META-CDM: Multimodal, Efficient Transportation in Airports and Collaborative Decision Making

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Abstract

Be it snow, volcanic ash or strikes, crisis events impose high costs on the air transportation system and society. Airlines have progressively learned to mitigate the irregular operations arising from such events through procedures such as Airport Collaborative Decision Making (A-CDM) for traffic flow and airport departure management; however the passenger's door-to-door journey during difficult times often remains unpleasant.
Meta-CDM (Multimodal, Efficient Transportation in Airports and Collaborative Decision Making), aims to take a passenger-centric approach and to examine how airside and landside CDM can be interlinked with other transport modes to minimize the impact of severe disruptions. We provide an analysis of past successes and failures of passenger-centric operations, by investigating representative disruptive events. We focus on the links between different transportation modes and the practicalities of switching modes in a crisis situation. We analyze if and how passenger metrics could be used to measure the performance of an extended A-CDM concept.

Keywords: A-CDM; disruptive events, passenger centric metrics, resilience, multimodality.

Résumé

Les crises affectant le système du transport aérien (évènements météorologiques, éruption volcanique, grèves) se révèlent non seulement couteuses pour celui-ci mais également pour la société dans son ensemble. Si les compagnies aériennes parviennent progressivement à réduire les irrégularités de leurs opérations grâce à des procédures telles que celles liées au A-CDM (Airport Collaborative Decision Making), le voyage porte à porte des passagers aériens continue à être fortement impacté et peut ainsi être vécu comme une désagréable expérience pour ceux-ci. L'objectif du projet Meta-CDM (Multimodal, Efficient Transportation in Airports and Collaborative Decision Making) est d'étudier comment le CDM pourrait être amélioré pour permettre de minimiser l'impact des perturbations importantes. Dans cet article, après avoir analysé des évènements perturbateurs passés, nous étudions les liens entre les différents modes de transport en situation de crise ainsi que les métriques passagers qui pourraient être utilisés pour mesurer les performances d'un concept CDM étendu.

Mots-clé: A-CDM ; évènements perturbateurs, métrique centrée sur le passager, résilience, multimodalité

Nomenclature

A-CDM Airport Collaborative Decision Making
ANSP Air Navigation Service Provider
CDG Charles de Gaulle
KPI Key Performance Indicators
TTOT Target Take Off Times

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1. Introduction

The objective of making each passenger or cargo's door- to-door journey seamless cannot be achieved without a better understanding of the multi-modal transportation network. In its vision for Europe in 2050, the European Commission (European Commission (2011)) sets the goal: "90\% of travellers within Europe are able to complete their journey, door-to-door within 4 hours. Passengers and freight are able to transfer seamlessly between transport modes to reach the final destination smoothly, predictably and on-time." The regular occurrence of significant perturbations that propagate through the system and sometimes even paralyze it highlights the need for further research on its resilience and agility and for adequate coordination at the network level. At the airport level, this is beginning to be addressed by Collaborative Decision Making (CDM) initiatives, tools and procedures. The objectives of the META-CDM project are to study the conditions under which Collaborative Decision Making can help the transportation system deal under nominal or perturbed conditions.

A number of European airports have, over the past decade, taken major steps that aim at coordinating surface operations with airborne traffic. These Airport CDM or, in short, A-CDM programs have resulted from many years of implementation efforts. Several European airports have by now completed their conversion to A-CDM. The objectives of A-CDM are to reduce delays and improve system predictability, while optimizing the utilization of resources and reducing environmental impact. Airport Collaborative Decision Making is one of the five priority measures in the Flight Efficiency Plan published by IATA, CANSO and Eurocontrol. An airport is considered a CDM airport when A-CDM Information Sharing (ACIS), Turn-Around Process (CTRP) and Variable Taxi Time Calculation (VTTC) concept elements are applied at the airport. In Europe, airport CDM has been implemented successfully at several airports and are expanding. Collaborative Air Traffic Management is now a key component in both SESAR and NextGen.

