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Evaluating conditions and impact of intermodal traffic management involving airports and railways

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Abstract

Developing a transport system meeting the requirement of seamless door-to-door travel as envisioned by the report Flightpath 2050 necessitates a conjunction of different modes in the form of physical connections, encompassing management structures, and appropriate business models. We employ our simulation environment comprising of microscopic simulation and associated management tools to evaluate the possibility of not only exchanging information, but also adjusting operational parameters on the basis of the overall situation. The questions are what information exchange is needed, how large is the operational impact, and how can the anticipated success of an overall traffic management be assessed. Reliable data are crucial for management and evaluation. We show that on the one hand, management capabilities can be enhanced by determining the overall state of an airport and on the other hand by considering the so-called passenger trajectory. The state can be retrieved from Key Performance Indicators and Key Control Parameters which represent adjustable parameters. The passenger trajectory consists of pairs of points in space and time, where the passenger passes a certain milestone of the journey. This data can be used to compute the remaining time to the airport or even to a specific gate determining whether a passenger can be at the gate in time. If a critical mass is reached, intermodal operations can be adjusted. Our management system based on the microscopic simulation includes a connection to railway and aircraft movement management together with a forecast to estimate the propagation of the state of the airport. The evaluation capability of our system is demonstrated by a scenario consisting of a delay of a train leading to passengers not being able to reach their flight. Based on the data, the system – including microscopic simulation and management structure – provides the sensitivity of Key Performance Indicators such as boarding score on the change of delay profiles. This provides a measure for the feasibility of an action based on its extent focusing on cross-modal operation changes.

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Keywords: Intelligent Intermodal Transport Management; Performance Based Airport Management; Microscopic Simulation; Active Intermodal Traffic Management; Passenger Trajectory

1. Introduction

Developing a transport system meeting the requirement of seamless door-to-door travel as envisioned by the High-Level Group on Aviation Research in it's report Flightpath 2050 (cf. High Level Group on Aviation Research (2011))

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necessitates a conjunction of different modes in form of physical connections, comprehensive management structures, and appropriate business models. Physical connections seem to be sometimes more accidental than planned. All stakeholders of the intermodal travelling chain need to be aware of seamless physical connections and the need for comprehensive management. The motivation for a change of approach can result from an objective assessment of the impact of intermodal traffic management, which also may induce the development of appropriate business models. Such models need to include not only providing information on door-to-door journeys, but also taking responsibility for the services being offered.

In this paper we employ our simulation environment comprising of microscopic simulation, database, forecast, and associated management tools to assess the impact of an intermodal disruption in the form of a train delay. The questions are what information exchange is needed, how large is the operational impact, and how can the expected achievement of an overall traffic management be assessed. To carry out the assessment we use various Key Performance Indicators (KPIs) for the landside of an airport introduced by Total Airport Management (TAM, cf. EUROCONTROL and German Aerospace Center (DLR) (2006)) based on similar KPIs for the airside as proposed by A-CDM (cf. EUROCONTROL (2006, 2012)). Reliable data are crucial for management and evaluation. We show that on the one hand, management capabilities can be enhanced by determining the overall state of an airport and on the other hand by considering the so-called passenger trajectory. The state can be ascertained from KPIs and Key Control Parameters (KCPs) which represent adjustable parameters.

The key ingredient of our approach is a customer-centered view addressed by the so-called passenger trajectory. It consists of points in space and time, where the passenger passes a certain milestone of the journey. This data can be used to compute the remaining time to the airport or even to a specific gate and determine whether a passenger can be at the gate in time. If a critical mass is reached, intermodal operations can be adjusted. We develop an indicator for assessing the number of passengers failing to reach their flight because of a train delay. This is a delicate task, since delaying a flight because of late passengers increases the delay for all other passengers. In contrast to the milestone-approach of Laplace et al. (2014), our system is designed to be transparent, i. e. the passenger is not required to be able to assess the time and distance to certain task stations. The system itself should have this information and be able to make the right suggestions.

Real-time information about delays and gate changes can be disseminated using the internet, since mobile internet is broadly used and it's usage will increase in the future. Our approach suggests real-time computation of the remaining time for a passenger on the basis of the passenger trajectory without the need for stakeholders to disseminate all their information.

