STANDARDIZED CONCEPT FOR PASSENGER GUIDANCE SYSTEMS AT AERODROMES

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Abstract

Airport standards regarding to the corporate identity often have a higher priority than passenger perception or efficient guidance concepts. The primary task of the optimal information processing and appearance is often insufficiently managed. Against the background of missing legal restrictions the presented work reveals essential requirements for guidance systems. From passengers view signage is one of the first perceived airport terminal features but it is still disregarded in common level of service concepts. A standardized implementation approach is presented in this paper. To analyze terminal environment and to concept optimized signage a multi-agent simulation environment is used. The agents are characterized by individual environment perception, different intentions and self-acting behavior.

Keywords: airport, terminal, guidance, service level, passenger perception, agent simulation

INTRODUCTION

Aerodromes represent a central component of the traffic system as intermodal traffic junctions. They are sophisticated buildings that are primarily supposed to ensure the smooth transition (dispatch procedure) between the traffic carriers. To simplify and to facilitate orientation in these partly confusing buildings, the aerodrome management ensures the signposting of important processing points. The labeling should follow a clearly structured, immediately recognizable logic. The primary task of the optimal information processing and presentation is often insufficiently managed due to very individual ways of design of the guidance systems at traffic aerodromes. In addition, this situation is favored by non-standardized requirements on the part of the regulatory institutions. Up to now only general recommendations for guidance system design have been developed. These publications have merely recommendation character and do not represent an obligatorily set of rules to be obeyed.

At German aerodromes the guidance and information systems are primarily based on individual design concepts. Airport standards regarding to the corporate identity often have a higher priority than passenger perceptions or efficient way-finding concepts. Additionally, airport operators have to balance both passenger needs for directional way-finding and the airport demands for revenue-earning (advertising) signage. Expert interviews with aerodrome operators confirm the user's perception that there is no globally standardized concept. The passenger explores the airport by using the guidance system, so naturally airports have to be very sensitive to the needs of passengers for clear information. In this context Mijksenaar [1] refers to the Global Airport Monitor survey of the International Air Transport Association [2] that the second highest rated airport service item is the "Ease of finding your way through the airport/signposting". A personal interview survey at airports from J.D. Power and Associates emphasizes this fact: approximately 25 % of all passengers have a strong correlation between quality of service and the supply of orientation information. (see [1])

The paper starts with an overview of common level of service specifications and additional approaches to classify quality measures like individual environment perception or information providing. Design concepts for guidance system components are presented considering graphical symbols, color contrast and information alignment. Several specific airport solutions for signage concepts are shown. In the second part the common idea of the Sense-Plan-Act [3] approach is determine by introducing the five-level concept of perception, processing, decision, planning and action. These steps are fundamental for a simulation environment based on virtual humans (agents).

To evaluate guidance concepts, these agents populate the simulation environment and act as adaptive controllers [4] trying to maximize their subjective utility (micro-economic approach). Due to the direct perception of the provided (guidance) information agents decide regarding to their experience and available time budget. This individual decision process influences the airport environment in several ways. Even inside complex structures well-defined signage eases the orientation and ensures a low individual stress level which yields increasing time budget for further passenger activities.

1. GUIDANCE SYSTEM

The guidance system is an essential part of the superior airport concept. Passengers, who are not familiar with the complex airport environment, are strictly relying on way-finding information. Although the lack of information will have an explicit influence on the level of quality, the char-

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acteristics of guidance system is ignored in current level of service (LOS) concepts; the costumer perception is disregarded as well.

1.1. Level of Service

The availability of space is one important factor for the quality of service realized by the passenger. Thus, developed LOS concepts use the factor required vs. available space as a key performance indicator for designing terminal facilities. There are numerous LOS definitions for airport terminals (e.g. Fruin, 1971 [5], TRB, 1987 [6], ACI, 2000 [7], International Air Transport Association (IATA), 2004 [8]). These definitions base on observations at different environments, as level of service for walkways, stairs or queues. In complex buildings like aerodrome terminal all these special LOS have to consolidate to an overall key performance index considering the special terminal areas (e.g. commercial area or security check).

