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Passenger-centric airport management via new terminal interior design concepts

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Abstract

Meeting the needs of passengers will increasingly become a competitive factor for airports. Information is one of the most valued services for passengers. Therefore, timely providing of real-time data to the passengers is high on the list of airlines and airports. Since not every passenger has a mobile device at hand, relevant information need also be disseminated offline. Static and dynamic signs cover the above mentioned issues, but the place, where such signs are installed is crucial. The goal of our new design concept for terminals is providing information to passengers, where and when they need it. Each service point — from check-in through security check to boarding — has been designed using curved layout design and furniture along with large displays for information. The size of the displays is chosen such that passengers are able to recognize important information with respect to the specific service point at one glance. Waiting seats are surrounding the service point to provide an unhindered view to the displays and to promote communication. We implemented our design ideas in our artificial terminal building of an international airport. The impact of information displays is modeled by a microscopic simulation. Adopting the assumption that the information displays make it easier for the passengers to figure out the way through the terminal we simulate a whole day at the artificial terminal.

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1. Introduction

Travellers dream of a seamless world in transportation. With respect to the Air Transportation System this vision was formulated by the High-Level Group on Aviation Research in it's report Flightpath 2050 (cf. High Level Group on Aviation Research, 2011). Intermodality of transport is one aspect of this vision (as e. g. discussed by Vespermann and Wald, 2011, Janic, 2010, and Milbredt et al., 2017). Parallel to examining intermodal connections the potential for mitigating the main cause of breaking the seamlessness within the Air Transportation System itself needs to be explored. Delays of flights were discussed in various ways; from monetary impact (cf. Cook et al., 2004) through statistical prediction of delays using real-time data (cf. Aljubairy et al., 2016) to aircraft routing minimizing propagated delay (see Yan and Kung, 2016).

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Operations at airports are already streamlined to mitigate delays. On the airside this was achieved by introducing a collaborative approach for making decisions (A-CDM, description of concept: EUROCONTROL, 2006 and description of implementation: EUROCONTROL, 2012). Including landside operations at airports completes the operational treatment of flight delay causes (Total Airport Management, TAM, see e. g. EUROCONTROL and German Aerospace Center (DLR), 2006 and German Aerospace Center (DLR) et al., 2012). What remains is the factor "passenger".

Meeting the needs of passengers will increasingly become a competitive factor for airports. Treating passengers as disruptions for the perfectly planned operations may not address the issue of delays in its entirety. To understand the issues a passenger is faced with, a passenger-centric view needs to be employed. Transit passengers failing to find their way to the required gate is a big cause of flight delays (see Mueller and Chatterji, 2002). Therefore, successful passenger guidance increases both, passenger comfort and punctuality of flights.

Even if the impact of delayed (transfer) passengers on the flight network may have decreased in past years, these passengers are an issue in view of passenger comfort. Finding the way inside a terminal is not only a problem of the past. Recently, an EU project called SPENCER (2013) was launched to tackle this problem. Within this project a robot will be developed to help passengers reaching the appropriate gate. The robot will be tested at Amsterdam's airport Schipol. The EU project DORA (cf. DORA, 2016) considers dynamic routing of passengers using real-time data. Both indoor navigation and routing options are to be generated which every passenger can then use.

Customer satisfaction is crucial for any transportation mode. Passengers can become very frustrated if information on disruptions are not provided by the transit agency (see e. g. Caulfield and O'Mahony, 2007 and Papangelis et al., 2013). According to Garcia et al. (2012), the provision of real-time data is seen as a particularly important service and is essential for assisting passengers en-route. Passenger Information Systems (PIS) describe systems which provide information to passengers of a transportation mode of any kind. An example for a static PIS is a timetable at a bus station, whereas dynamic PIS provide real-time data.