Our simulation environment was developed within the project OPTIMODE. The objective of this project is to extend A-CDM which is already established on the airside of an airport to the landside and to ground transportation. Key ingredients of A-CDM are the definition of various indicators for the performance of an airport and exchange of information among all stakeholders (cf. EUROCONTROL, 2006). A-CDM furthermore defines an infrastructure for using the shared information to establish a collaborative decision-making based on a common situational overview. Collaborative decision-making agreements offer the potential for increased efficiency which can optimize the overall system in contrast to individual optimizations (cf. Modrego et al., 2009)). Adding passenger related processes to the view of A-CDM was also the objective of TAM. The project OPTIMODE can be seen as extension of TAM by including intermodal traffic management.

In Spies et al. (2008) A-CDM was enhanced by adding process-oriented landside airport information while Helm et al. (2014) describes a further extension comprising of adding passenger related process information at an airport. The possibility to control passenger flow within an airport terminal building by using priority rules similar to those used by airlines for product differentiation (first cabin class, business passengers, frequent flyers, cf. e. g. O'Connor (2001) was first described by Grunewald and Popa (2014).

The passenger trajectory is determined by assuming the existence of special sensors within the airport terminal and at start and end points of the railway line. Furthermore, the sensors are assumed to be able to record passenger events and provide the data to the management layer. Passenger events as part of the passenger trajectory could be the arrival at or departure from a task station. These data are linked to specific individuals by way of a personal primary key. Even though such sensor systems are not in common use, the technology itself is already available. An example is radio-frequency identification (RFID), by which passengers can be successfully tracked when the passenger carries a RFID chip. Other radio standards could also be used, as e. g. cellular radio (cf. Oberli et al., 2010).

Table 1: KPIs considered (cf. Milbredt et al., 2015)

Symbol	KPI	Description
S_B	Boarding score	Denotes the ratio of all passengers who reached the gate in time to all passengers who wanted to take the flight.
T_C	Process time at check-in	Since there may be more than one open check-point, the waiting time is proportional to the queue length although we assume the processing speed to be constant.
T_S	Process time at security check	As above
T_I	Overall process time	Denotes the time for a passenger from entering the train station to reaching the gate of his/her flight.
$\frac{T_I}{T_{\text{sched}}}$	Ratio between overall process time and scheduled process time	*Scheduled process time* or *recommended process time* denotes the time from entering the train station to reaching the gate including buffer time for arrival at the airport as recommended.

While the focus of this paper lies on disruptive events, the passenger trajectory is intended to facilitate intelligent management for all operational states of an intermodal traffic management. With the introduction of trajectory approaches for subjects (passengers, freight) and for system components (traffic infrastructure and vehicles), A-CDM is complemented by interaction with the traveler. With the aid of a forecasting model, the passenger trajectories are continuously updated using the predicted infrastructure capability utilization for the remainder of the day.

With such a tool at hand the overseeing management is now able to optimize the entire system beyond the borders between stakeholders rather than only optimizing individual parts of the system. As a connecting element between the stakeholders, the passengers now influence KPIs which measure the stakeholder's ability to perform his actions. The management solution can now include the passenger's view instead of optimizing a traffic situation exclusively from one stakeholder's perspective. This leads to a better situation for all stakeholders. Passengers on the other hand can utilize the information they are provided with and interactively organize the path of their journey, instead of being uninformed and forced to just react to events.

2. Methodology

We consider an enhanced set of KPIs based on the definitions made in the project TAMS based on A-CDM and ATMAP (see German Aerospace Center (DLR) et al., 2012; EUROCONTROL, 2012; Performance Review Commission, 2009). The focus of this paper lies on landside processes of an airport. We therefore restrict ourselves to KPIs and KCPs affecting landside processes and the landside intermodal connection. Airside processes at an airport are included in the form of a flight plan, but in this paper we do not consider changing the scheduled plan.

2.1. KPIs and KCPs

The following section describes the KPIs and KCPs we employed within the simulation. The definitions are adapted from Milbredt et al. (2015). Based on Cook et al. (2009) and Cook et al. (2013), we introduce additional passenger-centric metrics (see Laplace et al., 2014), since in this paper propagation-centric metrics focusing on the airside are not considered.

