnel means that all passengers switched to train services from UK cancellations who are travelling to continental Europe will be travelling on the same line. Similarly, the Øresund Bridge connecting Denmark and Sweden may be a bottleneck for rail and road traffic affected by disruptive events in Scandinavia.

Another key concept is that, at least initially, existing ground transportation services should be used rather than expecting ground transportation companies to provide extra services. Based on information from the interview stage of MetaCDM, the ability of ground transportation providers to lay on extra services for stranded passengers is limited. These limitations arise from many sources, including lack of spare rolling stock, staff availability and training for the routes needed, and infrastructure limits (e.g. train tracks are often operated at close to the limit of capacity). Even if these constraints can be overcome, a notice period is typically needed to assemble the necessary resources (the example of a day's notice was given for UK rail services at the second MetaCDM workshop). Zhang and Hansen [19] study the corresponding situation for substituting US air services with buses. As noted in [6], many types of disruptive event are associated with smaller notice periods than this. In addition, some disruptive events which have greater notice periods may not be suitable for ground transport substitution: for example, general strikes or snow events where ground transport is also disrupted. For these reasons, we assume that existing services are used.

For this analysis, we concentrate on rail as this is the mode to which a majority of passengers were directed to in most of the examples given above. Table 13 shows typical characteristics of European train services, taken from [20]. Rail services typically have more seats and lower load factors than aircraft. This means that the number of free seats available on an average high-speed or intercity service is typically enough to accommodate all passengers from one or two intra-European flights. The other key variable is service frequency, which affects both access times and capacity to accommodate extra passengers. Here rail services differ significantly. The key intra-European high-speed routes typically run services every 1-2 hours [15]. At the load factors given in Table 13, this equates roughly to a spare capacity per high-speed or intercity train line of 1,000-6,000 seats per day. In comparison, the maximum number of stranded passengers in the examples given above of 10-hour closures at major European airports is around 20,000. Given that many of these passengers will take later flights, some may use road transport, and the rail passengers will typically have a choice of several major rail lines heading in different directions (see e.g. Figure 9), it seems likely that sufficient rail capacity will usually be available in the absence of other complicating factors (e.g. bank holiday weekends).

More complex rail journeys, involving multiple connections, low-speed links or segments via ferry can sometimes have only one feasible departure per day. However, these routes are also typically unattractive from a journey time point of view.

Type of train service	Typical capacity, seats	Typical passenger load factor	Typical spare seats per service
High-speed	510 (750 for Eurostar)	0.65	178 (270 for Eurostar)
Intercity (electric)	480	0.4	288
Intercity (diesel)	330	0.4	198
Local city	750	0.35	488

Table 13: Typical capacity and load factor by type of train service

As a specific example of a highly-constrained situation, we consider the scenario illustrated above of a 10-hour cancellation block at Heathrow. This scenario involves the greatest number of passengers to find alternative transport for, compared to similar disruptions at other airports. The most constrained scenario for ground transport is where passengers are offered ground journeys to their destination but not the option of ground transport to an alternate airport. In this case, 19592 passengers need to be re-accommodated after the cancellation block. Of these, 4894 are accommodated on later flights, 1214 are assumed to travel by road, and 2365 take intra-UK rail services (e.g. to Manchester or Edinburgh). The remaining 11119 passengers are assigned to rail services to continental Europe, i.e. via the Channel Tunnel. This suggests that the Channel Tunnel will be a significant bottleneck. Demand from these passengers is spread out evenly throughout the day.

This can be compared to the Eurostar schedule for a comparable May weekday [15]: 18 trains were scheduled from London to Paris and 10 trains to Brussels, at intervals ranging from 30 minutes to 2 hours. At typical load factors, this implies a total of 7560 spare seats available for service through the Channel Tunnel, i.e. about half of the rail passengers in this example would have to either take a rail service the following day, use road services instead, or take a later flight. As a result, in reality the delays experienced by these passengers would be higher than indicated, and fewer delayed passengers would switch to rail. This situation is, however, significantly improved for airports with lower numbers of passengers to re-accommodate, for airports without the constraint of the majority of passengers travelling via a single rail line, and for all airports when the option of ground transfer to an alternative airport is included. For example, in the case of a 10-hour cancellation block at Paris Charles de Gaulle, excluding ground transfer to an alternate airport, 1590 passengers are projected to take Channel Tunnel services – well within the capacity available. This suggests that the general concept is still feasible but that individual airports should conduct bottleneck analysis in collaboration with ground transport stakeholders before implementing MetaCDM.

4.5 Environmental Impacts

There is increasing concern about the environmental impacts of aviation (e.g. Lee et al. 2009, [21]). In particular, aviation greenhouse gas (GHG) emissions are projected to rise at a time when emissions from other European sources are falling [22]. Aviation is also associated with other negative externalities, including airport-area noise, local and regional air quality degradation via emissions of particulates and NOx and local water pollution from airport runoff [23]. Since aviation emissions are relatively difficult to reduce in comparison to those from other sources, this means that any policy or technological interventions aimed at changing the aviation system should be carefully scrutinised to make sure they do not make any problems associated with aviation's environmental impact worse.

Operation under severe disruption is usually omitted from analyses of aviation emissions, which assume average conditions prevail at airports. In general, the impact of severe disruption is a reduction in emissions. For example, cancelling a flight and increasing the load factor of later flights by rebooking passengers onto them will significantly reduce per-passenger GHG emitted as well as noise and local emissions. For less severe disruption there is the possibility of an increase in emissions if delays occur with engines on (e.g. via increased taxi time or holding). There may also be an increase in the energy use of airport buildings if, for example, extra heating is needed because terminals are occupied by stranded passengers overnight when they would otherwise be unused. However, for the types of major disruptive event targeted by MetaCDM total environmental impacts are likely to be lower than they would be in the non-disrupted case. A reasonable standard of acceptability of any change in disrupted operations, therefore, is whether they would raise GHG emissions or the impact of other externalities above the non-disrupted level.

