Intermodal Augmented Scheduling

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Abstract

Intermodal augmented scheduling frames a concept for research of interdependencies and interactions between planning and execution of travel chains from the infrastructure owners' and travelers' points of view. It focusses on a generic airport as a complex interface between various transport modes, especially between air transport and ground-based transport carriers.

Keywords : airport ; operations ; passenger ; management ; infrastructure ; network

Résumé

La planificationaugmentéeintermodaleencadreunconcept pourla recherchedes interdépendanceset des interactionsentre la planificationet l'exécution deschaînes de transport du point de vuedespropriétairesd'infrastructureset desvoyageurs. Il met l'accentsurun aéroportgénériquecommeune interface complexeentre les différentsmodes de transport, notammententre le transport aérienetles transporteursterrestres.

*Mots-clés:*aéroport; opérations; passagers, gestion, infrastructure, réseau

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1. Introduction

The growth in mobile device utilization and the resulting constant availability of electronic data processing capabilities allow the individual traveler to plan his journey anywhere at any time, taking his individual travel preferences into consideration. Plan updates for the travel chain's key points can be accessed for each transport carrier at any time. Currently, there is no standardized and network-wide cross-transport-mode update and datasharing mechanism available. The Total Airport Management (TAM) concept introduced an airport-centered concept where the impact of passenger process delay on the air transport mode is recognized by incorporating airport airside and landside processes and passenger data into the airport stakeholders' decision processes and operations steering. But TAM addresses neither the passenger's travel chain nor cross-modality including ground transport carriers; it focusses on airport operations only. In general, it is widely unknown what impact a delayed flight or the usage of an alternate arrival airport has on the remainder of the journey. In the worst case, the journey comes to an end as it is not possible to continue. The traveler involuntarily changes his role from a planning to an uninformed passenger. The infrastructure owners' ability to dynamically manage their own resources is frequently limited to their own range of authority only. With the goal of obtaining a cross-stakeholder optimized resource management solution, a superordinate planning and management coordination layer will be designed with the focus on its application to an AirPort Operations Center (APOC), managing intertwined landside and airside airport operations. The airport, with the multitude of different stakeholders that provide and execute operational services, is the ideal field of application as disturbances due to non-managed dependencies of the processes regularly occur.

Three scenarios of increasing complexity and different expansion stages are defined. The airport as the central transportation node is addressed as the focal point in the first stage, while the augmentation with ground-based public transport is conducted in the second. Finally, the expansion towards a metropolitan region with an additional regional airport as a diversion alternate defines the third stage scenario. As a use case example that is set within the third stage scenario, the utilization of the diversion alternate airport in the most efficient and flexible way for the traveler will be outlined. The principle idea is to address this two-airport system as a single transport node infrastructure that is coupled to a ground-based traffic network, following the basic intention of the European Commission. Focusing on Germany, applicable candidate metropolitan regions are identified and the prerequisites for airline operations and airport infrastructure requirements are discussed and balanced against the benefits for the traveler.

2. The Problem

He who travels has something to recount. The modern traveler plans his multimodal travel chain including consideration of necessary buffer times himself or, at least, bears the risk of not being able to continue his journey or having to arrange a new travel agreement at his own expense should a connection not be met. The information available at the time the journey is planned usually consists of static timetables. In reality, the day of travel will see unavoidable deviations to the plan. These may be due to common situations arising within a known traffic variance distribution or due to unforeseen disruptions to operations. In the current system, the customer can at best only react to such events when he actively seeks real-time information or when such information is provided on dynamic passenger information displays. It remains true that the traveler bears the risk of meeting connections himself and has to arrange to meet the next transport mode connection himself. Transport service providers generally do not know the current transportation demand or at least not in detail and they do not exchange such information with interconnecting providers. A downstream transport provider does not know which form of transport the passenger has just used and also does not know whether the transport provider is running to schedule or not.

This situation of individuals being uninformed forms a cumulative disadvantage for transportation operators.Their infrastructure runs at best according to the rigid timetables they have set for themselves and, only too often, according to spontaneously decided emergency schedules when service disruptions occur. Consideration of the current demand situation, i.e. the sum of individual origin-destination transportation enquiries, during the management of traffic processes fails in the current system due to the non-availability of this information. Airlines generally only find out the location of the passenger when he arrives at the check-in desk or perhaps even at the gate. Neither the customer nor the airline therefore have an effective way of proactively reacting to the current traffic situation before the journey begins. Proper management taking into account the infrastructure operator's parking options andtaking into account the individual traffic demands would help to optimize the use of resources and, at the same time, serve each customer individually. Then he who travels would be able to count on it.