Tab. 1 shows the KPIs used within the test phase. Prior to giving the detailed definition of the KPI "Boarding score" we introduce several statuses of passengers participating in the intermodal transport process. The statuses used are defined in the following way.

Passed Passengers who are labeled as "Passed" boarded their flight and the off-block time for their flight is in the past.

Table 2: KCPs considered (cf. Milbredt et al., 2015)

Symbol	KCP	Description
c_C	Open checkpoints at check-in	Adjustable parameter directly influencing the KPI Process time
c_S	Open checkpoints at security check	As above
Δt_F	Flight schedule change	The off-block time of a flight can be adjusted to wait for late passengers.
Δt_T	Train schedule change	The train schedule can be adjusted to pick up passengers who would otherwise fail to reach their flight.

OK The label "OK" describes passengers who are or will be at the gate in time

Late Passengers who are or will be at the gate less than 30 mins before the off-block time for their flight have the status "Late".

Fail This label is reserved for passengers who failed or will fail to reach the gate in time.

The status of a passenger therefore depends on the time, at which one polls the information. A passenger can have a changing status dependent on time. The status *Passed* is reserved for passengers who boarded their already departed flight. The statuses *OK*, *Late*, and *Fail* include the forecast mechanism of our software system. Even a passenger labeled as *Fail* can change to *Passed*, if the OBT of his/her flight is in the future and the circumstances at the airport are appropriate.

We assign the following tuple to each flight.

$$F = \left(\mathrm{OBT}, \mathrm{Pax}_{\mathrm{All}}, \mathrm{Pax}_{\mathrm{Passed}}\right) \in \mathbb{R}^3, \tag{1}$$

where $\mathrm{Pax}_{\mathrm{All}}$ denotes the number of passengers booked for the specific flight.

The "boarding score" S_B^F for a flight F is then defined by

$$S_B^F(t) = \begin{cases} 0, & t < \mathrm{OBT}, \\ \mathrm{Pax}_{\mathrm{Passed}}/\mathrm{Pax}_{\mathrm{All}}, & t \geq \mathrm{OBT}. \end{cases} \tag{2}$$

The idea behind defining the boarding score to be 0 for the time prior to the OBT of any flight is defining the number of passed passengers to be 0. Let $F_1, \dots, F_n$ denote the tuples defined by Eq. (1) of n flights and suppose $\mathrm{OBT}_1 \leq \cdots \leq \mathrm{OBT}_n$, then we introduce the "boarding score" of these flights by

$$S_B^{F_1,\dots,F_n}(t) = \begin{cases} S_B^{F_1}(t) & 0 \leq t < \mathrm{OBT}_2, \\ \left(\mathrm{Pax}_{\mathrm{Passed}}^{F_1} + \mathrm{Pax}_{\mathrm{Passed}}^{F_2}\right)/\left(\mathrm{Pax}_{\mathrm{All}}^{F_1} + \mathrm{Pax}_{\mathrm{All}}^{F_2}\right), & \mathrm{OBT}_2 \leq t < \mathrm{OBT}_3, \\ \vdots & \\ \left(\mathrm{Pax}_{\mathrm{Passed}}^{F_1} + \cdots + \mathrm{Pax}_{\mathrm{Passed}}^{F_n}\right)/\left(\mathrm{Pax}_{\mathrm{All}}^{F_1} + \cdots + \mathrm{Pax}_{\mathrm{All}}^{F_n}\right), & t \geq \mathrm{OBT}_n. \end{cases} \tag{3}$$

The process time T_C is defined by

$$T_C(t) = \text{process time at check-in of the latest passenger being processed at time } \leq t. \tag{4}$$

and the other process times T_S and T_I are defined analogously. In contrast to Milbredt et al. (2015), the overall process time has an index I to emphasize that the definition includes the time from the train station to the airport, i. e. it includes the intermodal momentum of the journey. The ratio $T_I/T_{\mathrm{sched}} \geq 1$ is a measure for the disruption of the scheduled processes. It includes the passenger-centric KPIs *delay time* and *additional waiting time* proposed by Cook et al. (2013) and Laplace et al. (2014).