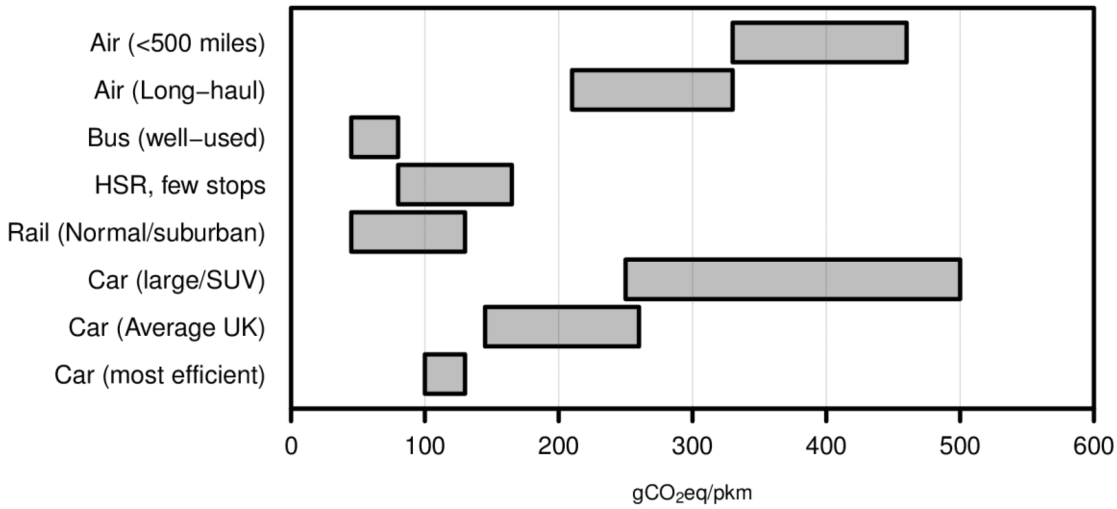

Figure 15: Typical GHG intensity per transport mode

The changes in environmental impact associated with the MetaCDM concept are of two types. For less severe disruption, improved passenger information is aimed at streamlining the passenger journey – for example, making sure that the passenger does not turn up too early for a delayed flight and have to wait a long time in the airport. In this case, passengers will likely spend longer at home and less long at the airport than they otherwise would under disrupted conditions. Consequently, their home energy and water use and emissions may be slightly higher, and the airport's energy and water use and emissions may be slightly lower. In this case, disruption (and the response to it) largely shift the location of environmental impacts rather than changing their amount: in the non-disrupted case the passengers will spend more time (and use more energy) in their destination location. The second case is when disruption is severe enough that flights are cancelled[3], and passengers may be given advice that leads them to take another mode. In this case, environmental impacts can be assessed by comparing the GHG-intensity of different modes. Mode-switching in response to disruption is likely to apply primarily to short-haul flights. A comparison of the typical GHG-intensity of different modes is given in Figure 15 (data from [24]). GHG-intensity is affected by journey length, load factor, speed and stopping behaviour and weather, amongst other factors, so it should be noted that the full range of possible values can extend beyond those shown here. However, short-haul flights have significantly higher emissions per passenger-kilometre (pkm) than nearly all other transport modes shown. In particular, redirecting passengers to existing bus

[3] One complicating case is when a flight is subject to a multi-hour delay but not cancelled. In this case, offering alternative mode transportation to passengers who want it and then flying the original flight with a lower load factor would likely lead to increased emissions, as well as potentially increased costs for the airline. Under these circumstances offering the option of other modes may not be suitable. Similarly, emissions may be greater than in the non-disrupted case if passengers are redirected to other modes but a positioning flight with an empty aircraft is made because the disruption resulted in aircraft being at the wrong airports for the schedule to be flown.

and train services is likely to roughly quarter the emissions associated with those trips compared with the equivalent air journey. The situation is less straightforward if the passenger is redirected to ground transportation to travel to a non-disrupted airport to take a flight to their destination from there. However in this case the passenger is assumed to be added to an already-existing flight, i.e. the total number of flights is still lower than in the non-disrupted case but the load factor of the alternative flight is higher. Under these circumstances emissions from the alternative flight are only marginally higher than in the non-disrupted case and total system emissions should remain below the non-disrupted case.

In general, these conclusions apply also to other externalities of aviation. Because disruptive events involving cancellations lead to fewer flights taking off and landing, noise and local emissions will also be lower than the non-disrupted case. As the MetaCDM concept assumes that passengers taking ground transport modes will join existing services, only marginal increases in environmental impacts from increased load factors on these services are anticipated. Therefore, although in the general environmental impacts of MetaCDM will be greater than if all passengers on cancelled flights chose not to travel, they will be significantly lower than the case in which the flight was not cancelled. Table 13 gives a summary of the expected effects of disruption and MetaCDM on the main areas of aviation environmental impact.

Impact type	Behaviour under severe disruption	Expected effect of MetaCDM concept
GHG emissions	Flight cancellations plus rebooking strongly reduce per-passenger emissions; delays may increase per-passenger emissions if incurred with engines on.	Passengers taking trains, coaches or typical cars to their destination should have lower per-passenger emissions than those flying, so emissions should remain below those in the non-disrupted case.
Noise	Flight cancellations plus rebooking strongly reduce per-passenger noise impact; delays have minimal effect (but may lead to flights operating during noise embargo periods)	Aircraft noise will remain close to the current level under severe disruption, i.e. significantly lower than non-disrupted case; possible but marginal noise increases from ground transportation.
Air quality	Flight cancellations plus rebooking strongly reduce per-passenger air quality impact; delays may increase per-passenger local emissions if incurred at airport with engines on	Similar to noise impact, i.e. much lower aircraft local emissions than non-disrupted case, possible but marginal increase in emissions from ground transportation.
Water quality	De-icing may impact on airport runoff under winter weather conditions.	Minimal change from normal disrupted conditions.
Terminal energy and water use	Stranded passengers may spend longer in the airport, requiring more heating, lighting and water use than under non-disrupted conditions.	Fewer passengers at the disrupted airport, leading to lower excess energy use.