Smartphone applications exist for various airports providing real-time data (e.g. Toronto airport, Los Angeles airport, Frankfurt airport, see Google Play-Store). Airports use these apps to also make passengers more aware of the airport layout (e.g. gates, shops) in addition to the flight plan and possible delays (cf. Frankfurt airport). Since not every passenger has a mobile device at hand or uses it for phoning only, checking the status of a flight or the way to the appropriate gate needs to be possible offline. Static and dynamic signs cover the above mentioned issues, but the place, where such signs are installed is crucial.

In this paper we present a new design concept for the interior of terminals covering the information dissemination from the infrastructure perspective. The goal of this concept is providing information to passengers, where and when they need it. Seamlessness is the guiding vision of our design concept. Each service point — from check-in through security check to boarding — has been designed using curved furniture along with displays for information. The size of the displays is chosen such that passengers are able to recognize important information with respect to the specific service point at one glance. Waiting seats are surrounding the service point to provide an unhindered view to the displays and to promote communication.

Service points only represents a part of the interior of an airport. Our approach is intended to be complementary to already existing information signage such as the big centrally installed display showing information about each flight and the guidance covering the gate infrastructure. Due to data protection issues, it not possible to display information about the passenger's individual flight at e. g. the check-in. Interactive terminals are a way to circumvent this problem, but it thwarts the idea of information at a glance. This leaves us with big displays showing information for all flights in a certain time range as it is in operation by the centralized display.

The impact of the new design ideas is assessed using our simulation environment. It comprises of a terminal building of an artificial airport called GIA (Generic International Airport) and a microscopic simulation covering all tasks for a passenger — from entering the terminal through security check to passing the gate. The microscopic nature makes it possible to track each passenger's way and the time he/she needed for the several milestones required for boarding. The artificial airport GIA includes a broad range of infrastructure for different passenger scenarios such as border control, transit area, finger and bus gates, and self-service check-in.

a b c

Fig. 1. (a) Welcome area at check-in; (b) check-in area; (c) boarding area.

2. Related work

In Elkady and Ismael (2009), wayfinding in an airport terminal building is considered. Some points the authors raise are commonly used such as using written maps and instructions. Others focus on architectural design. Firstly, the authors propose a limitation of user movements by specific paths. The authors propose separation space built by levels, gates, paling, and walls of various kind. The second method for limitating movement is guidance by attracting the passenger's attention. This could be done by different colours or different names of large spaces.

Fewings (2001) describes in his paper the problem of wayfinding within an airport terminal building. The author considers signs and maps. He identifies several factors influencing the quality of the guidance for passengers. Are signs and maps are placed at decision making places? Are the signs visible from a far enough distance?

In her thesis, Livingstone (2014) considered the impact of airport terminal retail area on the passenger's experience. One suggestion for terminal design comprises of creating a closer physical link of departure gates and retail area, so that passengers do not have to be concerned about boarding their flight in time.

In his essay, Hubregtse (2016) discusses the impact of design and artwork on passengers. On one hand the impact on wayfinding of passengers inside an airport terminal is examined and on the other hand the impact on the tendency of passengers to visit commercial offers. Subtle artwork such as ceiling designs and flooring patterns may influence the movement of passengers.

3. Methodology

The interior design concept is about rethinking the airport experience, exploring how key operational functions, products and the interior environment can be designed differently to optimize process flow and enhance experience. During the design process, three main concepts were developed: *welcome and check-in area*, *luggage drop-off area* and *boarding gate area*. The design concepts were developed using CAD surface models of the different areas and interior hardware, including new functions such as a circular layout and furniture, as well as large hardware to accommodate passenger information displays. These are central to the layout of the design concepts, providing passengers with unhindered views of displayed information and also promoting social interaction between users. Figure 1 illustrates some results of the design concepts — *low fidelity prototypes* —- which were used in the context of the PASSME project to aid the discussion between specialist partners in view of assessing their validity. The *welcome and check-in area* includes a circular-layout seating area and curved furniture with self-check-in devices. The large central area works as a meeting point with a large and clearly visible information display above it. The area promotes sociability between passengers, all of whom are able to recognize important information at first glance. The *luggage drop-off area* includes circular *islands* of drop-off hardware and specific passenger interfaces. Each island promotes the easy flow of passengers through an informal queuing layout and includes a large central display to accommodate passenger information. Just as in the case of the *welcome area* these displays allow for unobstructed views of the information displayed. The *Boarding* area has a semi-circular layout which includes seating, relaxing and working areas. Passenger information is provided via a display above the centre of the space as well as by a curved screen at eye-level. Both are large display systems that provide clear information about boarding times and