Tab. 2 shows the parameters which can be adjusted. Besides the number of open checkpoints, an operator can intervene in the schedule of trains and flights. The quantities Δt_F and Δt_T denote the change of the respective schedule of a specific flight or train. As a change the value Δt_T attains values ≤ 0 or > 0. Waiting for late passengers because of a late train means delaying the journey for other passengers and therefore extending the overall process time.

2.2. Delaying a flight

In this section we develop a decision support methodology for the question of whether to wait for passengers using a delayed train.

Suppose n to be the number of passengers booked for the specific flight and let m_1 be the number of passengers booked for the specific flight on the delayed train. Let $m_2 = n - m_1$ denote the number of passengers which are booked for the specific flight, but do not use the delayed train. We suppose the passengers not using the train to have passed through all processes in time. For simplicity we assume the overall service rate of the remaining processes to be a constant $t_0 > 0$ with dimension [passengers/unit time] such that we arrive at a delay of the flight given by

$$\Delta t_F = \Delta t_T + \frac{m_1}{t_0}\,. \tag{5}$$

Here, the assumption of the passengers not using the train was included. We compute the total delay of the first group and relate it to the total delay of the second group which gives us

$$f(m_1, \Delta t_T) = \frac{2m_1^2}{t_0} + 2\Delta t_T m_1 - \frac{nm_1}{t_0} - n\Delta t_T\,. \tag{6}$$

The function f is a polynomial of order 2 with respect to it's variables. If $f > 0$, then the total delay of the first group using the delayed train is greater and if $f < 0$, then the total delay of the other group is greater. For fixed delay time $\Delta t_T > 0$ we have

$$f(0, \Delta t_T) = -n\Delta t_T < 0 \quad \text{and} \quad f(n, \Delta t_T) = \frac{n^2}{t_0} + n\Delta t_T > 0 \tag{7}$$

and for fixed $m_1 > 0$ we derive

$$f(\Delta t_T) \begin{cases} > 0, & m_1 > n/2 \\ < 0, & m_1 < n/2\,. \end{cases} \tag{8}$$

This gives an operator real-time decision support providing all information is available. The function f is relatively simple and is only chosen to show the concept of using real-time information for decision support. For real world applications, this function can be adjusted according to the requirements.

3. Simulation environment

3.1. GIA

The scenario created for the evaluation was chosen to show the effects on other management systems in a simulation environment. Therefore, an airport classified as international airport was chosen for the scenario. This airport has a passenger volume of approximately 13.5 million passengers per year distributed over some 160,000 flight movements. These figures make this airport one of the 30 largest airports in Europe (see Rudolph et al., 2014). In this scenario, the passenger movements and the corresponding information for the departure traffic are depicted from entering the terminal from the entrance or the train station to leaving the airport. Figure 1 shows the scheme of the selected airport. The check in area is marked with a blue rectangle and the security area is marked with an orange one.

3.2. Pax_radar

An innovative tool called *pax_radar* was developed to visualize a large amount of airport operational information in a compact layout. pax_radar shows the current state of all planned departure flights and related passengers at an airport within the upcoming day of operations. The layout of the GUI is based on a radar view where each segment represents one gate at the airport. Each circle represents one flight and the size of the circle correlates with the number

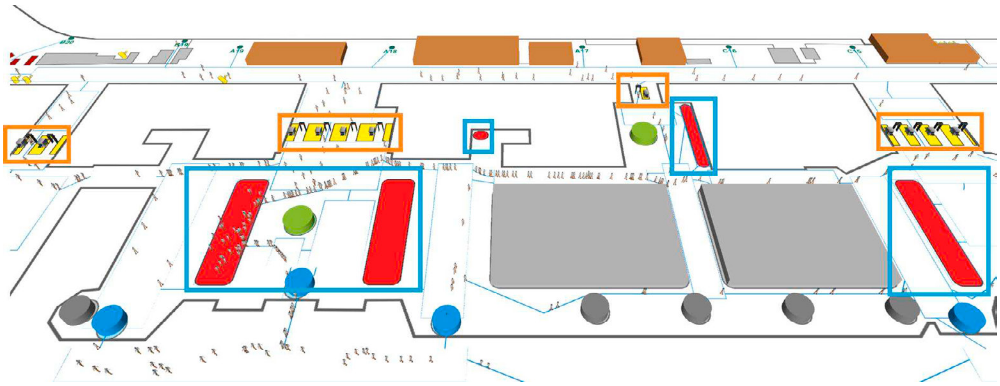

Fig. 1: Scheme of a sector of the airport model used within the simulation (see Rudolph et al., 2014)