Table 14: Effects of disruption and MetaCDM on aviation environmental impacts

5 Key Research and Development Areas

The final stage of the MetaCDM project is to provide a roadmap for future research. This can be research that leads towards the ultimate goal of an operational MetaCDM concept, or more generally research that aims to improve the door-to-door passenger travel experience. This chapter explores the research avenues that our work on the project has led us to conclude should be further pursued. In particular, to enable the MetaCDM concept, and to contribute to improved passenger satisfaction under normal conditions and in the case of disruptive events, the following areas should be addressed by future Research and Development (R&D) activities:

5.1 Airside and Landside Integration at Airports

The integration of airside and landside processes has been addressed by the R&D community and partially also by industry for many years now (in particular in the framework Total Airport Management concept). However, significant room for improvements exists in airport operations. Major shortcomings are competition and trust concerns over data that could risk position/customer base as well as incompatibility of data, systems and working practices. In particular, the following areas which could benefit from future research:

- *Prediction*. Prediction of process and transfer times at airports (both landside and airside) and the according information sharing is considered to be a key enabler for MetaCDM. Although some industry products are available in the market to support these predictions, only a few airports have implemented (or are implementing) these solutions.

- *“Buy-In” Concepts*. The situation described above indicates that further development of concepts that provide proven benefits for all involved stakeholders is needed. The current A-CDM concept can be seen as a good example how to enable “buy-ins” for all stakeholders. Thereby, definition of globally harmonised metrics and reporting strategies, with adequate objectives, will contribute to overcome some of the current barriers.

- *Global Harmonization*. Also with regard to global harmonization, Europe needs to keep sharing its own experience with the world. ACI and CANSO are currently looking at promoting implementation of A-CDM worldwide. For example, Singapore and Bangkok airports are undergoing A-CDM trials in late 2014. To provide the best overall service to passengers a showcase of Best Practices, information sharing and transparency, and network level optimization are needed.

5.2 Travel Experience

Providing the passenger with the required information is considered as a key element in the MetaCDM concept. A further key element is to provide the passenger with system support to enable a satisfying travel experience and to consider their individual preferences. This requires further R&D in the following domains:

- *Passenger demand and expectations*. In order to identify how updated information, all along the journey, would impact passenger demand in a multimodal transportation network, the drivers of passenger demand and the expected decisions made by the passenger after they receive updated information must be identified. This data driven demand modelling requires integrating different decisions made by the passengers and their expected impact on demand. Advanced mathematical approaches to passenger analysis could be used to identify passenger objectives beyond the goal of travelling from A to B.

- *Definition of performance indicators*. Each stakeholder has individually defined KPAs/KPIs, and a lack of transparency and communication on each stakeholder's performance assessment remains a hindrance to global performance reporting with useful and meaningful metrics. Performance indicators should therefore be set for the system as a whole and also according to the various actors involved in the whole process with a specific focus on the passenger's point of view. To the usual set of indicators that address cost, delay, safety, and sustainable development it could be worth adding passenger satisfaction according to their motivations and concerns for the whole door-to door journey. While some work has been done in this area [7], this is in general an area ripe for further investigation and implementation.

- *Costs and benefits of different passenger options*. Particularly in the case of disruptive events, airlines have a range of options that they could offer to passengers, with a range of costs and benefits attached. The benefit assessment in MetaCDM was necessarily at a high level only, as befits the assessment of an initial concept. To take MetaCDM further would require a more detailed assessment of the costs and benefits. In particular, many of the benefits are in areas that are poorly-understood at present and would require passenger surveys to explore more fully. For example, how does passenger satisfaction (and hence passenger loyalty, and soft costs to the airline of cancellation) change if the passenger is given more options to get to their destination sooner? Is there a benefit to airlines in passengers experiencing a 10-hour delay rather than a 24-hour delay, and how can this be quantified? How is delay spent at home valued compared to delay spent at the airport or delay experienced while travelling on an alternative mode?

5.3 Information Sharing with Passengers and Others

A further key R&D area suggested by the work done in MetaCDM is the need to further foster solutions that enable a seamless door-to-door journey for the passenger. However, due to significant barriers related to incompatibilities between systems and data, it is recommended to focus on the development of direct communications between the passengers (respectively their travel agents) and each transport provider (respectively alliances of transport providers). Provision of door-to-door travel support, e.g. provision of alternatives in case of flight cancellation, could anyway be implemented as a de-centralized service, if supported by the required information sharing.

The following particular topics should be addressed by R&D:

- *Identification of existing data availability, technology and data flows*. This activity would identify available data, technologies and software that could be used to share data, and examine current data flows to passengers and between stakeholders. To accurately evaluate performance, the available data from many data sources and reporting methods used across Europe needs to be understood as a whole. Unless given incentives or provided with potential benefits, stakeholders are concerned that by sharing their data they are submitting themselves to open comparison with competitors. Therefore, a cost/benefit analysis of action upon stakeholders and the overall system is necessary. One could imagine a trade between the data passengers are ready to provide and stakeholders' data. Data provision and analysis could also be a way to enable multimodal ticketing, which could help significantly in streamlining multimodal journeys. Finally, identifying gaps in data provision could help to identify and address bottlenecks in the passenger journey, particularly where those bottlenecks arise from lack of information provision.

- *Identification of multimodal passenger flows and multimodal issues.* Following on from the previous area, multimodal issues and bottlenecks resulting from operational processes, deficiencies in existing technology, and lack of information exchange have to be examined using the available data sources. Given the level of complexity encountered in the multimodal transportation system, advanced methods could be used to explore uncertainty issues and networked interdependencies in order to reveal both the current issues and bottlenecks which have not yet occurred, but may do in future due to currently-foreseen system changes (e.g. increases in demand).

- *Experience and integration of Freight.* Although MetaCDM is a passenger-centric project, passengers are not the only users of the air transport system and a MetaCDM concept in practice might need to integrate with freight carriers as well. In addition, freight operators have longer experience with multimodality and mode-switching in cases of flight disruption and may be able to contribute via their own experiences and systems in turn.

- *Data framework*. A real-world MetaCDM implementation would involve (sometimes substantial) data flows between many stakeholders. A system combining a Big Data process to collect the numerous data from the various stakeholders (including passengers, Airport CDM, landside transport operators and others) and data flow management should securely treat these data and distribute accurate and reliable information to each stakeholder. The technical issues surrounding such an implementation are another area where ongoing research would be useful.