The research into the transport system modeled, which is described in more detail below, is aimed amongst other things at the top level goal of the ACARE FlightpathVision 2050 "Meeting societal and market needs". In particular it is expected that integrated management on both the supply and demand sides of the modes of transport organized within the network will fulfill the following three explicit goals of Vision 2050.

- European citizens are able to make informed mobility choices
- 90% of travelers within Europe are able to complete their journey, door to door, within 4 hours.
- Flights arrive within one minute of the planned arrival time (approach: not only is the punctuality of the flight improved but, and above all, the quality of planning increases.)

3. The Idea

"Intermodal Augmented Scheduling" is intended to show how the information exchange between the transportation providers and the passenger when there is a change in the transport chain guarantees the best possible continuation of the journey. The passenger is immediately offered alternative travel routes (even involving other transport modes) via his mobile device. Conversely the transportation providers receive intermodal information on the passengers' process status. This intermodal information can support the transportation providers in making decisions by allowing a forecast of when delayed passengers are likely to arrive. In the concept presented here, there is on one hand organization of the availability of timetable-based and real-time based infrastructure, and on the other hand the integrated exchange of passenger-related status data. Passenger-related information primarily includes the so-called passenger trajectory, which describes the intermodal travel process, assists organization and serves as an interface to the end customer. In the design of the idea it is therefore less about the implementation of new technologies than about establishing new processes which guarantee connections in line with demand by means of flexible adjustment to the infrastructure.

The information exchange between the different transportation providers and passengers should allow early reaction to changes in the transport chain. This means that the passenger can adapt his journey to the current situation. The transportation providers are also in a position to adapt their own schedule to the situation using the passenger status information and, for example, delay departures or optimize the resource capacity utilization for commonly used infrastructure on the basis of passenger arrival forecasts.On the other hand, arrival at the destination is the key factor for the passenger and less so the choice of interim locations in the travel chain. It is of lesser importance to the passenger as to whether his destination is reached via airport A, airport B or train C, as long as arrival at the destination is assured. And precisely this is the approach taken in "Intermodal Augmented Scheduling".

The subject of punctuality has already been addressed as a high priority in the past since increasing punctuality means that a reduction in waiting times and resource requirements may also be expected. Punctuality, however, is related to planned values. Since the quality of these planned values at the time of enquiry cannot be further investigated and since the actual situation will differ from that of the situation upon which the plan is based, abiding by planned target times could be disadvantageous to the efficiency of resource utilization. It is therefore preferable to align transport demand and transport infrastructures with one another in a targeted manner – in real time and using current information and making appropriate decisions across resource responsibility boundaries.

The focus of the investigations for the concept is the airport as an intermodal traffic node which is used by different stakeholders who are, at the same time, competing with each other. The concept presented here will contain the set of rules for communication and a concept for implementation of a management headquarters to not only share information.

4. The Details

This section defines the 3 scenarios in each expansion stage.These three scenarios each describe a particular scope of study which is expanded with each individual scenario so that the complexity of the issue of the modes of transport increases with each scenario.Each subsequent stage builds upon the last. In the first scenario, the focus is on the airport, in the second the rail connection is added. The third scenario describes a metropolitan region in which the original airport is examined in combination with a regional satellite airport. Different combinations of airports are presented and discussed. Since they have been abstracted from a real example the scenarios permit a certain level of validation since, at the least, real and current demand data are available for evaluation and process changes can be modeled and their effects tracked.

4.1. Standard Edition

An airport classified as an international airport is selected for the chosen scenario. This airport GIA (Generic International Airport) has a passenger volume of approx. 13.5 million passengers per year, distributed across around 160,000 flight movements. These figures make this airport one of the 30 largest airports in Europe. In this scenario, the passenger movements and the corresponding information for the outbound traffic are depicted from entering the terminal to leaving the airport. For the inbound traffic, the passenger movements are depicted from entering the airport over the airbridge, through baggage claim and on to leaving the airport on the landside and on the airside for transfer passengers. External updates are taken into account via the on and off block times and the aircraft parking positions.This scenario focuses on looking at the management of airport processes across all stakeholders.

