

# COLLABORATIVE AIRPORT PASSENGER MANAGEMENT WITH A VIRTUAL CONTROL ROOM

Florian Rudolph, Erik Grunewald, Martin Schiele, Amir Ayazkhani

German Aerospace Center (DLR), Institute of Air Transport and Airport Research, Lilienthalplatz 7,  
38108 Braunschweig, Germany

## Abstract

Key performance indicator-driven connection management at airports with public transportation services

Integrated traffic management across a range of shareholders within a widespread network requires a definition of KPIs to assess intermodal performance. Their purpose is to monitor and analyze the technical performance of individual modules of a transportation network, e.g. an airport. Actions recommended to optimize operations and to maintain operation during disruptions are ideally based on an understanding of the system-wide impact of the action and for the entire intermodal chain of the journey from door to door. With all the numerous possible parameters and indicators which can be monitored within a complex transportation network, not every indicator is necessarily a key indicator. We show which indicators can depict a situation consisting of a system status and a system forecast, which allow inter-stakeholder optimization and which serve as an enabler for a Mobility as a Service (MaaS) concept.

Examples of intermodal-oriented KPIs include the "Amount of useable travel time", the "Boarding Score" and the "Connectivity Matrix". Useable travel times are defined as the longest, continuous travel and waiting times which can be used for productivity or relaxation. The Boarding Score accounts for reaching a connection on time, e.g. catching the desired flight after travelling to the airport by train. The Connectivity Matrix dynamically expands the Minimum Connecting Time MCT (which is known from airports and is

important for booking systems), allowing forecast values to be offered based on the demanded connecting journeys instead of on average spreadsheet values.

With the deployment of the new key performance indicator set a tool is given to visualize situational awareness at an airport. This includes nowcasting as well as forecasting awareness which is required to assess different options of intervention. The method of calculation of the KPI set is enriched by a concept of visualization using virtual reality options to maintain usability within distributed management teams. For validation purpose, the Optimode.net simulation environment is used.

## 1. Introduction

With the digitalisation of travel, the distribution of the roles of transport providers and infrastructure operators will change fundamentally. The universal availability of planning and real-time information alone alters the participation in the competition for the mutual customers. In addition, the possibility exists of specifically targeting customer demands, for example by providing transport offers on the basis of actual demand and not simply running through an established plan. Such a near future is described by the concept of Mobility as a Service (MaaS).

Instead of focusing on the customer experience, the trend points towards seamless transportation. Not only the transport offer is hereby interruption-free but also, above all, the traffic management as well as the fare and claim management. In today's world, however, there is a lack of prerequisites which

could prompt companies to raise their management to the next level. Even if the will is there, from the economic point of view, the foundation which would justify such changes would still be lacking.

Traffic management in today's world is driven by the horizon of the hierarchical authority of a company. The operator of a regional train can influence his train movements. He cannot, however, delay the connecting flight of one of his passengers in order to secure their onward journey despite arriving late at the airport/station. Even if it were possible to pass on this information, thereby triggering a reaction and helping the customer effectively, this would not have a positive effect on the key performance indicators of the train operator. His criteria for the evaluation of the company operations do not usually recognise a value for the successful transfer of the passenger to the next stakeholder, who might possibly even be a competitor.

Within the framework of our project, research was performed regarding the introduction of innovative key performance indicators for the networked traffic management of planned traffic. Existing performance indicators were thereby examined concerning their intermodal orientation and new indicators were added. Using these indicators, performed traffic management has the potential to increase efficiency in transport networks. Firstly, because the systematic, performance indicator-based monitoring of the traffic situation as well as the forecast for future traffic situations is suitable for the prevention of undesirable developments. Secondly, through the collaboration, the possibility is created of improving the overall performance of the transport network. Each transport operator within the network will be in a position to implement solutions for the day-to-day business in co-operation with the other partners and competitors, which he would not be able to do alone due to the lack of existing

authority to issue directives. This has the potential to improve the system efficiency, which would not only be useful in the event of occurring disruptions but would also generate advantages for the day-to-day business.