- *Competition vs cooperation*. The MetaCDM concept involves information exchange between various stakeholders who may be competing. The different data sources, their availability, and aspects of confidentiality have to be investigated. A trade-off between the performance of the solution of a multimodal network optimization and constraints in data provision should be established.

- *Crisis management needs.* An analysis of how the conclusions of research in the previous areas may change under crisis conditions, would help in setting recommendations for how data provision and exchanges would need to be modified when the aviation system is disrupted (e.g., if the passenger's flight is cancelled).

- *Understanding aviation disruption in the context of wider societal risks*: Disruption in the aviation system is inextricably linked to wider multi-system disruption, both as a cause (e.g. cancelled flights leading to problems with supply chains) and as a consequence (e.g. airport closures resulting from earthquakes, flooding or civil unrest). Similarly, aviation disruption may occur unrelatedly to ongoing wider disruptive events, but could require a response that is aware of them (e.g. making the decision to put passengers stranded by snow on ground transport during a flu pandemic). Understanding the links between aviation and other systems helps to devise ways of dealing with aviation disruption that are sensitive to what may be happening in a wider societal context and help rather than hinder responses to any wider disruptive events.

- *Service and Products Design*. Information needs to be delivered to passengers in a way that is user-friendly, simple and straightforward; passengers may need to access information at a variety of stages associated with their journey, ranging from months beforehand to whilst they are travelling. Similarly, the differing needs and preferences of passengers suggest that multiple approaches to data delivery are needed. Services should be useful, useable, desirable, efficient, and effective by drawing from the current customer experience and focusing on enhancing the quality of the journey as the key value for success. Inputs from the research activities described above would then help for the design of the required services. This could also lead to the development of the technological framework to deliver improved information via an integrated toolset. Once the tools and services have been designed and developed, the developed tools would have to be subject to modification based on the result of testing and experimentation in real-world situations.

- *Benefit analysis*. A more detailed network-wide benefit analysis of the concept would be necessary to support uptake and assess key economic and environmental aspects of the widespread uptake of a MetaCDM concept (in particular the performance-based travel management) and the supporting toolset and services.

6 Recommendations to the EC and other stakeholders

Achieving widespread adoption of the MetaCDM concept assumes a change in culture, attitudes and, to a certain extent, priorities. Many, if not most, of the delivery agents involved in providing an air transport service and its associated airside services have tended to be focused upon their own business imperatives and KPIs. Whilst actors within the sector necessarily have to connect, the processes by which planning, communication and response actions are co-ordinated are still relatively limited. Often these are between a few key organisations that are one layer up or down in the hierarchy and mostly lack any system wide connectivity.

Improving the systemic connection, communication, alerts and mitigation approaches requires recognition of current obstacles and implementing change. Some of the main barriers and potential actions, identified through interviews and subsequent analysis, are summarised below:

Barriers	Actions
Extend CDM from airside to landside	Expand the community engaged in A-CDM and Crisis cell network dialogue
Secure stakeholder good will to commit time to such a dialogue	EC/Governments to commission thorough economic analysis of the costs of delay/crisis events and the pros and cons of competition vs collaboration
Address high level issues such as legal liability, baseline information requirements, common/divergent features	May require EU/national level guidance/regulation
Limited data sharing across borders and between transport sectors	EC/Governments and sector trade bodies to formalise a MetaCDM dialogue
Incompatible national and international systems, data and practice	Initiate (EU level?) work and dialogue to share methodologies and move towards baseline compatibility
Competition and trust concerns over data that could risk position/customer base Common language/metrics - incompatibility of working practices	Define minimum requirements for effective interface between stakeholders Local authority orchestrated fora to examine stakeholder custom and practice, convergence criteria and to identify and

	reconcile stakeholder priorities
Practical inter-business conflicts: 1. Commonality of data and systems 2. Handling proprietary data 3. Through-ticketing/rebooking 4. Control, precedence and priority (between actors) 5. Agree standard journey milestones for data capture, prediction, monitoring and control 6. Open up on metrics and KPIs	Expand dialogue between sectoral trade bodies and operators, initially at local/national levels to include emergency services and local/national authorities
Trust and privacy concerns	Examine data-sharing protocols and a model to test with passengers
Access to GPS locational data	Need buy-in from major ISP/carrier to exert common platform pressure upon contributing stakeholders and address 'big data' issues
Lack of suitable comprehensive Apps and software	Dialogue between stakeholders, software providers and ISPs
Provision of systems that cater for non-technophiles and augment mobile communication	Develop connection with ground providers of alert/info networks: road gantry, station, bus, in-car systems, etc
Address pax brand loyalty, conservatism, caution, willingness to shift modes, etc that are constraints to applying effective MetaCDM	Initiate socio-economic/preference research into practice, habits and levers, e.g. between empowered and guided passengers

Table 15: Barriers and actions for the implementation of the MetaCDM concept

These and other actions could be taken forward by a large number of stakeholders ranging from international down to local bodies. Each will have their own sphere of influence but all can contribute to the right environment and the necessary steps towards delivering operational MetaCDM.

6.1 The European Commission

A major influencing player capable of promoting and enabling the development and adoption of MetaCDM is the EC. Below are a number of areas that the EC may wish to consider:

Initiating a states and delivery agents dialogue on a MetaCDM approach as part of delivering the 4 Hour D2D goal

It is suggested that the Commission could actively promote a dialogue – given its multi-sectoral interests – with States and between stakeholders in the context of its 4-hour door-to-door journey time ambition. It is in an ideal position to address high-level issues such as who takes responsibility for enabling different aspects of MetaCDM and providing some of the coordination mechanisms by which the community can get together. None of the individual sectoral trade bodies or organisations have equivalent reach and influence to simulate interest beyond their own specific interests so the strategic vision that the EC provides is a strong asset in helping to mobilise experts across transport modes, the hotels sector, emergency services and regional representative bodies. Moreover, with business resilience being a boardroom priority, the influence of the EC in calling for corporate engagement could help to secure the engagement of major transport, travel and logistics players.