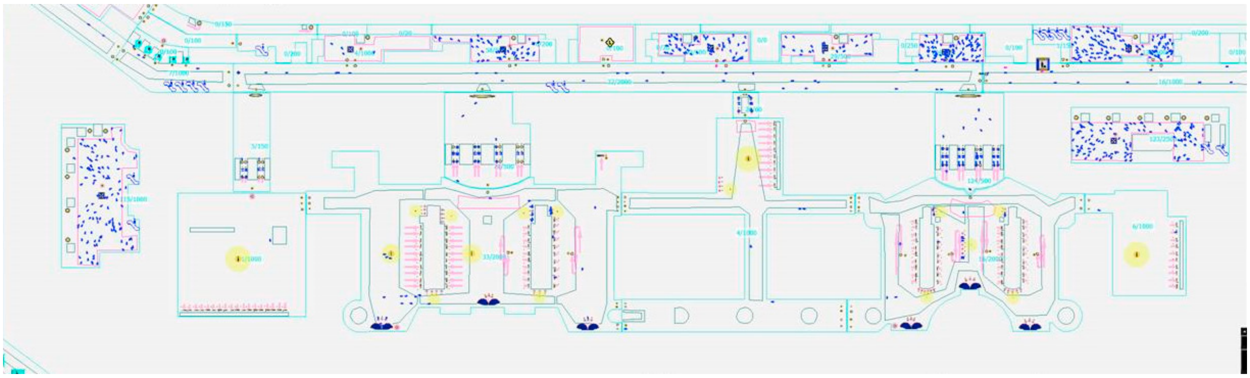

Fig. 2. Check-in counters, security checkpoints, and gates with waiting areas.

processes at a glance. The evaluation of the design concepts with large circular information displays was modelled by a microscopic simulation tool, applying a generic medium-sized airport scenario.

4. Simulation environment

4.1. TOMICS

The tool TOMICS (Traffic Oriented Microscopic Simulator) is a microscopic simulation developed in our institute. It focuses on passenger movements inside an airport terminal building, but it is also capable of simulating the boarding of an aircraft. Each passenger is modeled as an individual agent finding his/her way through the building together with avoiding collisions with other passengers.

Two parameters influence the way passengers behave during wayfinding. The first one — *entropy* — corresponds to the characteristics of a room. It is a measure for the complexity of a room. This parameter includes all characteristics of a room such as interior architecture and signage. The higher the entropy of a room, the higher is the time needed to find the way within this room. The entropy is not solely based on architectural characteristics. An unstructured room with good signage can have a low entropy than an open room with bad signage. The range of the parameter entropy is from 0% to 100%. A value of 0% corresponds to the situation that passengers can find their way from any position. A value of 100% corresponds to the situation that passengers will search for the correct way forever. The second parameter — *information level* — denotes the degree of information a passenger has about a room. If the entropy of a room is very high, having been there often can reduce the time for wayfinding to a normal value. The range of the parameter information level is from 0% to 100%. A value of 0% corresponds to the situation that passengers are not able to find the correct way. A value of 100% corresponds to the situation that passengers will always find the correct way.

4.2. GIA

The simulation environment should show a change of the difference between time of entering the airport and arriving at the appropriate gate. We expect to see a change if the scenarios considered provide enough service points that are required. Therefore, an artificial airport model called Generic International Airport classified — as the name suggests — as international airport was chosen for the scenarios. 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).