The objectives of Airport Collaborative Decision Making (A-CDM) are to reduce delays and improve system predictability, while optimizing the utilization of resources and reducing environmental impact. Several European airports have by now completed their conversion to A-CDM. Airport Collaborative Decision Making is one of the five priority measures in the Flight Efficiency Plan published by IATA, CANSO and Eurocontrol. Collaborative Decision Making (CDM) has been hugely successful at enabling advanced air transportation concepts such as ground delay programs and airport departure managers.

These observations prompt the following questions: What is the coherence and coordination of the many systems that are part of delivering the traveller through an airport? When crises hits, how well can contingency plans minimize passenger inconvenience? How can alternative transportation modes and communication media help the air transportation system to minimize personal disruption during crisis situations?

Meta-CDM (Multimodal, Efficient Transportation in Airports and Collaborative Decision Making), aims to provide preliminary answers to these questions by taking a passenger-centric approach and to examine how airside and landside CDM can be interlinked with other transport modes to minimize the impact of severe disruptions. The final outcome of the project will be a set of recommendations based on best practice for European or global airports, and as a roadmap for future research areas.

Airports where A-CDM has been fully implemented now include Munich, Brussels, Paris-Charles de Gaulle, Frankfurt, London-Heathrow, Helsinki-Vantaa and most recently, Düsseldorf and Switzerland’s primary hub, Zurich. A-CDM deployment is being facilitated by the Network Manager, with a target of 20 major airports by the end of 2014. Collectively, these airports welcome over 250 million passengers a year and their efforts have yielded significant benefits for airlines and passengers. The most cited benefits to Airlines and Passengers are better punctuality, with an average 3 minutes reduction in aircraft taxi time, and fuel savings for airlines, up to 20.8 million euros last year.

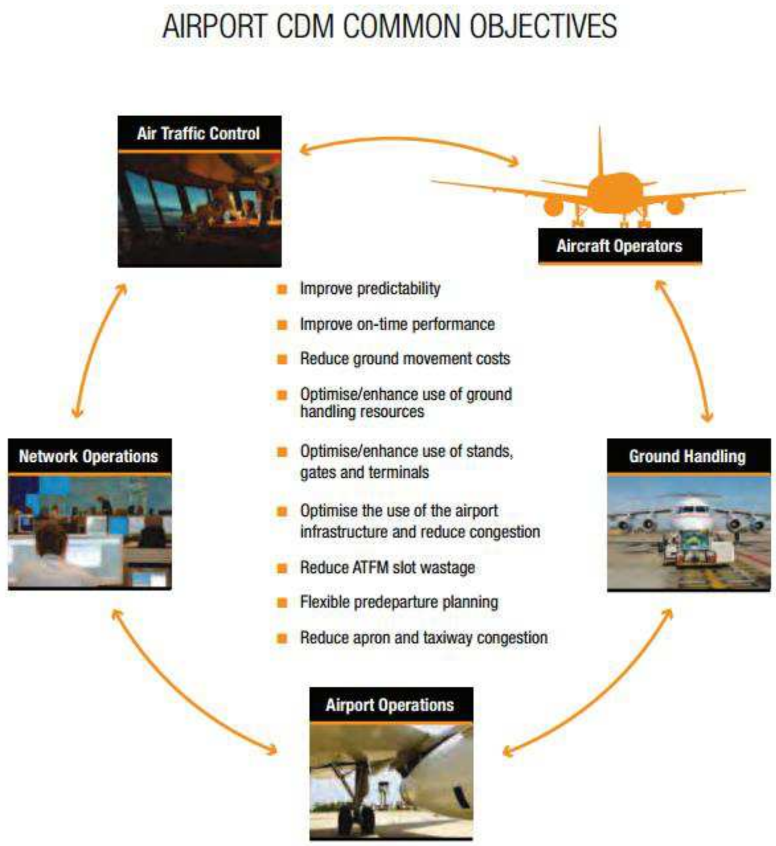

Figure 1: Collaborative Decision Making Process

There is little theoretical literature on Collaborative Decision Making and its impact. Ball et al. developed and analysed two approaches to incorporate stochastic optimization models in a CDM-like setting. These models are able to create a traffic flow management plan for a set of flights whose flight plan intersect a volume of airspace undergoing a severe capacity reduction. In their scenarios, the ANSP allocates certain resources to the flight operators and the flight operators then optimize the use of resources they are given.