Promote high-level European conferences that encourage big players to share strategies, tactics and data

The Commission could consider promoting an international conference, aligned with the 4-hour door-to-door journey time goal that gathers together those who could:

- Expose experience and lessons learned from major disruptive events;
- Identify obstacles to realizing MetaCDM;
- Share research knowledge and current best practice in the sector;
- Outline a policy path towards development of systems and protocols that would facilitate the progressive roll-out of MetaCDM.

Support further targeted research across transport and communication domains

As the research community having now identified many of the main issues and obstacles to MetaCDM implementation through a number of FP7-funded projects, the time is right to move the debate on to the beginnings of the strategic planning and delivery phase for Meta-CDM. However, there are still important issues needing further research to smooth the path towards implementation including:

- Prediction of process and transfer times at airports (both landside and airside);
- Cost/benefit analysis towards ‘buy-in’ by stakeholders;
- Global harmonization and network level optimization analysis linking with organisations such as CANSO and ACI;

- Analysis of the drivers for passenger demand and expected decisions made by passengers after receiving different types of information;
- Definition of performance indicators that work for multiple stakeholders;
- More detailed cost and benefit analysis of mitigation options to be offered to passengers in case of disruptions. This may necessitate passenger survey work;
- Identify available data, technologies and software that could be used to share data with passengers and others, and examine current data flows to passengers and between stakeholders;
- Identification of multimodal passenger flows and multimodal issues, bottlenecks and technology obstacles;
- Experience and integration of Freight;
- Data framework including system issues kinked to big data requirements;
- Unpacking competition vs cooperation issues to secure stakeholder co-operations;
- Understanding aviation disruption in the context of wider societal risks
- Service and product design for a MetaCDM world.

Initiating a crisis 'resources bank' where international or national level support services can be accessed

In pursuit of its policy ambition to enhance the resilience of the transport network and to apply lessons learned from previous serious disruptive events, the Commission could consider establishing a 'crisis bank' that identifies and collates national and international resources that could be mobilized in the event of major events. The Icelandic volcano eruption event and some winter snow events have spurred some sharing of knowledge, resource and equipment. The existence of a register of such capabilities and mitigation support could be a valuable asset and resource to assist transportation service providers and others to deal with crisis events. This could also extend to the development and sharing of core contingency planning approaches and ways to communicate with passengers in the event of disruptive events, including the coordinated usage of media opportunities to alert travellers of disruption and offer advice on actions to ameliorate the worst effects.

Developing positions that could be offered to an ICAO MetaCDM dialogue

With significant attention having already been given to resilience, CDM, multi-modal connectivity, passenger protection and business resilience by the EC, it is ideally placed to take a leadership role in advancing the case for MetaCDM with the global organisations such as the International Civil Aviation Organisation (ICAO). The EC, in conjunction with ICAO member states, could promote a programme of wider international activities, underpinning protocols and international research that would pave the way to some common enablers and practices that would help its own 4-hour door-to-door goal realization and help the aviation and linked systems to become more resilient.

Examine the production of guidance and protocols for media engagement/use/cooperation in crisis situations

The intervention of the media in crisis situations can be immensely helpful to ameliorating some of the worst effects of disruption but it can also act to exacerbate problems. Analysis of past media engagement with crisis events to learn lessons and consider ways to work with the media to work effectively with stakeholders, improve information dissemination to travellers and forestall or ease some of the potential catalytic effects.

More generally, the Commission could help to define a policy path towards development of systems and protocols that enable MetaCDM working alongside Eurocontrol, ECAC, ACI, IATA, CANSO and the trade bodies connected with other modes of transport. A key first step in moving the MetaCDM dialogue forward is to establish fora that allow for the issues to be discussed. This should be something that the Commission could propose, even if it is practically taken forward by one of the trade bodies.

6.2 Other high-Level Organisation Involvement

As noted, the Meta-CDM concept necessarily involves multiple stakeholders. Key enablers of MetaCDM are:

Air Navigation Service Providers (ANSPs)

ANSPs are critical players and Eurocontrol has already done a lot to advance the CDM concept and its operation in a number of locations across Europe. They could further assist the wider airports network in a number of ways and it may be worth giving further consideration to:

- Protocols that enable levels of filtered alert information to be passed through the network. This would clearly require a significant dialogue with stakeholders about the types, ranking and description of relevant alert information. It would also need to be based upon a clear understanding of the extent of the network of contributors and receivers of information;
- A web 'dashboard' of status information to which stakeholders could contribute. This could be run using a 'traffic light' system to help airports, airlines and others initiate appropriate levels of preventative or mitigation action and when to alert passengers to possible disruption;

- The establishment of intelligence/alert units that can capture non-operational features such as meteorological or security data and make that available to the network;
- Undertaking further work towards implementing an A-CDM-Lite process for smaller airports that are unable to commit the resources and time to a fully detailed A-CDM system. The greater the extent of adoption of A-CDM Lite, the easier it would be to transition to a MetaCDM process for these smaller airports.

Trade bodies

The importance of the trade bodies being involved is significant as they can help to win the interest and support of their members towards the benefits of MetaCDM. They can help propagate a discussion amongst the airports and air carrier networks and distil from members the attributes that they would like to see involved in MetaCDM. As repositories of sector knowledge, the trade bodies are also very well placed to gather and then disseminate 'best practice' information, such as Frankfurt Airport's colour coding approach towards disruption management, that can help to improve the efficiency of the sector in crisis situations.

Trade bodies could:

- Work to gather 'best practice' knowledge and share it with those who work daily with the issues in different parts of the sector;
- Encourage members to engage with national, regional and local resilience fora;
- Once broad concepts are agreed amongst industry stakeholders, offer training to member companies (whether in person or via desktop modules) that communicate A-CDM and MetaCDM practice.

6.3 National and local organisations

MetaCDM implementation requires that there close practical engagement at the airport, local and regional level to coordinate planning, operational and resilience measures beyond the core airport, airline and ANSP partnership. Actions that can be initiated, if they do not already exist, by airports, local authorities and regional agencies include:

- Wider local to regional planning and resilience networks that treat transportation as an integrated service and seek to coordinate planning, pool data and facilitate response action when needed;
- A national dialogue of interested parties under the auspices of the relevant government departments. That means the development of a stronger dialogue with governments about the benefits of MetaCDM for national transportation resilience and passenger experience;
- National guidelines and protocols that make it easier for the sharing of knowledge and data and minimize the competitive sensitivities of business by showing that those

organisations that engage will see improved operational predictability and reduced disruption costs. The development of such guidance would require further research and the analysis of case studies to illustrate the benefits;

- Simplified communication conduits for intelligence on transport disruption drawing upon security agencies, governmental embassy networks and the media. Early warning is crucial to effective preemptive action and mitigation so the importance of horizon scanning and downstream communication cannot be overstressed.