### *1.1. Total Airport Management*

In aviation, efficiency-enhancing procedures have been establishing themselves for some time. These rely on the exchange of operating information across the span of stakeholders. The arrangement of a system-wide information exchange on the airside of an airport, the so-called system-wide information management SWIM (Crescenzo, Strano et al., 2010), alone leads to a significant gain for the participants through an increased situational awareness and the individual opportunity of being able to react to alterations. With the so-called Airport Collaborative Decision Making (A-CDM), the processes at appropriately upgraded airports are being optimised based on SWIM. A-CDM thereby relies on the optimisation of the capacity utilisation and the improvement of the predictability of events. All air-side operations during an aircraft turnaround as well as the pre-departure sequencing were incorporated into the process. The introduction of A-CDM is intended to increase productivity and reduce costs for all companies participating in the system. Airports should therefore receive more reliable plans for the occupancy of the aircraft parking positions and less congestion on the apron and taxiways through optimised traffic flows. The airlines should benefit from an increased situational awareness, as they receive through A-CDM current status information, for example concerning the departure sequence. As an option, when available, their own flight planning can be optimised through the notification of an Estimated Offblock Time (EOBT) for A-CDM departures. Air navigation service providers

(ANSPs) benefit from the more accurate scheduling in the utilisation of the available runway capacities as well as from demand-capacity balancing for the subsequent airspace. The allocation of airway slots ("ATFM slots" for air traffic flow management slots) is then performed on the basis of the more accurate predictions instead of the original flight applications.

As by Eurocontrol, A-CDM is currently already established at 20 selected European airports and therefore already state-of-the-art. The concept of the Total Airport Management TAM (Spies, Piekert et al., 2008), which provides a holistic challenge to the management, goes a significant step further. The land-based processes at the airport are hereby also taken into account and the time horizon is expanded significantly. Whilst A-CDM places more focus on the current operation with a lead time of up to three hours, the TAM demand extends from up-to-date events through to strategic management. In the TAM concept - not yet in operation at any airport - all participants follow a joint plan, the so-called Airport Operations Plan.

Total Airport Management may, however, possibly necessitate the establishment of an airport control centre, a so-called AirPort Operation Centre APOC (Piekert, Schier et al., 2015). The mutually-managed resources are administrated mutually in this war room. This means that the use of the resources of a stakeholder in the APOC is decided by the group and not necessarily by the stakeholder itself. However, the necessity of the physical creation of a mutual control centre infrastructure may perhaps deter the transport operators from bearing the corresponding costs and possibly losing competence. In this respect, virtual control centres provide a possibility in which the mutual interaction can be controlled from the stakeholders' internal control centres and mutual decisions can be realised through

virtual networking. Using the example of a virtual link between airport management and railway management (Milbredt, Rudolph et al., 2016), it was possible to demonstrate the additional value that knowledge of operational information could have for the respective other stakeholders if the traveller's connection reliability represented an added value. The simulations showed how the knowledge of the connection quality for the flight-willing train passengers can lead to targeted interventions in air traffic as a reaction to disturbances in rail travel in order to secure the connections. The TAM system recognises the occurrence of the problem, in this case the route disruption of the railway stakeholder, and limits its negative consequences through co-operative management and the provision of fast lanes for the affected parties in order to ensure faster handling in the terminal; the time that is then still required is realised by means of determined departure delays. This vision of networked management also enables a so-called "what-if" cycle, in which not only one option can be considered as to how the current operation could be influenced, but instead a multitude of options can be tested virtually. In (Milbredt, Werner et al., 2016), this functionality was finally investigated. Various intervention possibilities were hereby analysed in parallel as what-if cycle. By means of a preliminary evaluation function, a ranking of the variants was produced. The solution that maximizes the evaluation function (or minimizes its costs) heads this list. It is thereby precisely the key performance indicators which (must) find their way into the evaluation function in order to achieve their desired effect. The safeguarding of travel connections must be assessed accordingly through the KPIs, which was ensured in the tests by taking into account the KPI "Boarding Score" in its aircraft-precise specification.

## 1.2. Mobility as a Service MaaS

The trend towards new forms of mobility is supported by the subsistence of the so-called Internet of Things, IoT. In conjunction with smart solutions for complex ecosystems, above all the Smart Cities, a completely unique understanding of mobility develops which, from the perspective of the traveller himself, is self-designed. With the concept of "Mobility as a Service (MaaS)", the networked transport system is approaching a vision from the municipal and inter-municipal sectors. (Heikkilä 2014) defines MaaS as a coherent system which offers the users mobility services through service operators. These providers act as integrators for the services which they themselves purchase from the various modes of transport. Highlighting the efficient application of infrastructure resources (land use), an intelligent, networked (local) traffic system is outlined (Rantasila 2015), taking into account public and individual modes of transport. Attention is also drawn to the fact that MaaS should not be regarded simply as a database link with an app, but instead more importantly as a paradigm shift towards user orientation in the planning of offers.