of passengers booked for that flight. The segment in which a flight is placed on this radar display represents the gate for which the flight is planned. As time passes, the flights (circles) move in from the boundary toward the center of the radar view. If a gate change or a TOBT update occurs, the circle representing the flight moves from one segment to another, also connected by a line to a black dot representing the previous gate. The center point represents the present time. The inner circles of the radar display represent the more relevant time horizon of the last 1–2 hours and are stretched in order to provide higher differentiation. When clicking on a circle, detailed information is provided concerning the chosen flight. For a detailed explanation of *pax_radar* please confer Urban et al. (2012).

3.2.1. Passenger trajectory and generic passengers

An individual passenger trajectory is ascertained in the management system for all of the passengers in the simulation to describe the process. In this simulated world, a traveler is identified at checkpoints while the entire planned travel process is also recorded. There is therefore a data connection for departing passengers linking the personal ID with the transport mode used to come to the airport and the booked flight.

When the passenger trajectory is established, these details are linked with the details from the transport mode operator and the infrastructure operator. In the simulated world, these could be the airport train service operator and the authorities operating the control center. The transport mode operators publish real-time information supplementary to the timetables for their vehicles, while infrastructure operators continually update their service times at the relevant checkpoints with the aid of forecasting based on fast-time simulation.

In addition to this information, booking systems provide at least the roughly expected passenger numbers for each flight. So-called generic passengers are defined for the quantity of all passengers resulting from the total number for a flight minus the passengers already logged by sensors in the terminal and minus the passengers connecting to the flight from another flight. These represent the future demand to be met on this day of operation. Generic passengers are also necessary for the forecasting functionality, as they define the infrastructure capacity utilization required to establish the trajectories.

Generic passengers are expected at the airport at a specific time point which can be arbitrarily chosen for individual cases, but for the mass corresponds as exactly as possible to the actual arrival time point measured later relating to the planned departure. So distribution statistics are created for the people who have physically already arrived at the airport which depicts the probability of arrival in relation to off-block time. From this distribution, compiled from passenger arrival data gathered at the arrival sensors, a value is then selected and assigned to a generic passenger as an expected time of arrival at the airport before departure. The mass of generic passengers thus appears with the same arrival distribution profile as the passengers who have already arrived. Now an expectation value for the train passengers modal split can be ascertained from the history.

Generic passengers assumed to be arriving by train are expected on a train with an arrival time correlating to that chosen previously. The arrival of the chosen train is now key to the assumption of the time point when this passenger will arrive at the airport. Each passenger identified by the simulated sensor systems as having arrived at the airport reduces the number of remaining generic passengers for the same flight.

Once all of the passengers for a flight have been detected by the sensors at the airport and thus documented as being physically present, there should now be no generic passengers left for that flight. This, however, only applies when the expectation value for the passenger numbers agrees with the actual value. If generic passengers still remain, these are demand elements which were expected but did not appear. Typical to the industry, these generic passengers (who are not replaced by real passengers by the time of departure) are labeled as no shows. No shows are not considered when calculating the KPIs.

3.3. Forecast

Ability to forecast. An event-based network model was developed for the forecast to allocate specific properties and attributes to each object in the simulation. The aim of the forecast is to make a comprehensive situation report available to the airport management for the operating day in question. The simulation calculates the waiting and service times at each service point and passes these on to the management for the passenger trajectory. These values are used to ascertain the anticipated waiting times at each station of each passengers journey. With the information from the management system, the end user can be sent relevant details for example via smartphones or smartwatches to help plan his journey. Another advantage of the use of the event-based network model is the strict division between the event logic and the airport layout. This allows the model to be relatively easily adapted to other airport layouts. Each individual element in the simulation can be assigned specific properties and attributes, allowing groups of people to be classified and depicted with their own specific behavior patterns.