One of the first efforts to evaluate the potential of CDM at the network level is undertaken by Bertsimas and Gupta (Bertsimas (2011)). They propose an Air Traffic Flow Management model with a CDM framework from an airport setting to an airspace context incorporating fairness and airline collaboration. Their empirical results of the proposed model on national-scale, real world datasets, show promising computational times and a proof of the strength of the formulation.

Goni Modrego et al., from Eurocontrol, performed a study to measure the impact on the network if 42 of the most delay constrained airports in Europe were to implement CDM in a near future. Their results suggest that, if more airports were to implement A-CDM and provide the CFMU with accurate Target Take Off Times (TTOT) via DPI messages, the benefits could extend from the local airport environment to the network. They compute a potential sector capacity increase within the European area of up to 4%, that is between one and two aircraft per sector. Their analysis of A-CDM on delays points out a room for improvement between 33% and 50%.
In the US, Montoya et al. tackled the topic of improving departure runway usage through a market-based approach between airlines. Their dynamic second price auction method for allocating runway usage lead to analytical and simulated results suggesting that the method does not increase total delay, but that now almost all the delay is spent at the gate, hence saving fuel. Compared to the current first-come-first-serve mechanism, this approach would help reduce airlines costs via fuel savings, and generate a more equitable spread of delay across all airlines.

This paper aims at providing the results of a series of on-site stakeholders' interviews at various European airports. Our team investigate how increased collaboration and information sharing can improve passengers' door-to-door journey. This question is examined at the airport level, at the airport network level and at the boundaries between modes in urban settings.

This paper is organized as follows. First, an analysis of information sharing procedures and current needs at both CDM and non-CDM airports is presented. Second, the challenges of multimodality are described, as well as examples of cooperation between modes. Third, the question of performance monitoring and reporting is tackled to identify the areas where increased information sharing and collaboration are needed.

2. The benefits of information sharing

The information sharing is at the heart of the airport CDM concept which aims at making the communication between stakeholders easier, by using adapted procedures and tools. The greatest benefits obtained by A-CDM are a common situational awareness between the stakeholders and an increase in operational predictability. It provides better arrival estimates that benefit not only the stakeholders but also the passengers.

In nominal conditions of operations, stakeholders generally agree on the ability of A-CDM at providing a common situational awareness between stakeholders as well as an increase in the operational predictability.

However, in case of disruptive events, A-CDM procedures are no more adapted. Airport stakeholders, as well on A-CDM platform as on non A-CDM platform, complain about the difficulty to get and share information at two levels:

- At the network level
- At the airport level

2.1. At the network level

Stakeholders complain about the lack of information coming from other platforms facing disruptive events. The impacts of the snowball effect in the propagation of the disturbances between airports can indeed be all the more disastrous that stakeholders cannot anticipate them.

An illustration of this is the snowball effect between London Heathrow, Paris CDG and Toulouse Blagnac airports during the heavy snowfalls period occurred in December 2010 in Europe. While Paris CDG airport was functioning close to its maximum capacity due to heavy snowfalls in the region, London Heathrow airport had to close its operations due to these snowfalls. However, Paris CDG airport was not aware of this closure a long before and had to accommodate on short notice long-haul flights that were expected to land at London Heathrow. Knowing in advance that London Heathrow airport could potentially close its operations and that some flights could be eventually rerouted to Paris CDG airport, would have helped stakeholders anticipating these new constraints and better organize themselves.

Finally, Paris CDG airport had to also close its operations because of missing deicing fluids. This closure had important impacts on Toulouse Blagnac airport which had to accommodate on a very short notice also, long-haul flights planned to land at Paris CDG airports. In particular, as Toulouse airport is one of the scarce regional airports having a runway adapted to the A380 requirements, numerous A380 flights were rerouted to this airport, involving difficulties in the aircraft parking as well as in terms of additional passengers stuck at the airport. Knowing earlier that some long-haul flights could potentially be rerouted to Toulouse Blagnac would have not prevented from a critical situation in this airport. Nevertheless such information would have allowed the airport to better organize to welcome the unexpected traffic on the platform.
Due to the lack of official information coming from the other platforms, some stakeholders try to get information by their own. Then, the transfer of collected information between stakeholders reveals not efficient: not structured and generally only made by oral between people.