Referenced Documents

[No.] Title / Identification / Version and Status	Company
[1] 9th annual SITA survey, http://www.sita.aero/content/improving-passenger-experience-no-1-driver-airport-investment	SITA
[2] ETSI EN 303 212 "Airport collaborative Decision Making (A-CDM); Single European Sky Interoperability Regulation EC 552/2004", Version 1.1.1, June 2010	European Committee for Standardization (CEN)
[3] Travel Market Report, 2012. "Airports' new passenger focus could sideline agents." http://www.travelmarketreport.com/business?articleID=7333&LP=1	Travel Market Report
[4] EN 13816:2002-07: "Transportation – Logistics and services – Public passenger transport; Service quality definition, targeting and measurement", 2002	European Committee for Standardization (CEN)
[5] EN 15140:2006: "Public passenger transport - Basic requirements and recommendations for systems that measure delivered service quality", 2006.	European Committee for Standardization (CEN)
[6] Marzuoli, A., Laplace, I., Feron, E., Dray, L., Gardner, R., Günther, T. and Spies, G., 2013. MetaCDM D1.2 – Analysis of Recent Disruptions of the Air Transport System. MetaCDM Work Package 100 Final Report, http://www.meta-cdm.org/Deliverables/META-CDM_D1.2_1.0.pdf	MetaCDM project
[7] Cook, A., Tanner, G., Cristóbal, S. and Zanin, M., 2014. Final Technical Report, POEM project.	POEM project
[8] ACI, 2014. Passenger Traffic 2012. http://www.aci.aero/Data-Centre/Annual-Traffic-Data/Passengers/2012-final	ACI
[9] Eurostat, 2014. Air Passenger Statistics database. http://epp.eurostat.ec.europa.eu/portal/page/portal/transport/data/database	Eurostat

[No.] Title / Identification / Version and Status	Company
[10] Eurocontrol, 2013a. CODA Digest – Delays to Air Transport in Europe 2012. http://www.eurocontrol.int/sites/default/files/content/documents/official-documents/facts-and-figures/coda-reports/CODA-Digests-2012/coda-digest-annual-2012.pdf	Eurocontrol
[11] Eurocontrol, 2013b. Network Operations Report – Annual 2012. https://www.eurocontrol.int/publications/network-operations-report-annual-2012	Eurocontrol
[12] Carbonell, F., Martínez, Y. M., 2012. MODAIR Deliverable D3.1: Report on High-speed Train Connections.	MODAIR project
[13] OAG, 2005, Official Airline Guide Schedules for 2005. http://www.oagdata.com	OAG
[14] TravelMath Journey Planner, 2014. http://www.travelmath.com	TravelMath
[15] Deutsche Bahn, 2014, Online Journey Planner. http://www.bahn.de	Deutsche Bahn
[16] MapQuest Journey Planner, 2014. http://www.mapquest.com	MapQuest
[17] OAG, 2012. Official Airline Guide schedule database for 2012. http://oagdata.com.	OAG
[18] HM Revenue and Customs, 2014. Approved mileage and fuel allowances. http://www.hmrc.gov.uk/rates/travel.htm.	HM Revenue and Customs
[19] Zhang, Y. and Hansen, M., 2008. Real-time intermodal substitution: Strategy for airline recovery from schedule perturbation and for mitigation of airport congestion. *Transportation Research Record* **2052 (1)**, 90-99.	
[20] Andersson, E., Berg, M., Nelldal, B.-L., & Fröidh, O., 2011. TOSCA WP3 Final Report. http://www.toscaproject.org/FinalReports/TOSCA_WP3_RailPassenger.pdf	TOSCA project

[No.] Title / Identification / Version and Status	Company
[21] Lee, D.S., Fahey, D. W., Forster, P. M., Newton, P. J., Wit, R. C. N., Lim, L. L., Owen, B. & Sausen, R., 2009. Aviation and Global Climate Change in the 21st Century. *Atmospheric Environment* **43**, 3520-3537.	
[22] EC, 2014. Eurostat Energy Statistics. http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/introduction	EC
[23] ICAO, 2013. 2013 Environmental Report. http://cfapp.icao.int/Environmental-Report-2013/files/assets/basic-html/index.html#1	ICAO
[24] OECD/ITF, 2008. "Greenhouse Gas Reduction Strategies in the Transport Sector: Preliminary Report", Report to the International Transport Forum, http://www.internationaltransportforum.org/pub/pdf/08ghg.pdf	OECD/ITF
[25] Lan, S., Clarke, J.-P., Barnhart, C., 2006. Planning for Robust Airline Operations: Optimizing Aircraft Routings and Flight Departure Times to Minimize Passenger Disruptions. *Transportation Science*, **40 (1)**, 15-28.	

Annex 1: Airports used in the feasibility analysis

For the feasibility analysis for ground transport substitution, passenger traffic between the top 50 airports for passenger traffic in Europe in 2012 was analysed, including Turkey, Norway and Switzerland but excluding the former Soviet Union countries (so as to have a similar scope to Eurocontrol's CODA reporting). Details on these airports are given in Table 16, including major disruptive events experienced in 2012.