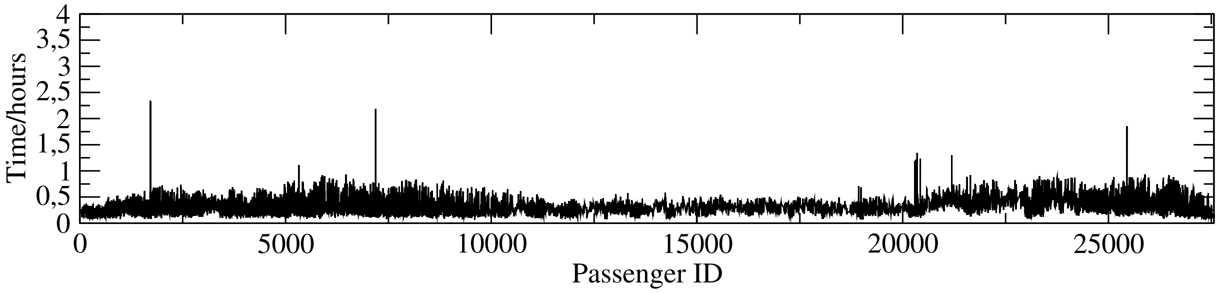

Fig. 3. Time from entrance to gate of passengers throughout 24 h at entropy = 35%.

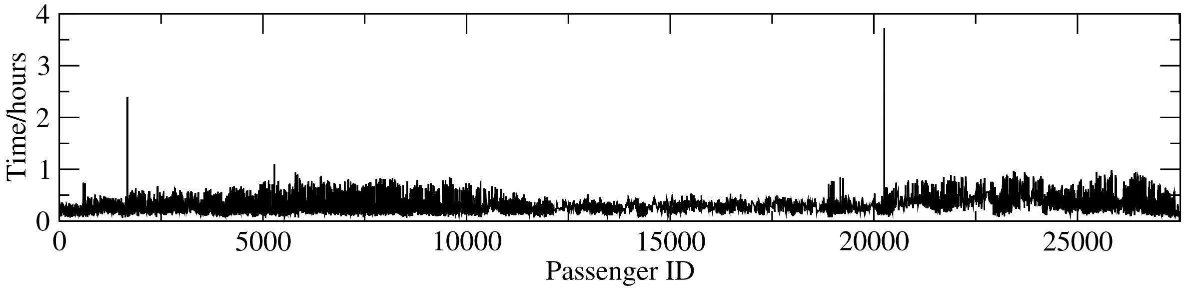

Fig. 4. Time from entrance to gate of passengers throughout 24 h at entropy = 15%.

5. Calculation/Results

In this section we describe the scenarios 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 constructed two scenarios to simulate the impact of information displays.

Scenario I This is the baseline scenario. We assume the entropy (complexity) of the airport to be 35%. This value is a conglomerate of all signs, displays, and signage throughout the airport. The layout of our artificial terminal is fixed. The assumption can therefore be seen as a condition on the signage.

Scenario II In this scenario we assume the new design suggestions for the interior of a terminal to be installed. We assume further that the new design results in a decreasing of the entropy. To emphasize the additional character of the information displays, we assume the entropy to be 15%.

The assumption of decreasing the entropy in Scenario II stems from the definition of the entropy of a room including the signage. The exemplary decrease of 20% is based on the observation that information dissemination by displays at the top (see Fig. 1) at important service points leads to a high decrease. To what extend the providing of relevant real-time information at service points decrease the entropy needs to be explored by an appropriate survey.

In all scenarios we assume the information level of the passengers to be distributed as 40% of the passengers have an information level of 100% (business, frequent flyer, frequently smartphone app user), 35% of the passengers have an information level of 50% (passengers, who need some orientation, but in principle know the layout), 25% of the passengers have an information level of 30% (passengers, who often need orientation, rudimentary knowledge of the layout).

Fig. 2 shows a screenshot of the microscopic simulation TOMICS with the terminal building GIA. The blue dots depict passengers. The loose clouds of passengers on top and far left and far right of Fig. 2 show passengers in the waiting area of gates, where the far left and far right ones are waiting areas for bus gates. The remaining areas are arranged as tubes to enter the restricted area at the top. The left one is empty with some passengers processed at the border control for entering the EU. The second one is arranged similarly to the fourth one. At the bottom there are check-in desks arranged in four rows. Above these check-in desks you can see four security checkpoints. As in the case of the border control, some passengers are waiting or are processed. This can be seen by the colour of the dots; a grey dot corresponds to an empty slot.