2.2. At the airport level

During disruptive events, the A-CDM system is generally in fail soft mode. Communications are only based on a "human system" and generally lead to delays in the reception of information. Hence, if all airports have a crisis room in which stakeholders can meet regularly, the non-automatic transfer of information leads to a lengthy information sharing process.
As a consequence, there is few or no information to communicate to passengers which are stuck at the airport.
It was for instance the case in Toulouse airport, during the December 2010 crisis, where airline representatives were not aware of the location of their planes in the other platforms and had no information to communicate to the others stakeholders or to the passengers.
Some airports have however started putting in place procedures so as to provide to passengers as much information as possible and providing them solutions. A good illustration of this is the "Terminal Colour Concept" developed conjointly by Fraport and Lufthansa at Frankfurt Main airport. In situation of crisis, a dedicated team combining the Fraport Care Team and the Lufthansa Passenger Irregularities Team, deploys in the terminals. Each area of the terminals is associated to a specific color and numerous sign elements referring to these colors aim at optimizing the orientation and information distribution of passengers.
One of the first tasks of the Fraport/Luftansa team is to provide to passengers information on the color of the area in which they have to go. Then in each area, the staff uses tablet computers to access the Lufthansa system in which real time information are available for each passenger of the Lufthansa airline. The application on the tablet computer provides the different solutions that the staff is able to provide to each passenger (rebooking on another flight, rebooking on train for domestic passengers, hotel booking, etc…).
This "Terminal Colour Concept" was used 5 or 6 times already and received good feedbacks from the passengers. Fraport and Lufthansa consider this concept as successful mainly because:

- communication channels are well defined,
- the concept is easy to understand for passengers and staff,
- the concept helps reducing waiting time and provide a constant assistance to passengers by trained staff.

This concept seems to be a good practice to improve the communication process between the airline/airport and the passengers during crisis events. However, the system is not directly linked to the CDM system and does not prevent from the slowness of the human system communication between airside stakeholders during disruptive events.

In case of degradation, at most A-CDM airports, there are predefined crisis plans and associated cells at most airports of sufficient size in Europe. At hub airports, such as Paris CDG, a room, called Plateau CDM, may be dedicated to gathering all the decision makers and stakeholders in one place to ensure common situational awareness and improved decision processes. Several types of events, such as snow falls, icing prediction, social strikes announcements or bomb warnings, trigger alerts that lead to predefined responses,
Even labeled A-CDM airports continue improving their response to perturbations. For instance, at Brussels airport, adverse conditions, attributed mostly to bad weather here, remain to be addressed in the CDM implementation. It entails sharing data and milestones from Eurocontrol on the start and end of deicing. Better capacity management in adverse conditions and common decisions on reducing the capacity at the airport are needed. In the past, a few severe weather episodes led to serious sequencing problems and it has been identified as an area of improvement. The issue of contingency planning in case of computer system deficiency is often not yet addressed. If there was a system failure in Brussels, each stakeholder has its own contingency planning, but none exists at the CDM level. For example, if the TOBT was out of link for the SNA, the EOBT would serve as a back-up for sequencing. Accurate and regularly updated tailored weather forecast is a key factor to reduce uncertainty in airport operations. For spoke airports of significant size, out-of-the-shelf solutions may be too expensive and not suited to their needs.