4.2. Rail Access

Building on the first scenario, in this case the scope of study is expanded by adding in arrival by local rail transport systems.The accessibility of the airport is a critical factor for a traveler’s choice of airport. The time and costs involved in reachingthe airport are critical elements of this. The modes of accessing the airport can be divided into personal transport and public transport. The accessibility can be understood as a parameter in the difficulty that a potential passenger has in reaching an airport, which then affects the choice of airport.

The rail connection is an important element in the mix of access modes. This applies for long and short distance journeys to the airport. It offers a potentially fast journey avoiding busy traffic on roads and a high capacity. Many local transport connections also offer a high frequency, allowing the passenger to travel more efficiently and thus reduce waiting times. The following Table 1 shows those airports among the 30 largest which have a rail connection.

Table 1 - Airport accessibility by rail for the 30 largest airports in the European Economic Area + Switzerland (2008) [Source: DLR compilation]

Nr.	Rank	Airport	Short-distance Trains	Long-distance Trains
1	**1**	London Heathrow	73	
2	**2**	Paris Charles de Gaulle	142	62
3	**3**	Frankfurt	214	167
4	**5**	Amsterdam	294	377
5	**6**	Rome Fiumicino	101	
6	**7**	Munich	116	
7	**8**	London Gatwick	80	
8	**9**	Barcelona	37	
9	**13**	London Stansted	76	
10	**14**	Zurich	185	116
11	**15**	Copenhagen	182	40
12	**16**	Manchester	171	
13	**17**	Vienna	126	
14	**18**	Oslo	156	32
15	**19**	Milan Malpensa	39	
16	**20**	Brussels	114	2
17	**21**	Stockholm Arlanda	76	
18	**22**	Düsseldorf	332	45

19	**23**	Athens	17	
20	**27**	Hamburg	110	
21	**28**	Malaga	70	
22	**30**	Geneva	58	31

The result is that, of the 30 largest airports, 22 have direct access to rail transport with local and long-distance connections. For a large proportion of the airports, the number of local connections is 3-digit, which indicates a high frequency and thus a quick continuation of the journey. It becomes apparent that the accessibility of an airport has a considerable influence on the traveler's choice and a good connection to the rail network can significantly increase the likelihood of the traveler choosing the airport.

Table 2 - Access modes for all passengers by rail at German airports 2008 [Source: German Air Passenger Survey 2008]

Access mode	
Bus/coach	29%
Tram	1%
Underground	1%
Metro rail(„S-Bahn“)	46%
Short-distance rail (Regional trains)	8%
Long-distance train (Intercity/ICE trains)	15%

When looking at the different ways of reaching the airport by public transport (Table 2), it can be seen that the journey to the airport by public transport is dominated by the S-Bahnmetro rail (46%) while long-distance trains only account for 15% of passengers. These figures show that a significant number of passengers who travel a longer distance to the airport by public transport first reach the main train station in the city where the airport is before completing the journey on metro rail.

In order to take these connections into account for future studies, a region is defined for the chosen scenario to accommodate the airport chosen for the first scenario which has an S-Bahn connection and a long-distance train station in the center of the region.The passenger's communication with the respective transport mode becomes ever more important for efficient connection to the rail transport network when the demand on capacity increases.Besides the passenger movements described in scenario SE, the inbound and outbound rail transport is also depicted for the Rail Access Scenario. Here the times for arriving and departing trains are added to the updates to the airside schedules. The management system provides the rail transport system with passenger and flight information.The name of the city for the Rail Access Scenario is A-Castle. The city has a population of around 525,000, this is assumed to suit the size of the international airport.

4.3. Remote Capacity

In this scenario the Rail Access concept is extended. Disruptions due to a variety of adverse conditions may lead to changes in airport operations and to the necessity of diverting flights to regional alternate airports. This alternate is ideally able to accomodate and handle mid-size aircraft and is less than 200 km away from the original, primary destination airport. A selection that is less distant would narrow down the alternatives. As the table presented below shows, a 150 km criterion would eliminate 3 alternates for Frankfurt, while a 100 km criterion would eliminate all alternates for Munich and Hamburg and would leave Frankfurt with only one.