Network transfer. The servicing times at each specific station are provided to the trajectory application in the Optimode system via the connected database following each simulation run. At the same, the forecast simulation applies the updates provided to the system each time it runs. The direct connection to the database system enables the results to be passed on efficiently so that intermediate steps (which are necessary in the System Dynamics forecast) are not required. The event logic depicts the process stations for the passenger in the airport. The logic begins for the departing passengers at the source before entering the terminal. The interfaces to the process stations are defined directly via the airport layout, from which the route/time relations are then ascertained. Decision options in the process chain are implemented as an algorithm in Select Outputs. Call-offs can then be made directly from an objects internal attributes or even from data from external sources.

Performance. In order to achieve quickly updated results, there is no cross-influence between the objects. Such a detailed depiction is not necessary in calculating the forecast. It is more important that a fast loop is achieved in the forecast runs. With the current configuration, 24h runs are performed within a few seconds. This provides the user with constantly-updating forecast values for further usage.

4. Calculation/Results

In this section we describe the scenario used within the simulation. We employ our software system for simulating a day at a generic airport model developed in our institute using a flight plan comprising of 219 departure flights. We assume the airport to have a railway connection being served every 30 mins. Besides a baseline scenario we consider two scenarios involving delayed trains. We assume the delay to be a consequence of a a full closure of the track to the airport starting after 08:22. In the first scenario the full closure is assumed to last 60 mins and in the second scenario it is assumed to last 120 mins. The full closure is supposed to be sufficiently close to the airport such that the delayed trains and the scheduled one arrive within a few minutes. In Figs. 2 and 3 the x-axis shows the simulation time, where $t = 0$ corresponds to 06:00.

Fig. 2 shows the evolution of the boarding score during the simulation. The x-axis represents the time from 06:00 in minutes. Fig. 2a shows the evolution of the boarding score for the baseline scenario. The black graph depicts the boarding score at a specific time resulting from the simulation and the blue one shows the boarding score at the end of the day determined by the forecast mechanism at a specific time. At 10:02 for example, the simulated boarding score is 0.96 and the boarding score at the end of the day as predicted by the forecast-mechanism at 10:02 is 0.93. The simulated boarding score up to 10:02 is already included in the predicted boarding score. Even if the forecast-mechanism predicts the boarding score at the end of the day, its result depends on time. The close the simulation

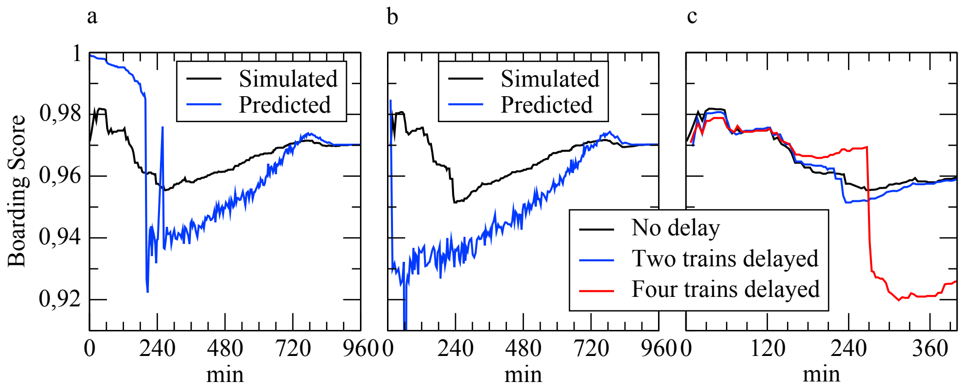

Fig. 2: (a) Boarding score of the baseline scenario; (b) Boarding score of two succeeding trains delayed; (c) Boarding Score of all three scenarios.

approaches the end of the day the closer are simulated and predicted boarding score. We see that the predicted boarding score is highly sensitive on time, but is able to predict the right shape. In Fig. 2b the evolution of the boarding score – resulting from the simulation and forecast – for the first delay scenario is shown. Here, it seems to be more difficult for the forecast-mechanism to predict the first four hours. From 10:00 the predicted shape coincides with the simulated one. Fig. 2c shows the boarding score for all three scenarios. The black graph shows the simulated boarding score of the baseline scenario. The blue graph – resulting from a simulation with two trains delayed – does not differ much from the baseline scenario. In contrast four delayed trains have a tremendous impact on the boarding score – depicted by the red graph – resulting in a drop of the boarding score to 0.92.