The differing system worlds of the Total Airport Management TAM and those of the Mobility as a Service MaaS meet in the literal sense at the interface of land transport to air transport. Whilst the MaaS concept is driven in particular by the White Paper of the European Commission (European Commission, 2011), the TAM concept is oriented on the objectives of ACARE (ACARE, 2011). Both have in common the aspirations towards increased efficiency and networking.

## 2. Intermodal-oriented indicators

### 2.1. Measuring intermodality?

Intermodality describes the transport of persons or goods with more than one mode of transport on a seamless journey (Jones, Cassidy et al., 2000). Intermodality is therefore differentiated from multimodality and monomodality (Chlond, Last et al., 2004). In monomodality, solely one single means of transport is used and this applies to all the incidental recurring journeys (e.g. the daily route to the office with one's own car). Multimodality means that there is a change in the mode of transport used over an observed period of time, but that the individual journey is always made with only one means of transport. Intermodality, in contrast, means a change during the trip; a multimodal change over time is not directly affected by this. Even though real intermodality may be relatively rare in daily journeys - (Nobis 2015) speaks of a mere three per cent of all journeys in Germany - air travel is almost always intermodal. For an airport, to all intents and purposes the prototype of an intermodal traffic node, the calculation of intermodality would appear to be particularly important. State-of-the-art in airport benchmarking is the comparison of the available functionalities and traffic quantity structures (Oum, Yu et al., 2003) as well as the punctuality.

For the assessment of the intermodal performance capability, particularly punctuality is currently available. It indicates whether an aircraft is more or less than 15 minutes behind its planned time.

Rank	Arrival Airport	ICAO Code	Average delay per Flight (mins)	Average Delay per Flight Percentage Change	Average Delay per Delayed Arrival	Percentage of Delayed Arrivals
1	ISTANBUL-ATATURK	LTBA	18.4	37%	33.1	55.6%
2	LONDON/GATWICK	EGKK	16.5	15%	36.4	45.4%
3	LONDON/HEATHROW	EGLL	13.1	7%	30.5	43.1%
4	ROME FIUMICINO	LIRF	12.0	41%	31.6	38.0%
5	DUBLIN	EIDW	12.0	21%	28.4	42.2%

Table 1. All-causes delay. Top 5 affected arrival airports 2015 (Eurocontrol CODA, 2016)

Table 1 shows the five most unpunctual airports in Europe in terms of arrivals. At these airports, a considerable portion of flights land unpunctually. It can be expected that these circumstances are bad for intermodal travel plans; at the very least, they necessitate an extensive inclusion of buffer times in order to avoid remaining without connection. Indeed, the poor on-time performance of landing aircraft does not enable deduction of the extent to which intermodality is actually affected. The supply of flexible means of transport (e.g. taxi), a high frequency of recurring services (e.g. local transport) and the planning of buffers can effectively be the basis for acceptable intermodality - alone, we do not really know.

In order to make this measurable, we implement the Boarding Score in order to introduce an intuitively ascertainable performance indicator, which measures the connection performance capability of the link.

## 2.2. Boarding Score

The KPI Boarding Score records the proportion of passengers who have actually reached their planned means of transport (flight or public transport). Due to differing demands, the Boarding Score is given as an absolute value (Boarding Number) and as ratios (Boarding Score) in the analysis.

The Boarding Score can be used as a core value for the entire airport for a defined period of time, e.g. for an operation day. The

calculation presupposes that it is known who wants to reach which means of transport and that this achievement or non-achievement is documented. With the introduction of the so-called passenger trajectory (Milbredt, Rudolph et al., 2016), a technological scenario was defined which is necessary for data acquisition and data analysis. On the assumption of a passenger-based data exchange (the passenger himself decides with which mode of transport and which infrastructure operator his information will be shared), solely the booking information for the individual modes of transport along the intermodal travel chain provide a corresponding basis. For up-to-date traffic management, however, it may be advisable to filter according to target group in order to perform an ongoing analysis of the Boarding Score. The Boarding Score can then take place within an airline or an airline alliance or in accordance with the flight number, or can document intermodal (passenger) changes. Particularly in the case of changing the mode of transport, the traveller assumes the sole responsibility. With the recording of the Boarding Score, it is now possible to see whether the change was actually successful.