For the baseline scenario we simulated 27565 passengers. We recorded the time between entrance of the terminal and arrival at the gate. A measurement of the time between entrance and boarding would have distorted the results due to the waiting time at the gate. This can directly seen by the blue dot clouds in Fig. 2. Only 19053 passenger were chosen, since transfer passenger could not be considered. Fig. 3 shows the difference time between entrance and gate. The oscillation is not so high as it seems, since many passengers are packed in a small scale. The mean value for the baseline scenario compute to $\mu = 0.308$ h, and the standard deviation is given by $\sigma = 0.137$ h. The mean value corresponds to $\mu = 18.48$ min.

The second scenario was simulated using 27524 passengers. As in the previous scenario we omitted the transfer passengers and ended up with 19069 passengers for the measurement. The result is shown in Fig. 4. The shape of the result is similar to the result of the baseline scenario shown in Fig. 3. An inspection of the dataset reveals that the mean time from entrance to gate decreased, as it was expected, to $\mu = 0.298$ h, whereby the standard deviation remains with $\sigma = 0.138$ h approximately the same. The mean value in the second scenario corresponds to $\mu = 17.88$ min.

6. Conclusions

Meeting the needs of passengers will increasingly become a competitive factor for airports. Information is one of the most valued services for passengers. Static and dynamic signs cover the issue of dissemination, but the place, where such signs are installed is crucial.

Each service point — from check-in through security check to boarding — has been designed using curved furniture along with displays for information. The size of the displays is chosen such that passengers are able to recognize important information with respect to the specific service point at one glance. Waiting seats are surrounding the service point to provide an unhindered view to the displays and to promote communication.

We implemented our design ideas in our artificial terminal building of an international airport. The impact of information displays is modeled by a microscopic simulation. Adopting the assumption that the information displays make it easier for the passengers to figure out the way through the terminal, we simulate a whole day at the artificial terminal.

We decreased the entropy, our measure for the complexity and signage of a room, to model the impact of information displays. The simulation of 24 h showed that the mean time from entrance to gate decreased by 0.6 min and the standard deviation remained approximately the same. This value corresponds to a decrease of 0.03%. The exemplary decrease of 20% is based on the observation that information dissemination by displays at the top of the proposed design of important service points leads to a high decrease. To what extend the providing of relevant real-time information at service points decrease the entropy needs to be explored by an appropriate survey.

Considering comfort of the new design suggestions is not part of this paper. Since the consideration of passenger satisfaction is beyond the scope of our simulation environment, the question of passenger perception needs to be investigated by a survey, where parts of the design suggestions are implemented.

Future work will cover the impact of exact dimensions and the round geometry. Simulations are an inexpensive opportunity to accurately evaluate the impact of changing the infrastructure. Before installing a demonstrator at an airport it is possible to extract corner points of the performance of a new design.

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References

Aljubairy, A., Shemshadi, A., Sheng, Q.Z., 2016. Real-Time Investigation of Flight Delays Based on the Internet of Things Data. Springer International Publishing, Cham. pp. 788–800. doi:10.1007/978-3-319-49586-6_57.

Caulfield, B., O'Mahony, M., 2007. An examination of the public transport information requirements of users. IEEE Transactions on Intelligent Transportation Systems 8, 21–30. doi:10.1109/TITS.2006.888620.

Cook, A., Tanner, G., Anderson, S., 2004. Evaluating the true cost to airlines of one minute of airborne or ground delay. Technical Report. EUROCONTROL. URL: https://www.eurocontrol.int/sites/default/files/content/documents/sesar/business-case/evaluating_true_cost_of_delay_2004.pdf.

DORA, 2016. EU project. URL: https://dora-project.eu/.