Through our interviews, we were led to discuss the case of several airports that are considering taking the first steps towards obtaining the A-CDM label.
For an airport aiming at improving its operations and the coordination between stakeholders, the first step was to gain buy-in from all. To ensure that all stakeholders will be willing to participate, the actors need to show the potential benefits that CDM could bring to a given platform with its specifics. Organizing workshops to improve or change current processes is the second step, leading to the definition of a calendar and a first basis for the

information exchange set-up. Then it is time to see if current tools can be adapted to a more collaborative framework or if new tools need to be developed or bought.
For spoke airports, tailored solutions may be needed, because of the current cost of the current CDM tools available on the market. The full CDM process as defined by Eurocontrol takes time to achieve and airport first need to see that the premise of CDM, i.e. collaboration, can bring benefits on a particular topic of concern to the stakeholders.
For airports thinking of starting the CDM implementation steps, the most appealing aspects are more information sharing between stakeholders as well as better visibility and image. However, they are concerned with the cost and the weight of the full CDM procedures. When a spoke airport has a lot of flights to and from CDM hub airports, having a system to capitalize on the increased reliability of these airports to improve their own is of significant interest. This would mean providing access to the "CDM network" to non-CDM airports to improve performance at the network level.
Setting up a data sharing platform needs to be a tailored process as well. For instance, at Brussels airport, a central database, composed of a system to system link, is in place. There is operational follow-up of the data flow. Each stakeholder has a module on which it can interface its own API (Application Programming Interface) to extract the specific information it needs from the system. The CDM milestones have been developed for each stakeholder.
The CDM team also provides communication and training around CDM. After an initial big round of training about two years ago, now such activity is mostly ad hoc, or on request, for a CDM information course or refresher. Sharing the experience and difficulties met on one's platform is also part of the spirit of CDM, to help other airports improve their operations and bring benefits to the whole network.
Various technologies are currently available to support information sharing. Data link can improve data sharing, several systems can now link the ground and the air, and SWIM can benefit from the new generation of AODB airport or flight plans databases.
One particular issue raised is getting the TSAT in the cockpit for ACDM airports. In Brussels, docking guidance systems displays are installed, but a lot of airports do not have the means to install them.

3. Bridging the airside and the landside – multimodality

The linkage between airside and landside which appears essential to deal with disruptive events, can be called Airport multimodality. Multimodality is the use of several transport modes in one trip when the transport modes are coordinated thanks adequate intermodal infrastructure, and intermodal agreements concluded by transport operators. At an airport level, we can distinguish two different types of multimodality:

- Airport access multimodality, when the use of the land transport (bus, tramway, train, etc.) aims at linking the airport to the city center.
- Network integration multimodality, when the use of the land transport is in the scope of the airport integration in the regional or national network of the landside transport modes (High-Speed train, etc.).

Laplace and al. (Laplace (2006)) considered both multimodality definitions to study the conditions of development of the airport multimodality in Europe, in the MODAIR study funded by EUROCONTROL between 2004 and 2006. The aim of the study was to determine the conditions of development of the airport multimodality:

- At intermodal actors levels, by analyzing their expectations and incentives to develop intermodal agreements,
- At nations and Europe levels, by identifying the main modifications of the transport environment that may ultimately result in modifications in the level of multimodality.

The analysis on both levels was supported by the use of indicators of airport multimodality.
Interviews conducted with intermodal stakeholders (ANA Portugal airport, Fraport airport and Lyon airport, Lufthansa, RFF, REFER and Thalys) associated to literature reviews lead Laplace and al to conclude that “the actors are expecting the development of multimodality as a way to deal with a certain number of issues inherent of air transport: congestion and environment, competition and profitability”. They identified that the main drivers of multimodality development are:

- The existence of airside and landside congestion levels at airports;
- The existence of environmental pressure from the society;
- The objective of reducing operating costs;
- The objective of increasing of the catchment area.

On the other hand, the main obstacles of multimodality development are:

- The high investments needed for developing the intermodal infrastructure;
- The limit in coordination and collaboration incentives between intermodal stakeholders when they are also competitors;
- The lack of communication to passengers on intermodal products;
- The poor perception regarding rail transport that passengers can have in certain countries;
- The lesser competitiveness of the high speed train in countries at the "borders of Europe", since distances between the centres generator of traffic are longer than in the "core" European area.

Authors also concluded about the central importance of airlines in airport multimodality development. Despite the active role that airports or rail operators can have in multimodality development, the choice of intermodal products hinges on airlines needs and demands.