Table 3 - Primary-Alternate Airport Pairs

	Alternate		direct Dist. [km]	Airport Class	Runway Length [m]	A320/ B737 MTOW eligible	Distance	Duration			Speed Index [km/h]	
Airport Name		ICAO					Road [km]	Road [min]	Public Transp. [min]	Transfer time <= ~2h?	Road	Public Transp.
Frankfurt	**Hahn**	EDFH	95	Region	3800	Y	115	71	101	Y	80,28	56,44
FRA	**Cologne**	EDDK	138	Inter	3815	Y	168	94	54	Y	88,09	153,33
EDDF	Saarbruecken	EDDR	140	Inter	2000	N	165	98	173	Y	85,71	48,55
	Baden-Baden	EDSB	144	Regio	3000	Y	168	97	135	Y	89,07	64,00
	Stuttgart	EDDS	157	Inter	3345	Y	202	115	119	Y	81,91	79,16
	Kassel	EDVK	163	Regio	2500	Y	214	128	165	Y	76,41	59,27
	Paderborn	EDLP	176	Regio	2180	N	274	150	229	N	70,40	46,11
	Luxemburg	ELLX	176	Inter	4000	Y	221	147	232	N	71,84	45,52
	Dortmund	EDLW	180	Regio	2000	N	233	130	150	N	83,08	72,00
	Straßburg	LFST	180	Inter	2400	Y	226	132	151	N	81,82	71,52
	Duesseldorf	EDDL	189	Inter	3000	Y	227	127	87	Y	89,29	130,34
	Nuremberg	EDDN	190	Inter	2700	Y	230	130	160	N	87,69	71,2
	Erfurt	EDDE	198	Inter	2600	Y	260	138	180	N	86,09	66,00
Munich	**Salzburg**	LOWS	110	(Inter)	2750	Y	176	101	170	Y	65,35	38,82
MUC	Innsbruck	LOWI	127	(Inter)	2000	N	209	123	179	Y	61,95	42,57
EDDM	**Nuremberg**	EDDN	137	Inter	2700	Y	170	95	145	Y	86,53	56,69
	Linz	LOWL	178	(Regio)	3000	Y	257	145	216	N	73,66	49,44
	Friedrichshafen	EDNY	186	Regio	2356	Y	229	134	209	N	83,28	53,40
	Stuttgart	EDDS	193	Inter	3345	Y	229	131	234	N	88,40	49,49
Hamburg	Luebeck	EDHL	52	Regio	2102	N	52	63	83	Y	49,52	37,59
HAM	Bremen	EDDW	102	Inter	2040	N	102	80	118	Y	76,50	51,86
EDDH	**Hanover**	EDDV	131	Inter	3800	Y	131	97	149	Y	81,03	52,75
	Sonderborg	EKSB	149	Regio	1797	N	149			-		
	Braunschweig	EDVE	150	Regio	2300	Y	150	122	211	Y	73,77	42,65
	Sylt	EDXW	178	Regio	2120	N	178	176	253	N	60,68	42,21

To identify possible primary-alternate airport pairs suitable to the OPTIMODE RC conceptual approach with a focus on major German airports, a collection has been compiled that aggregates information of the considered example airports Hamburg (HAM), Frankfurt am Main (FRA) and Munich (MUC) that act as the primary destination and their potential alternates. The primary airports that have been chosen represent airports that are located in the northern, middle and southern part of Germany and have significant traffic and passenger figures – Frankfurt airport was selected over Düsseldorf because it is Germany's biggest hub (see Table 1). The alternates have been selected and sorted in the compilation based on the shortest linear and up to the 200 km distance selected as the limit from the primary airport. This delivers 13 commercially used airports as alternates for FRA and 6 for MUC and HAM. Whether or not the airports can provide sufficient infrastructure to accomodate and handle the aircraft will be exemplified by taking into account the runway lengths. In the case that a bottleneck situation occurs at these primary airports and coordination to divert flights has to take place, it is assumed that the impacted flights are mainly short haul flights since long haul flights are more dependent upon the base station (due to equipment, significantly less rotations and therefore higher priority and more passengers affected). Taking into account the typical lengths required for take off for typical short/medium haul aircrafts, e.g. an A320 with maximum take off weight (MTOW) requires 2,100m and a Boeing 737-8/9 requires 2,300m, the number of potential alternates reduces itself to 10 for FRA, 5 for MUC and 2 for HAM. It has to be noted nevertheless, that some of the excluded airports are able to accommodate these aircraft types, when these are not at their maximum take-off weight, but for this approach these have been omitted from further inclusion. The compilation further contains the required time to transfer between primary and alternate airports based on road traffic (google maps traffic planner) and by public transport connection (based on bahn.de information service provision).