## 2.3. Connectivity Matrix

According to the IATA definition, the Minimum Connection Time (MCT) indicates the minimum expected connection time that a passenger (and his luggage) requires in order to change from one flight to another. IATA

MCTs take into account solely static values. These are used in booking systems (such as Amadeus) to filter out the flights which are connectable with one another. MCTs of the airports should therefore ensure that the time between the arrival of the one aircraft and the departure of the subsequent aircraft is sufficient for the changeover. The more conservatively the MCT is calculated, the more secure the actually occurring linkage will be in reality. Unfortunately, the MCT cannot be conservatively estimated at will, as the overall journey time increases with longer minimum transfer times in the booking system. The chance of successful marketing of indirect routes decreases the longer a connection is in comparison with the competition. The competition takes place here between the hub airports, which compete for the end customers, although the actual contract of carriage is concluded with an airline. MCTs are therefore calculated as conservatively as necessary and as narrowly as possible in order to obtain acceptable error rates for the change connection in real operation with acceptable transfer times.

In contrast, the Connectivity Matrix, which is newly defined in the project, contains both the static factors, such as pure travel times between the respective gates, and the dynamic factors, such as queues at the intermediate process points. It is therefore necessary to apply forecast functionalities in order to predict the resource utilisation of the airport infrastructure, particularly in the transfer area, for the operating day. Ideally, the airport operator would be granted access to the demand situation of the airlines - either from these or directly from the end customers. The transfer relationships actually requested on this operating day can thereby be monitored and active intervention can occur if connections are at risk of being missed. Accordingly, the knowledge of up-to-date demand has the advantage that the

minimum connection time does not have to be met for all theoretical combinations of arrivals and departures (or even of all arrival gates and departure gates). If there is no demand for a connection, it does not have to comply with a level of service. Instead, the connections which are actually in demand are supported, for example through grouped placement (stands and gates in physical proximity).

#### *2.4. Amount of usable travel time*

For both commercial and private journeys, it is of advantage to the traveller if he can use parts of the travel time for productive or recreational purposes (proportion of usable travel time). The decisive factor for this is that the longest possible periods of time are spent in one place at a time. Surveys (Raux, Ma et al., 2011) have shown that travel time can be perceived very differently - from a complete loss of time through to a valuable time gain for activities which would have otherwise not been carried out. So far, however, it has not been possible to determine a quantitative model. In order to avoid the paradox that the classification of increasing travel times as usable travel time has a positive effect, the usable travel time is expressed as a proportion of the total journey time. Under any circumstances, transfers are associated with losses in comfort: distances must be covered on foot, the traveller must reorient himself and keep an eye on the next transfer time during the journey. Therefore, from the point of view of a traveller, the indicator is the transfer frequency for his journey chain.

The Schweizer Bahn (Swiss railways, SBB), uses the information shown in Table 2 to advertise the system-inherent advantage that the railway has compared to flying, indicating the more favourable proportions of usable travel times. From an intermodal perspective it is, however, also expedient to bear in mind the proportion of usable travel time. Passengers

whose connection situation has become problematic because, for example, a significant delay has occurred, could be offered a travel alternative by the tour operator. If the travellers can choose from a number of offers and if the question of cost takes a back seat, the proportion of usable

travel time can (help to) decide which alternative will be favoured. Such alternatives can be arranged intermodally; combinations with particularly frequent transfers will, however, appear at least unattractive due to the resultant loss of usable travel times.

From	To	Journey time by train	Journey time on a flight <sup>1)</sup>	Usable time by train <sup>2)</sup>	Usable time on a flight <sup>3)</sup>
Basel	Paris	3:03 h	3:30 h	2:53 h	0:50 h
Basel	Frankfurt (Main)	2:47 h	3:15 h	2:37 h	0:50 h
Basel	Cologne	3:53 h	4:05 h <sup>4)</sup>	3:43 h	0:50 h
Zurich	Stuttgart	2:58 h	3:10 h	2:48 h	0:25 h
Zurich	Munich	4:12 h	3:30 h	4:02 h	0:40 h
Zurich	Innsbruck	3:31 h	5:45 h <sup>4)</sup>	3:21 h	2:00 h
Zurich	Milan	3:26 h	3:45 h	3:16 h	0:40 h
Bern	Frankfurt (Main)	4:04 h	4:05 h	3:54 h	0:50 h
Bern	Paris	4:01 h	4:00 h	3:41 h	1:00 h
Geneva	Milan	3:53 h	5:10 h	3:43 h	0:50 h
Geneva	Paris	3:08 h	3:20 h	2:58 h	0:50 h
Lausanne	Paris	3:40 h	3:34 h	3:30 h	1:25 h

1) Incl. check-in/check-out and transfer. Flight times are approximate and subject to change.  
2) Calculation utilisation time by train: travel time for each journey -10 minutes, changing -10 minutes.  
3) Calculation of usable time when travelling by aeroplane: flight time -20 minutes  
4) No direct flights

Table 2. Information regarding usable travel times from the Schweizer Bahn SBB (SBB, 2017)

### 3. Virtual Reality

For the visualization of situational awareness by KPIs, the simulation research facility of the Optimode.net project was used and linked with the data interfaces of the installed services (Milbredt, Olaf und Rudolph, Florian (2017)). As an example, the KPI “amount of

usable travel time” is visualized for the security process of the airport. Control room personnel is virtually attending a management session. Therefore, a virtual table shows passenger progress taken out of the current simulation. Over time, passenger status has influence on the virtual appearance of the passengers, e.g. on their colour.