2012 Rank	Airport	IATA Code	City	2012 Passengers	Main 2012 Disruptive Events[4]
1	Heathrow	LHR	London	70,037,417	Strong winds, low visibility, snow events, thunderstorms, Olympics
2	Charles de Gaulle	CDG	Paris	61,611,934	ATC and general strikes, low visibility, thunderstorms
3	Frankfurt	FRA	Frankfurt	57,520,001	Airport personnel and cabin crew strikes, thunderstorms, low visibility, snow event
4	Schiphol	AMS	Amsterdam	51,035,590	Strong winds, low visibility, snow events, WWII bomb disposal
5	Madrid-Barajas	MAD	Madrid	45,190,528	General strike
6	Atatürk International	IST	Istanbul	45,091,962	Strong winds, low visibility, snow event, airline staff strike
7	Munich	MUC	Munich	38,360,604	Strong winds, low visibility, snow events, thunderstorms, ACC systems failure, ACC new systems trial
8	Leonardo da Vinci-Fiumicino	FCO	Rome	36,980,911	
9	Barcelona El Prat	BCN	Barcelona	35,144,503	General strike
10	London Gatwick	LGW	London	34,235,982	Strong winds, low visibility, snow events, thunderstorms
11	Paris-Orly	ORY	Paris	27,232,263	ATC and general strikes, low visibility
12	Antalya	AYT	Antalya	24,993,667	Airline staff strike
13	Zürich	ZRH	Zürich	24,802,466	Strong winds, low visibility, snow events, thunderstorms
14	Copenhagen Kastrup	CPH	Copenhagen	23,336,187	Snow event

[4] As reported by Eurocontrol's Network Operations Report 2012 [11]. For a more comprehensive list, see Annex 1 to the first MetaCDM report [6].

15	Palma de Mallorca	PMI	Palma de Mallorca	22,666,858	General strike
16	Vienna International	VIE	Vienna	22,165,794	
17	Oslo Gardermoen International	OSL	Oslo	22,080,433	Strong winds, low visibility, snow events, ATC staff shortages
18	Düsseldorf International	DUS	Düsseldorf	20,833,246	Thunderstorms, snow event
19	Manchester	MAN	Manchester	19,736,502	
20	Stockholm-Arlanda	ARN	Stockholm	19,642,029	Enroute delays from ATC upgrade
21	Dublin	DUB	Dublin	19,099,649	
22	Brussels	BRU	Brussels	18,971,332	Low visibility
23	Malpensa	MXP	Milan	18,537,301	
24	Berlin Tegel	TXL	Berlin	18,164,203	Thunderstorms
25	London Stansted	STN	London	17,472,699	Strong winds, low visibility, snow events, thunderstorms
26	Lisbon Portela	LIS	Lisbon	15,301,176	General strike
27	Helsinki	HEL	Helsinki	14,858,215	
28	Sabiha Gökçen Airport	SAW	Istanbul	14,487,242	Airline staff strike
29	Geneva International	GVA	Geneva	13,899,422	Snow event
30	Hamburg	HAM	Hamburg	13,697,402	Thunderstorms
31	Athens International	ATH	Athens	12,944,041	Radar failure, strikes
32	Málaga	AGP	Málaga	12,581,944	General strike
33	Nice Côte d'Azur	NCE	Nice	11,189,896	ATC strikes
34	Václav Havel	PRG	Prague	10,807,890	
35	Gran Canaria	LPA	Las Palmas de Gran Canaria	9,862,067	General strike
36	Stuttgart	STR	Stuttgart	9,720,877	Thunderstorms
37	London Luton	LTN	London	9,617,697	Strong winds, low visibility, snow events, thunderstorms
38	Frederic Chopin	WAW	Warsaw	9,587,842	
39	Adnan Menderes	ADB	Izmir	9,356,284	Airline strike

40	Cologne Bonn	CGN	Cologne/Bonn	9,280,070	Thunderstorms
41	Esenboğa	ESB	Ankara	9,237,886	Airline staff strike
42	Linate	LIN	Milan	9,229,890	
43	Edinburgh	EDI	Edinburgh	9,195,061	
44	Birmingham	BHX	Birmingham	8,922,539	
45	Orio al Serio	BGY	Bergamo/Milan	8,890,720	
46	Alicante	ALC	Alicante	8,855,444	General strike
47	Tenerife South	TFS	Santa Cruz de Tenerife	8,530,729	General strike
48	Liszt Ferenc International	BUD	Budapest	8,504,020	
49	Lyon-Saint Exupéry	LYS	Lyon	8,451,039	ATC and general strikes
50	Marseille Provence	MRS	Marseille	8,295,479	ATC and general strikes

Table 16: Airports used in the feasibility analysis and disruption experienced in 2012.

Annex 2: Passenger Rights and Cost of Delay

MetaCDM is a feasible concept only if it is cost-effective to implement. However, working out the true costs of delays and cancellations to airlines, airports and passengers is not straightforward. In this annex, the assumptions used to calculate airline costs of passenger delay in the feasibility analysis (Section 62) are detailed. We concentrate on passenger costs of delays and cancellations as it is these that MetaCDM addresses. Costs of delays and cancellations accruing to airlines from other sources, for example those associated with incorrect positioning of aircraft, are assumed to be identical to the situation without MetaCDM.

Length of Delay	Travel distance	Passenger rights
< 2 hours	all	none
> 2 hours	< 1500 km	Meal and refreshments; two telephone calls/telexes/faxes/e-mails
> 3 hours	> 1500 km, intra-EU flight	
	1500 < distance <3500 km	
> 4 hours		
> 5 hours	all	As above, plus reimbursement of ticket and return to origin
next day	all	As above, plus hotel accommodation and transportation to/from hotel

Table 17: Air passenger rights by length of delay.

Passenger costs can be divided into hard costs, which are the direct costs to the airline of providing passenger assistance (e.g. meal vouchers or hotel rooms), and soft costs, which are the costs that accrue to the airline as a result of disgruntled passengers changing their future travel behaviour as a result of their experience of delay. Although hard costs are relatively straightforward to account for, the situation is complicated in that many passengers do not take up their full rights as afforded by EC legislation. The main applicable regulation is EC 261/2004, which requires passenger compensation and assistance to be provided by the airline for denied boarding, cancellations or long delays. In addition, EC 2027/1997 and 889/2002 set out the limits of air carrier liability for passengers and baggage. EC communication 2011/174 clarifies the regulations on passenger compensation and assistance and suggests improvements in passenger information, and communication EC 2011/898 reviews the different rights passengers have by transport mode, including rights to information. The proposed legislation EC 2013/203 revises air passenger rights, strengthening the right to information, clarifying a number of grey areas and issues relating to enforcement. Current passenger rights are summarized in Table 17 above, adapted from [7].