Taking into consideration that in the case that the passenger is delayed by more than three hours until his arrival at the final destination, the passenger rights for EU passengers(2004) allow him to claim a compensation payment from the airline. It can be assumed that an airline tries to pursue means to prevent compensation payments and will decide pro alternate means of transportation for passengers if the overall costs for alternate means of transportation against compensation payments and customer satisfaction remain lower, where the customer satisfaction most probably will have a major deciding influence. Therefore, it can be further assumed the airline will provide an alternate means of transportation. When the aircraft has arrived at the alternate airport, certain amounts of time are required for deboarding, baggage unloading, possibly border control and customs and finally boarding the alternate means of transportation. Let us assume that the time until completion of these required processes takes about an hour, then the selection of alternate airports is narrowed down to those that should be accessible within approxmiately two hours to remain within the three-hour window. This further condenses the number of potential alternate airports for FRA to 6 and 2 each for MUC and HAM. This is explained by a discussion about the average travel times and travel speeds between the airports as the following examples show.

If we also look at the average speeds between the arrival airports and the alternates, the following can be seen. Frankfurt can be reached in similar times from the alternates in a vehicle with an average speed of ~82 km/h (standard deviation ~6 km/h, median ~83 km/h), which is due to its good connection to the autobahn network. Using public transport, there is an average speed of ~74 km/h (standard deviation ~32 km/h, median ~66 km/h). The speeds are sometimes very different here. The Frankfurt-Paderborn route, for example, could be traveled at an average speed of only ~46 km/h, while Cologne-Frankfurt allows an average speed of ~153 km/h. This shows clearly that Deutsche Bahn high-speed tracks which are immediately accessible (Frankfurt and Cologne are directly connected to each other) have a considerable influence on the speed and thus the total traveling time.
For Hamburg, there is an average speed for road of ~68 km/h (standard deviation ~12 km/h, median ~73 km/h). Lübeck is relatively slow to reach at around 50 km/h and Hanover much faster at 81 km/h. The transport infrastructure also plays a role here (the autobahn network in this case), although Hamburg is not as densely surrounded by autobahns as Frankfurt. The average speed using public transport is ~45 km/h here (standard deviation ~6 km/h, median 42 km/h). In comparison to Frankfurt, the average speeds between the alternates and Hamburg are distinctly lower. One explanation for this could be the lack of a Deutsche Bahn connection between the airport and the high-speed rail network.Munich is on average just as quick to reach from its alternatives as Frankfurt with a speed of ~76 km/h (standard deviation ~11 km/h, median ~78 km/h). The minimum speed between Munich and Salzburg is around 65 km/h, the fastest connection being with Stuttgart at around 88 km/h. The picture for public transport is similar to that for Hamburg. The average speed is around 48 km/h (standard deviation ~6 km/h, median ~49 km/h) and can also be explained in this case by a lack of a direct connection to the high-speed rail network at the airport.

Analyzing the compilation in this respect, it can be seen that for MUC only road-based transportation seems to comply with the two-hour requirement, while FRA and HAM airline operators have a choice between both modes, but with the clear advantage due to the greater availability of road-bound transportation that complies. For MUC this implies that the airline operators don’t even need to consider arranging train transport. The road-based transportation has the advantage of being a direct connection as well, whereas the train connections require transfers in the majority of cases or where it is required to get to a suitable train station first by public transport lines from the airport to the train station. Generally it can be noted that the availability of alternative means of transportation for a primary airport depends on the available traffic infrastructure in the surrounding greater vicinity. From these three airports, MUC has the least-optimal infrastructure connectivity, while FRA benefits from the best of these three. This fact may depend on the population density in these greater regions (more population usually means more cities and better infrastructure connectivity).For the above consideration of the feasibility of alternates and timely transfer to the original destination, it is assumed that road availability is given (no accident or building site induced major delays) and that even for non-schengen transfer passengers (that have to transfer at the original destination), an efficient and secure transfer without visa requirements can be arranged.