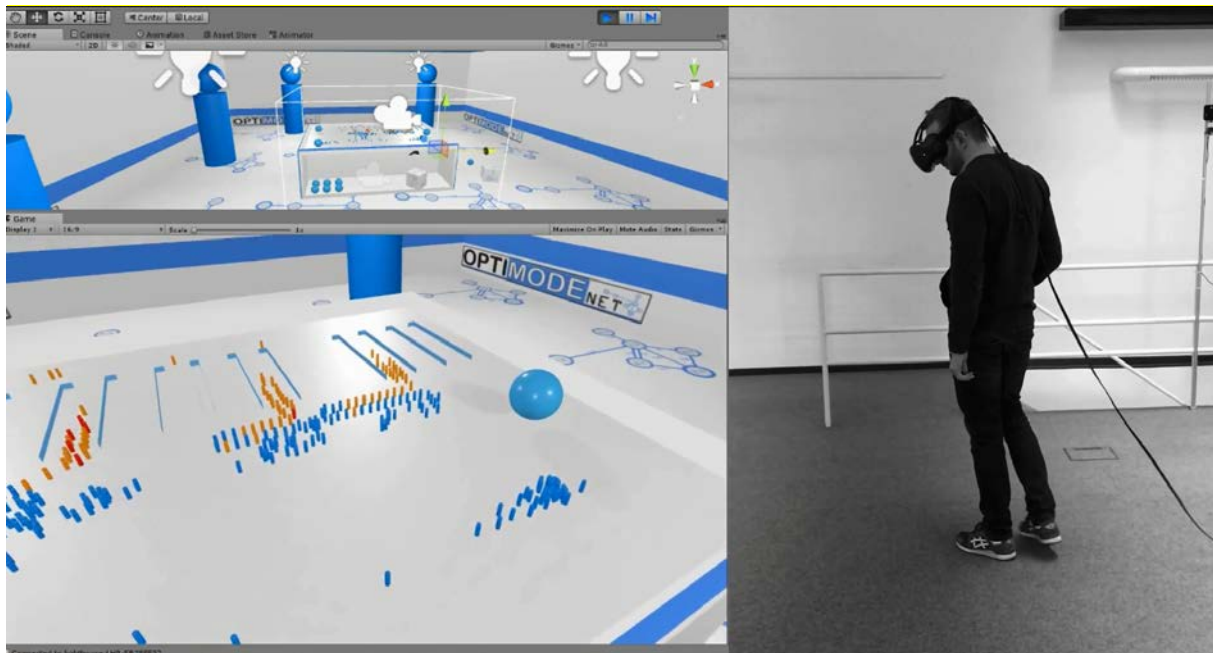


Figure 1: Virtual Control Room

Blue passengers for example have experienced a waiting time below 10 minutes, yellow passengers below 20 minutes, and red passengers were already long waiting more than 20 minutes. In figure 1, right part, one VR user is shown in its empty moving area, whereas in the left part of the picture is shown what the user can see. The user is empowered to gain an overview over the situation of focus and can trigger actions in the simulated what-if stream. The impact is instantly visible due to the virtual reaction on the management action.

#### 4. Outlook

With the introduction of intermodal-oriented performance indicators, an existing validation gap is closed, with which innovations for increasing the attractiveness and acceptance of intermodality could prove their effectiveness. In particular punctuality as a performance characteristic is only indirectly related to intermodality. Within a door-to-door travel chain, it is not so much the absolute punctuality that helps the traveller, but primarily the connection protection. With the Boarding Score and the Connectivity

Matrix for airports, two high-performance indicators are hereby presented. In further research, the quantity of information on travellers which is necessary in order to generate reliable statements concerning intermodal performance capability will be parameterised.

The current version of virtual multimodal control center allows the access for one person. Next step is the implementation of the multi-user functionality to allow for multi-stakeholder users to manage the traffic knot. Individual management tools will become included by projecting them onto the side wall of the virtual room including limited visibility for critical information not to be spread over all team members who can be competitors.

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