In practice, relatively few passengers request ticket reimbursement, although statistics on the exact number are hard to come by. We follow Cook et al. [7] in assuming that 20% of passengers request reimbursement and/or a return to their point of origin. We assign these passengers randomly; in practice, this means that 10% of passengers are assumed to be reimbursed and not travel at all (as they are already at their point of origin) and 10% of passengers are assumed to be reimbursed and also provided with transport back to their point of origin.

In terms of hard costs associated with passenger assistance, we use the following assumptions (adapted from [7]).

Length of Delay, t (hours)	**Provision**	**Cost (year 2012 euro) by scenario, 2 s.f.**		
		Low	**Base**	**High**
$1.5 \leq t < 2$	Refreshment	0	1.8	2.1
$2 \leq t < 3$	Refreshment and tax-free-voucher	4.9	8.1	9.9
$3 \leq t < 5$	Refreshment, tax-free voucher, meal voucher and FFP miles	13	20	24
$t \geq 5$, not overnight	Refreshment, tax-free voucher, meal voucher, FFP miles and ticket discount voucher	14	22	27
Overnight	As above plus hotel accommodation	54	87	105

Table 18: Passenger hard costs by length of delay.

Hotel costs in particular should be noted; these are typically significantly lower than walk-up hotel prices due to pre-arranged deals made between airlines and airport area hotels. For delays stretching beyond one day, we assume that this process, and the associated costs, repeats each day. In reality, the number of passengers who decide not to travel will increase with each further day of delay. However, we do not model this effect.

The other major component of passenger delay costs is soft costs, i.e. the cost to airlines of passengers who are dissatisfied following delays or cancellations and subsequently change their travel behaviour. These costs are difficult to measure. In particular, the system-wide cost is not the same as the cost to individual airlines as many passengers will switch to a different airline in future rather than choose not to travel at all. The impact of MetaCDM is also difficult to gauge. Offering passengers the option of switching modes is likely to alter their level of dissatisfaction, hopefully improving it. However, it is unclear if passengers who (for example) arrive at their final destination five hours late after switching to a high-speed train will have the same level of dissatisfaction as passengers who arrive at their destination five hours late via an alternate flight. In the absence of passenger survey data, we again use cost estimates from [7], assuming that passenger dissatisfaction is linked only to delay duration and not to the mode of transport used to reach the final destination. As in [7], we calculate system-level rather than airline-level costs and assume that these are around ten percent of the single-airline estimates. Costs are given in Table 19. Costs are capped after five hours of delay, at which point it is assumed that passengers are already extremely dissatisfied.

Delay (minutes)	5	15	30	60	90	120	180	240	300
Low Cost Scenario, year 2012 euros per passenger minute	0.01	0.02	0.07	0.20	0.26	0.28	0.28	0.28	0.28
Base Cost Scenario, year 2012 euros per passenger minute	0.02	0.09	0.26	0.73	0.96	1.01	1.02	1.02	1.02
High Cost Scenario, year 2012 euros per passenger minute	0.03	0.11	0.29	0.81	1.06	1.11	1.13	1.13	1.13

Table 19: Passenger soft costs by length of delay.

Taken together, these individual sources of cost lead to a per-passenger cost distribution as shown in Figure 16. The exact shape of the distribution will depend on the time of day the delay begins; Figure 16 assumes a delay beginning at 2pm. Under the assumption of system-level rather than airline-level soft costs, hard costs dominate for longer delays. This means that the overall cost to airlines of delayed passengers is relatively low. However, it should be noted that this outcome depends on several key assumptions, in particular:

- The assumption that relatively few passengers will ask for reimbursement. If passengers become more aware of their rights as a response to improvements in information provision, the cost of delay to airlines is likely to increase.
- The assumptions about the amount of system-level versus airline-level soft cost, about saturation of dissatisfaction, and about how switching modes may affect passenger dissatisfaction. These numbers are relatively poorly-known and the current assumptions lead to a relatively low level of soft cost. Greater soft cost would result in greater total cost of delay to airlines.
- Whether the base, high or low cost scenarios are used. Except where otherwise stated, we use the base scenarios in the document.

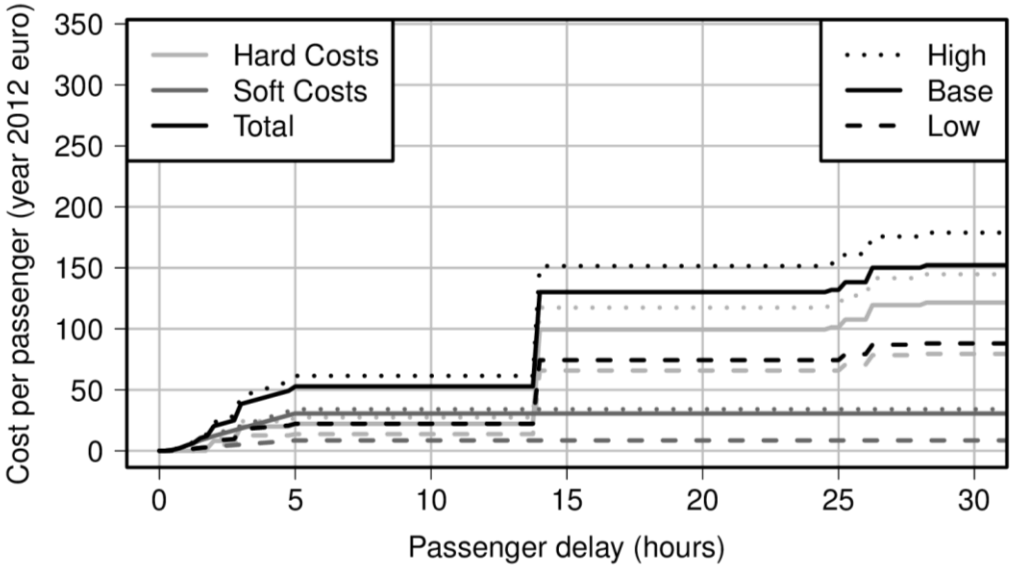

Figure 16: Assumptions about passenger hard and soft costs by length of delay