A future intermodal approach would no longer offer separate flights. Instead it would simply offer transportation from point A to point B. Any available transport provider can be integrated into the process. Assuming the airline had the possibility to directly integrate other service providers into the transport service, different possibilities and offerings would become available to the traveler. If we make the assumption that capacity restrictions are likely at the arrival airport, the option of landing at an alternative airport could be considered in the traveling time. This can make a guaranteed traveling time possible which results from the flight to the alternate and subsequent ground-based transport to the destination. Here is an example. A flight from Paris-Frankfurt is stated as taking 1h:15min (Source: Lufthansa). Assuming an expected alternative landing in Cologne and the provision of a train, an additional traveling time of around 90 minutes (deboarding Cologne airport [16min], luggage collection [10min], transfer to train [10min] and traveling time to Frankfurt airport [54min]) can be calculated in. The “travel mediator” thus guarantees that the passenger will be at Frankfurt airport in 2h:45min.This shows that in future it is not only purely the transport which must be accounted for in the traveling time – the time for all the other processes necessary at the airport through to the point where all the services for passengers and baggage have been performed must also be considered. If we take this into account, the passenger can, in the ideal case, land in Frankfurt in 1h:15min, but must then also plan time in for deboarding and baggage collection. In future, the travel mediator therefore state a minimum travel time of 1h:41min (assuming that deboarding and baggage collection take the same time as in Colonge). Under unfavourable circumstances, the total traveling time can, despite diverting to the alternate airport,be a similar to the time required if the ground processes atthe actual arrival airport had taken considerably longer.

Aircraft which currently land at alternate airports normally fly on to the original destination airport. If in future a travel mediator expects an alternate landing in Cologne on a connection to Frankfurt, it would then also be an option to plan the return flight to Paris from Cologne too. The train connection organized for the passengers traveling to Frankfurt could then also be used to carry passengers to Cologne. The result is, however, that services performed for the customer before the departure must be calculated into the traveling time like those performed after landing. These processes take different lengths of time in Frankfurt and in Cologne. The passenger hardly has any influence on these processes himself (he simply decides when he will undergo them – he cannot influence how long they take). But he must undergo the processes if he wants to fly. All the processes from check-in and baggage drop-off would have to be accounted for (security, possible passport controls, walking to the gate, boarding). This means that the passenger’s journey begins when he enters the airport at the latest. If there is an initial train journey or bus journey, the passenger must first be informed, should he have to catch the train earlier.

5. Related work

In order to make the information that is generated by and decided upon in the control level and the travel management usable for the passenger, an HMI concept was developed which showed the necessary KPIs and passenger trajectories in aggregated form. The concept considers use via a smart watch which the user uses additional to a mobile device. The concept is presented in the following chapter.
In the output display the application user sees his destination and the current arrival time besides date and time (Fig. 1.(a)). In the lower block, the user receives updates to the travel process. In orange, there are warnings which require closer attention. The bar at the bottom displays each point of the travel chain and its current status. The standard display of the travel chain is green, additional details are shown in yellow and warnings in orange.

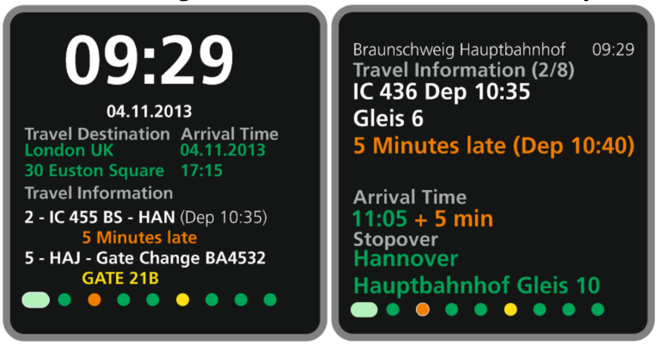


Fig.1.(a) Default View; (b) Travel Chain View

The following displays could be possible for each element of the travel chain (Fig. 1.(b)). The upper section begins with the user’s current location and his position in the travel chain (in this caseposition 2 of 8). There then follows the next element in the travel chain for the IC 436, which is scheduled to leave platform 6 at 10:35. The following warning shows, however, that the train is expected to arrive with a 5-minute delay. This then delays the arrival time at platform 10 of the A-Castle main train station by 5 minutes accordingly to 11:10. In the example shown, it can be seen that the 5-minutedelay is shown as an orange warning, whereas the travel chain destination is then in green. The delay of the train causes a shortening of the time available to the user at the A-Castle train station. The user must take this into account in order to be able to continue the journey.

The smart watch application should also display current times. It is not limited to displaying departure and arrival times – it also shows the walking and waiting times for each station in the travel chain. The data required for the display are fed in from a range of different sources via a central control system where the data is compiled in a form the smart watch application can use.The following example is used to show how the application works based on the scenario defined in Chapter 3. The application itself is an example of how the data discussed and created in a central control system can be aggregated for the user in order to support him in undergoing his journey. The focus is placed upon reaching the destination, while the intermediate stations on the way can vary.