Elkady, A.A., Ismael, B.S., 2009. Airports architectural design solutions and new design technologies, in: 13th International Conference on AEROSPACE SCIENCES & AVIATION TECHNOLOGY, 26 – 28 May, Cairo, Egypt. URL: http://www.mtc.edu.eg/ASAT13/pdf/CV14.pdf.

EUROCONTROL, 2006. Airport CDM operational concept. URL: http://www.euro-cdm.org/library/cdm_ocd.pdf.

EUROCONTROL, 2012. Airport CDM implementation — the manual, v. 4. URL: http://www.eurocontrol.int/sites/default/files/publication/files/2012-airport-cdm-manual-v4.pdf.

EUROCONTROL, German Aerospace Center (DLR), 2006. Total Airport Management operational concept. URL: http://www.bs.dlr.de/tam/Dokuments/TAM-OCD-public.pdf.

Fewings, R., 2001. Wayfinding and airport terminal design. The journal of navigation 54, 177–184. doi:10.1017/S0373463301.

Garcia, C., Candela, S., Ginory, J., Quesada-Arencibia, A., Alayon, F., 2012. On route travel assistant for public transport based on android technology, in: Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS), 2012 Sixth International Conference on, pp. 840–845. doi:10.1109/IMIS.2012.103.

German Aerospace Center (DLR), Siemens, Inform, ATRiCS, Barco, FSG, 2012. Total Airport Management suite – operational concept document. URL: http://www.tams.aero/documents/konzeptdokumente/TAMS_OCD_v-1-0-1_public.pdf.

High Level Group on Aviation Research, 2011. Flightpath 2050 — Europe's vision for aviation. URL: http://ec.europa.eu/transport/modes/air/doc/flightpath2050.pdf, doi:10.2777/50266.

Hubregtse, M., 2016. Passenger movement and air terminal design: artworks, wayfinding, commerce, and kinaesthesia. Interiors 7, 155–179. doi:10.1080/20419112.2016.1215678.

Janic, M., 2010. True multimodalism for mitigating airport congestion. Transportation Research Record: Journal of the Transportation Research Board 2177, 78–87. doi:10.3141/2177-10.

Livingstone, A.K., 2014. Passenger experience and their implications for airports retail environment design. Ph.D. thesis. Queensland University of Technology. URL: http://eprints.qut.edu.au/72761/.

Milbredt, O., Rudolph, F., Grunewald, E., Christ, T., 2017. Evaluating conditions and impact of intermodal traffic management involving airports and railways. Transportation Research Procedia 25C, 1740–1749. URL: https://authors.elsevier.com/sd/article/S2352146517304234, doi:10.1016/j.trpro.2017.05.132.

Mueller, E., Chatterji, G., 2002. Analysis of aircraft arrival and departure delay characteristics, in: AIAA's Aircraft Technology, Integration, and Operations (ATIO) 2002 Technical Forum, American Institute of Aeronautics and Astronautics. doi:10.2514/6.2002-5866.

Papangelis, K., Sripada, S., Corsar, D., Velaga, N., Edwards, P., Nelson, J.D., 2013. Developing a real time passenger information system for rural areas, in: Yamamoto, S. (Ed.), Human Interface and the Management of Information. Information and Interaction for Health, Safety, Mobility and Complex Environments. Springer. volume 8017 of *Lecture Notes in Computer Science*, pp. 153–162. doi:10.1007/978-3-642-39215-3_19.

Rudolph, F., Grunewald, E., Günther, Y., Piekert, F., 2014. Intermodal augmented scheduling, in: AUN-2014 'Airports in Urban Networks'.

SPENCER, 2013. EU project. URL: http://spencer.eu/index.html.

Vespermann, J., Wald, A., 2011. Intermodal integration in air transportation: status quo, motives and future developments. Journal of Transport Geography 19, 1187 – 1197. doi:10.1016/j.jtrangeo.2011.05.003.

Yan, C., Kung, J., 2016. Robust aircraft routing. Transportation Science doi:10.1287/trsc.2015.0657.