Steele et al. pose the problem of predicting the changes in passenger demand between different modes of transports during a disturbance of one or more of its systems (Steele (2011)). Their research develops a simplified dual-mode UK transport model using system dynamics and recent data, to test responses to disturbances. The partial substitution of some short-haul flights with High Speed Rail transport, either through modal competition or complementarity, is already in place in four European hubs (Frankfurt Main, Paris CDG, Madrid Barajas, Amsterdam Schipol). Janic (Janic (2011)) shows that the High Speed Rail substitutive capacity does not act as a barrier to developing air/rail substitutions at the airport. Even a modest substitution may produce substantial savings in airline costs and passenger delays.
For the passengers, traveling across several modes of transportation to complete their journey can be difficult, especially when it comes to planning travel times. To improve the passenger's experience, more and more advanced transport information systems (ATIS) provide services such as route planning, navigation, updates on disruptions, real time information alerts and replanning tools. Zhang et al. (Zhang (2011)) build a supernetwork, where the networks for different modalities are integrated. They distinguish road, rail, air, water transportation as well as private (e.g. foot, bike, car) or public modes (e.g. bus, train, tram, metro). Some links are time independent, others time dependent or stochastic time dependent. The travel time and monetary cost may also be computed. The authors tested their tool for the Eindhoven region with success and are working on improving the computation time of their model.

Multimodality is slowly becoming a reality, at least within the European transportation system. The principal difficulty is not whether it should be done or not - it is widely admitted that flights lasting less than one hour could be advantageously replaced by ground transportation, such as rail - but how. Indeed, finding an economically viable path towards fully integrated multimodal transportation will require leveraging today's resources and investing the profits in system improvement until satisfaction is reached.

The profitability of multimodality is indeed a trade-off between market effects and the balance of profit and loss (Bitterer (2013)). For instance, while an airport can expect higher retail revenues with an increased catchment area as well as higher airport charges thanks to slot substitution between short and long-haul flights, it may also face a reduction in car parking revenues.
One main challenge of the air/rail multimodality development is therefore to manage developing the cooperation between intermodal stakeholders which have different strategies and become alternately competitors and partners (Pfagner (2013)). A first illustration lies in the difficulty to integrate air and rail scheduling: airlines and railway companies mainly serve different markets and have their own sales strategies. As a consequence, many passengers complain about the longer air/rail transfer compared to the air/air transfer (Sallier (2013)).
In addition, offering an integrated ticketing distribution is also a main obstacle to the multimodality development: besides the technical difficulties linked to the connection between booking systems, air and rail stakeholders have to accept adopting a strategy of cooperation and not of competition.
The extra-cost sharing between stakeholders is also a main difficulty to solve since each stakeholder cost depends on its position in the cooperation. For instance, at Frankfurt Main airport, the intermodal infrastructure cost is only borne by the airport while the information system cost is shared between the airline and the railway

company. At the same time, the airline, the railway company and the airport share the costs linked to the luggage logistic or the marketing.

Such difficulty in cooperating between intermodal stakeholders in nominal operational conditions also mainly explain the lack of multimodal solutions proposed by stakeholders in case of disruptive events.

Nevertheless, some airports have chosen to bypass this problem by concluding specific agreements with rail companies in crisis situations. This solution has been for instance chosen by Toulouse Blagnac airport which has concluded an agreement with the French national railway company (SNCF) to transfer domestic passengers on trains in case of disruptive events.

It is however important to stress that if the use of ground transport solutions can prove useful to reaccomodate passengers stuck at the airport, it may only concern domestic passengers. In addition, in case of bad weather conditions, ground transport can also be disrupted and as a consequence not used as an alternative solution for passengers.

It is the authors' belief that before CDM can truly be established with other modes, several steps can be taken to start bridging the airside and the landside at the airport itself. Kim et al. (Kim 2013) studied robust airport gate scheduling for improved passengers' experience using flight schedules. Their objective was to minimize transit times of passengers in terminals, aircraft taxi time on ramps and gate conflicts. They showed that airport gate assignment has the potential to be improved regarding the efficiency of passenger traffic flow in terminals and on ramps and the robustness of the gate assignment. Landside and airside cooperation requires the identification of areas where collaborative improvement can bring benefits to all parties. This means that data and performance analysis need to be at least partially shared so these areas can be identified.