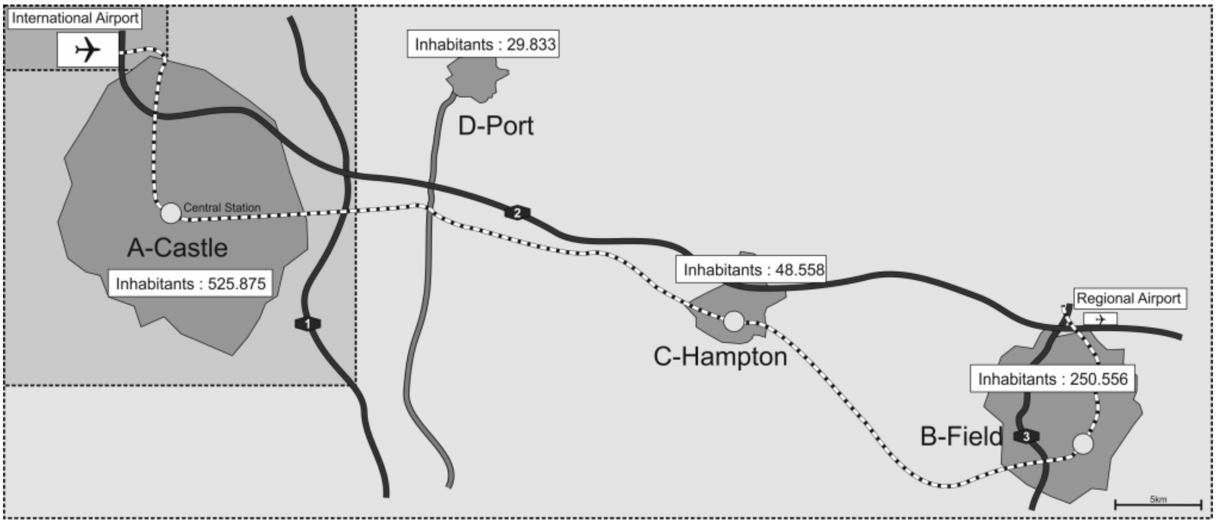
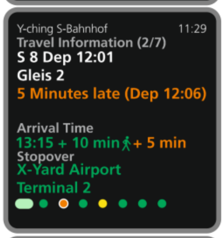
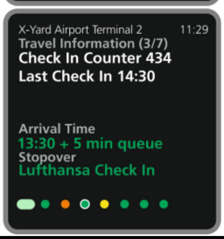


Fig.2. Metropolitan area for Remote Capacity

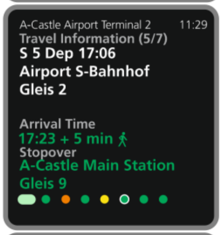
The metropolitan region is chosen as shown is Figure2. A-Castle has an international airport and the chosen alternative airport is in B-Field about 60 kilometers away and is a regional airport with a 2300 meter runway. The cities A-Castle and B-Field are connected by a motorway and rail network for local and long-distance trains. Both cities have their own public transport services.In the example, A-Castle airport is closed due to bad weather and the journey is continued to an alternative airport which, in this case, is the B-Field regional airport. The plane reaches the alternative airport 30 minutes later than the arrival time planned for the original airport. The user's destination is in C-Hampton. The application shows him his entire travel chain. The chain is divided up into 7 links and during the 4^{th} step of the journey, the bad weather leads to the use of the B-Field alternative airport. This event requires that the journey be re-planned and the user is informed of the changed itinerary.The following table shows the travel chain with the updates in detail.

Table 4 – Representation of the travel chain, as application

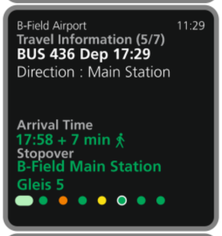
Displays of original travel chain	Description of the display	Displays of updated travel chain	Description of the display
	From the beginning of the trip in Z-hofen the journey starts with the bus line 952 to the local train station in Y-ching. Arrival at 11:59.		
	At S-Bahnhof, the journey is continued at 12:06 with a 5-minute delay (Line S8). Arrival with delay and walking time from S-Bahnhofto the terminal: 13:30.		
	In the X-yard airport, the check-in can be used until 14:30. Planned arrival at the check-in at 13:35 taking waiting time at the desk into account.		

At 15:00, boarding begins at the updated 21B. ETA in A-Castle is 16:40.

During the flight there is the announcement that the flight is being diverted to B-Field and will arrive there 30 minutes later than planned at 17:10. A new travel chain is calculated for the user.