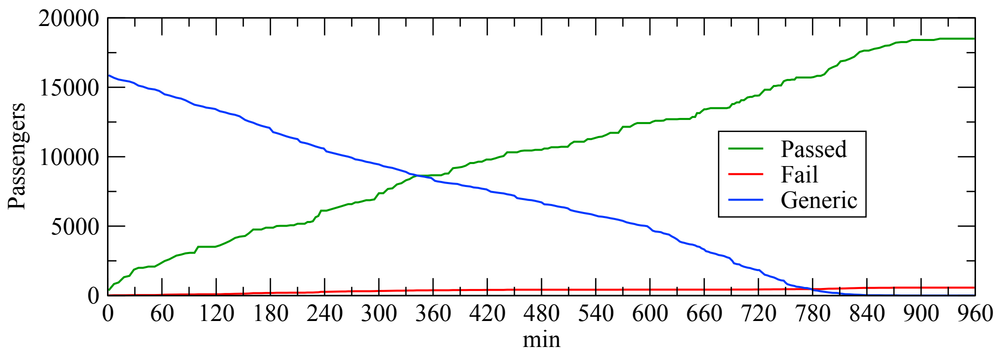

Fig. 3: Evolution of passenger numbers for the baseline scenario.

Fig. 3 shows the evolution of passenger numbers for the baseline scenario. The red and the green graph show the evolution of passengers labeled as *Passed* and *Fail*, respectively. Since the first flight has an OBT at 6:00 (corresponding to minute 0), the graphs start with a value greater 0. The number of generic passengers is shown by the blue line. It is descending, since generic passengers are imaginary passengers to be replaced by real passengers. At 6:00 approx. 3000 generic passengers are already replaced and at 20:38 all generic passengers are replaced.

The *pax_radar* in Fig. 4 shows the impact of the second scenario involving four delayed trains. The radial scale is logarithmic and ranges from 0 (centre corresponding to now) to the end of the day..The picture is taken at a simulation time 08:11 (corresponding to $t = 131$ minutes). According to Fig. 2c the drop of the boarding score happens in the range $[267, 274]$. Some flights are predicted as likely to fail, but the majority is marked as need for attention.

5. Conclusions

Achieving seamless door-to-door travel as proposed by Flightpath 2050 of the High Level Group on Aviation Research in Europe requires intertwining existing transport modes. To meet society's need for fast and reliable transport,