Performance indicators

The question of measuring performance can be approached from two perspectives: on the one side, the traditional airlines and airports point of view, on the other side, the passengers' point of view.

At any given airport, each stakeholder has internal KPIs which they usually do not share. The only quantification of CDM benefits at the airport level so far is in terms of tons of fuel saved and sometimes, the adherence to slots. Less qualitative and more quantitative data needed to showcase the benefits of CDM, and gain buy-in from the stakeholders.

CDM brings the most improvement when there is an acute problem to be solved that brings solidarity between the stakeholders. Interviews showed that the issue of the financing of CDM and the team responsible for it at airports is a sensitive topic, particularly when the benefits and their repartition across stakeholders are not explicit.

Concerning reporting of indicators, several stakeholders interviewed pointed out the need for more global performance reporting, along with detailed financial, economic, environmental and operational indicators.

In the dashboard of airlines and airport management, there needs to be indicators of punctuality and slot adherence. The baggage handling and the associated quality of service also fall into the scope of the performance reporting, since its reliability and monitoring impact the entire surface operations.

In practice, CDM measures the quantity of information regarding a flight and its state transitions.

At Charles de Gaulle airport, several performance evaluation levels exist in the context of CDM@CDG:

- at the airport level to be compared with competing airports,
- internally to test the CDM tools efficiency,
- within each major actor.

The KPIs used internally are usually specific to the airport in question. At CDG, Aeroports de Paris (ADP) mainly monitors taxi time and off-block delay. Delays are accounted for using month-to-month and year-to-year comparisons.

It is considered that CDM and GLD (Local Departure Management) allowed aircraft to save 1 minute of taxi time per flight, over all flights, including those which did not incur any delays. There is a specific accounting for departures at CDG, due to the fact it operates literally as two decoupled airports. Some discussion is still ongoing about the sensitivity of delay accounting to delay definition changes.

When it comes to each actor, there is little sharing the nature of their internal KPIs. However, one airline explained that they rely on KPIs on punctuality, flight connections and luggage access in particular.

Other KPIs are specifically used for CDM purposes: some are real time indicators, others monthly, others are oriented by the scope of the European Performance Scheme. One of the main European freight operator highlighted that most of the current performance evaluation is done by human operators, who often rely on experience, habits, to trigger contingency plans. Simply defining appropriate KPIs for each system, whether package sorting, routine maintenance or flight operations, constitutes a problem in itself. Relying on several sub-contractors makes it even harder to monitor the overall performance. So far, the performance of CDM@CDG disclosed to all actors was only the measure of tons of fuel saved. A baggage handler interviewed said that although they have no KPIs measures, an increase in operations efficiency with CDM was noted. This was through offering the possibility to change the estimated departures slots.
The main achievements of CDM, some of them quantifiable, are listed below:

- Safety, capacity, punctuality, equity and environmental benefits,
- less ground traffic,
- better load balancing,
- more precise en-route information,
- an aircraft that pushes back is ensured to be able to take off,
- one of the main airlines has gained in breaking and engines maintenance, while for another the Low Visibility Procedure brought a gain of 4 minutes per flight and 6 tons of fuel saved per day.

At Brussels airport, the stakeholders acknowledge that KPIs reporting deserves improvement and could potentially bring several benefits. For instance, currently no exact data on predictability is available.
There is no communication on the performance of CDM simply because there is no agreement on how it should be measured and which data is needed for this purpose.
A lot of insight comes from operational knowledge. A reduction in taxi time has been observed, because it is now preferred to delay aircraft at the gate instead of on the surface. From the airport point of view, it is best to keep aircraft at the gate to optimize the sequence and avoid unnecessary congestion. However, from the airlines' perspective, such delay is counted as airline delay, which does not seem to counterbalance the associated fuel savings. To ensure stakeholders' acceptance of A-CDM, it should not be perceived as too constraining or as adding stress on airline performance.
The importance of real-time performance reporting, or at least data sharing, has been stressed throughout our interviews. It is part of a larger need for airport and network health monitoring, to increase the reactivity of the system, particularly under disruptions. The earlier notification of signs of disruptions, such as the airport parking being close to capacity, would enable each stakeholder to regulate its operations and certainly mitigate the propagation and length of the disturbances.