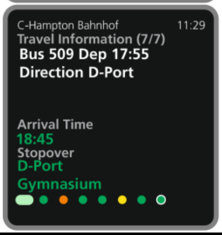
In A-Castle, the journey is continued to A-Castle airport on the S 5. Arrival taking walking time into account: 17:28.



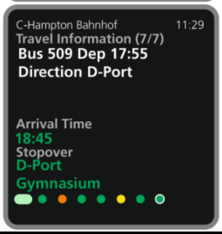
The journey is then continued from B-Field airport with Line 436 towards the main train station. Arrival at 18:05 taking walking time into account.

The regional train from A-Castle travels towards C-Hampton at 17:55. Arrival atthe bus stop at C-Hampton train station at 18:25 taking walking time into account.

At 18:20, the regional train RE 4854 leaves from C-Hampton. Arrival at 18:39 at the bus stop at C-Hampton train station taking walking time into account.



Leaving C-Hampton train station, the bus (Line 509) completes the travel chain at 18:49 at the Gymnasium bus stop.



Leaving C-Hampton train station, the bus (Line 509) completes the travel chain at 18:49 at the Gymnasium bus stop.

The example shows that, in an ideal case, the traveler can reach his destination despite deviations from the original plan without significant delay provided the central control system updates the journey with a focus on reaching the destination. Punctuality is not affected and the reliability of the connections is maintained. In the example, the real timetable information for the regional rail transportation and the local public transport were taken from a real metropolitan region. This means that the other transportation providers did not react to the schedule updates – only the original timetables were used. What was also not taken into consideration in this case was the higher passenger volume in B-Field for the two ground-based transportation modes.

It is nevertheless clear how intermodal travel management can serve the user in reaching his destination despite changes in the travel chain. The journey is completed without significant overall delay. The key to this is communication across all the transportation providers in order to achieve “Intermodal Augmented Scheduling”. The mock-up application helps us to see which transportation providers will have to feed information into the travel management system. Additional to the airport, these will include providers of regional train services and local public transport services.

The idea of the management system presented here lies in seeking opportunities for also adapting infrastructure to demand. Current systems provide rerouting by offering (at best) information on the current travel situation.With the new system, the bus would wait for the passenger, intermediate stops could be left out or shortcuts could be taken in order to serve passenger demands critical for connections in a targeted manner. The goal is not only to guarantee that passengers make their connections according to the timetable, but also consciously to effectuate changes to the plan in order to guarantee connections.

6. Conclusion and further work

The above discussion and the concept’s ideas shown need to be reflected in the light of the Flightpath 2050 goals, especially the 4-hour door-to-door target. The above depicted OPTIMODE RC approach has to be understood as an approach that is not employed as the default regular operation, it may find application only in bottleneck situations or adverse conditions. Therefore the application of the 4-hour goal can be considered as a soft constraint which has not been further defined concerning the rate or conditions in which it has been set.

The concept's ideas will be expanded upon in the OPTIMODEproject with the aim of compiling a set of rules and specifications to make this concept achievable. The aim ofOPTIMODE is to achieve an umbrella control center solution for a generic airport as described in this scenario. Both a verification of the effectiveness and the quantification of the benefit of this control center solution are required. The concept delivers the set of rules for joint communication among the various transportation providers and the preparation of data for the traveler, who can then refer to stable, reliable travel management to obtain the currently fastest connection to his destination.

An idea for the future would be that a travel agent could be offered an insurance when there are higher-frequency, stable connections which guarantees that the traveler will reach his next destination within a defined time period. Considered for individual elements of the transport chain, this will allow him continue his journey quickly. The traveler is thus offered a service which offers him the certainty of meeting a particular appointment such as catching a flight. At the same time, the flow of intermodal information should allow him a new, stable connection without him being left on his own.

One great benefit of this concept is therefore based on the communication between the traveler and the transportation providers. The prompt offer of an alternative route means that the traveler keeps his destination in his sights. The transportation providers receive more precise information on the status and, especially, the location of the traveler and can react with their transport scheduling.However, in order to achieve this it will be necessary to develop a concept of negotiation as the basis for establishing a shared understanding and a guarantee across all modes of transport. This concept of negotiation is itself a part of the DLR project OPTIMODE.

References

Regulation (EC) No 261/2004 (2004). *Establishing common rules on compensation and assistance to passengers in the event of denied boarding and of cancellation or long delay of flights.*