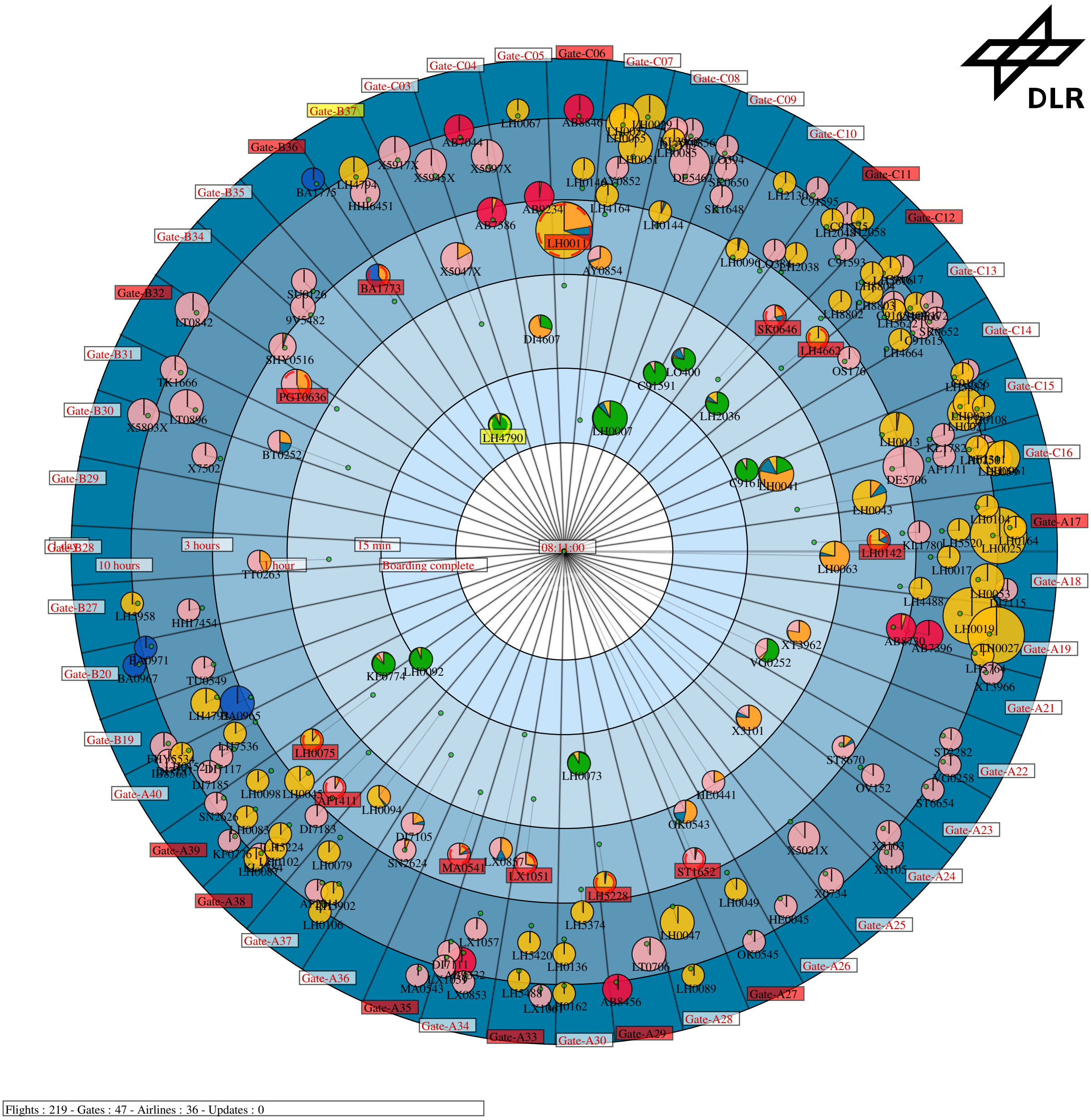

Fig. 4: “Pax_radar”

the connections between various transport modes need to exist both on a physical level, and also on a management level and they need to be oriented to the passenger. Furthermore, real-time information from stakeholders involved can be used not only for intermodal management, but also to inform the passenger and provide services to assist his/her journey.

We developed a software system considering the airport as an intermodal transport node. The software system comprises a microscopic simulation of airport terminal and platform, a management system for airport and intermodal management, and a tool for forecasting the state of the airport to be expected. The microscopic simulation substitutes reality for evaluating management decisions. Realistic values are produced by introducing the concept of sensors for transferring data from the microscopic simulation to the management layer. This concept reflects the ability to gather information on passengers and the state of the airport in a way which is used or in principle possible in real-world applications.

A passenger-centric view is achieved by the so-called passenger trajectory consisting of a list of milestones of the journey and the respective time of passing. These real-time data are enriched with intermodal transport schedules and forecasts for the utilization of infrastructure such as security checks. Such information can be part of a service for passengers providing the expected time for reaching the gate.

In this paper we employed our software system to simulate 24 hours at an airport with connection to railways. The simulation was carried out using a model of an international airport terminal called Generic International Airport (GIA) which we developed at our institute .

We considered the delay of a train for departure passengers and the impact on the transport node airport, affected flights, and passengers failing to reach their gate in time. The “pax radar” – a system developed at our institute for depicting information regarding every flight on the flight plan – shows that a delay of 1.5 h resulting in four trains arriving together creates a tremendous irregularity for the airport infrastructure for processing passengers and a high rate of passengers failing to reach their gate in time.

In future, the software system will be supplemented by a railway management system and a system for managing aircraft movements. These enhancements enables re-scheduling of trains and flights to evaluate the impact of intermodal traffic management and the effect on passengers. Furthermore, we will consider variation of KCPs and the impact on the KPIs. Another parameter which can be varied is the airport layout we used throughout the simulation. A variation of the terminal layout can shed light on the generalizability of the simulation results for similar or even quite different terminal layouts.

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