In recent years, a second point of view has emerged as a key aspect to include in performance reporting. The passenger, as a customer, does not perceive the quality of the air transportation system as airlines and airports traditionally do. Flight delays do not accurately reflect the delays imposed upon passengers' full multi-modal itinerary. The growing interest to measure ATM performance calls for metrics that reflect the passenger's experience. Cook and al. (Cook (2009, 2013)) design propagation-centric and passenger-centric performance metrics, and compare them with existing classical metrics, with regard to intelligibility, sensitivity and consistency. Their list of propagation oriented metrics comprises: departure and arrival delays, cancelled flights, extra flight time, extra gate time, reactionary minutes, back-propagation, reactionary disruptions and their depth. The passenger oriented metrics cover: departure and arrival delays, the ratio of scheduled trip time to final arrival delay, cancelled flights, missed connections, re-routes, extra flights, extra flight time, weighted load factor, aborted trips and extra wait time. The authors also identify the top ten critical airports in Europe according to three different network classifications.
Bratu (Bratu (2006)) et al. calculate passenger delay using monthly data from a major airline operating a hub-and-spoke network. They show that disrupted passengers, whose journey was interrupted by a capacity reduction, are only 3% of the total passengers, but suffer 39% of the total passenger delay.

Understanding the passengers' preferences is essential in a period of multi-airports regions' growth and intense competition between airlines, whether legacy airlines or low-cost. This is especially the case in regions where the increase in air traffic is most important. Four major competing airports are now located in the Hong Kong-Pearl River Delta region. Loo et al. (Loo (2005)) model the choices of air travellers for international and domestic flights, and describe scenarios of regional airport competition and airport coordination. Their continuum approach offers good results to understand the geography of air transportation, with possible simultaneous changes in variables. These variables comprise average propensity to travel, spatial distribution of air travellers, regional inflows and outflows of passengers, ground transportation infrastructure capacities, number and physical location of airports, ground transportation cost, congestion effect, cross-border cost, airport Level Of Service (LOS) and government's aviation policy.

In recent years, airlines have started to increasingly warn passengers unilaterally when their flight is at risk of being cancelled, and several offer the chance for a passenger to reschedule their flight in advance. Passengers also rely more and more on personal devices to check-in at airport and go through security. The potential for passengers to play a more active role in deciding how to pursue their journey when it has been disrupted remains to be explored. Multimodality cooperation and multimodal ticketing regulation could bring enormous benefits in terms of offering passengers to pursue their journey via other modes, while relieving airports overwhelmed by stranded passengers. The voluntary passengers' mode switch would have to be part of new performance indicators to be defined by stakeholders across modes.

Interviews have shown that, even though stakeholders are aware of the importance of passenger-oriented metrics, the processes to include them in the overall performance monitoring and reporting remain to be defined and implemented.

4. Conclusion

Collaborative Decision Making at congested airports has demonstrated that considerable improvements could be achieved at airports by air transportation agents, without sacrificing internal objectives and the means for different operators to achieve them. This paper presented the results of several interviews of stakeholders across various European airports. Through prior work and data analysis, interviews, and engineering design, the benefits of extending Airport CDM to include the landside, including ground transportation, can be shown to be real and significant for the passenger. The many options available to enable a true Multimodal, Efficient Transportation in Airports for the passenger's benefit in the spirit of CDM will require careful quantitative future analyses. Their practical implementation will benefit from the patient efforts and experience accumulated so far with Airport-CDM. The overall goal is always to pave the way for a more efficient, more resilient, and more passenger-friendly Air Transportation System, functioning harmoniously with other modes of transportation. It is reasonable to believe that a network-wide CDM can bring significant improvements to the performance of the entire air transportation system, and that the definition of multimodal cooperation, particularly under perturbed conditions, has the potential to make a big difference in the passengers' journey.

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