In the following figure (FIG 1) the LOS is subdivided in six parts; it ranges from Level A (green → center) to Level F (red → outer). Level A represents excellent conditions by means of free and undisturbed passenger flow with no delays and first-rate level of quality. The LOS decreases to a certain degree (Level C/D) until it reaches the unacceptable Level F (system breakdown). The plotted black polygon is an example for a characteristic LOS for walkways naturally determined by density, flow rate, capacity and average walking speed (Fruin's research [5] focused on bus terminal).

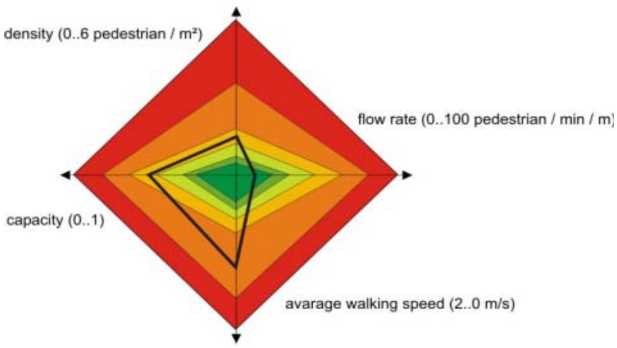

FIG 1. LOS according to Fruin [5]

For diverse airport facilities the dependent variables may differ as well as the required measured quantity. Empirical results [9] suggest that the space indicator varies between the different airport facilities. Even the direct connection between the facilities and areas require that facility quality measures and LOS concepts (e.g. space indicator) are evaluated from a superior airport system point of view.

Most of the established LOS standards do not consider the passenger input and their individual environment perception. Based on this fact Correia et al. [10] developed level of service standards for airport facilities by asking passengers at São Paulo/ Guarulhos International Airport (SBGR) to choose a rating for the quality of terminal facilities based on their experience. They used the methodology of Analytical Hierarchy Process (AHP) presented by Saaty [11] (see TAB 1) to obtain quantitative weights representing the relative importance of the terminal facilities and their associated LOS attributes.

In Saaty's scale of relative importance the intermediate values have the scale of 2, 4, 6 and 8 (1/2, 1/4, 1/6, 1/8 respectively). Regarding to the defined indicator quantity and the consistence level the maximum degree of importance is 0.90, which means that Element A is extremely more important than Element B.

Degree of importance		Saaty Scale	Description
Element A	Element B		
0.90	0.10	9	A is absolute important
0.80	0.20	7	demonstrated importance over B
0.70	0.30	5	A is strong important
0.60	0.40	3	weak importance of A over B
0.50	0.50	1	A equals B
0.40	0.60	1/3	weak importance of B over A
0.30	0.70	1/5	B is strong important
0.20	0.80	1/7	demonstrated importance over A
0.10	0.90	1/9	B is absolute important

TAB 1. Degree of importance, Saaty [11]

One advantage of the AHP approach is that the actual data set does not have to be perfectly consistent, which based on the pair wise comparison of each considered element. The occurrence of inconsistencies is caused by several reasons, as the lack of information or concentration or the fact that the real world itself is sometimes fairly inconsistent[2] [12]. At the same time the pair wise comparison is one of the disadvantages of the AHP approach because of the high operative expense if there are too many attributes to compare.

Terminal Area/Facility	Weights of importance	LOS - Attributes	Weights of importance
Parking	0.11	**Security** Availability of Parking Spots Courtesy	**0.48** 0.23 0.16
Departure Hall	0.13	**Orientation / Information** Security Services Comfort	**0.33** 0.20 0.19 0.15
Check-In	0.33	**Processing / Waiting Time** Courtesy	**0.54** 0.33
Departure Lounge	0.23	**Comfort** Courtesy	**0.47** 0.38
Concessions	0.1	**Variety of Stores** Courtesy	**0.44** 0.43

TAB 2. Weight of importance for different facilities, Bandeira [13]

For several terminal areas/facilities appropriate LOS attributes are shown in the above table (TAB 2), whereas

[2] At sports one can see Team A defeating Team B, after which Team B defeats Team C, after which Team C defeats Team A. This can explained due to random fluctuations. (see [12])

the LOS attributes are sorted by importance. These explicit weights are only representative for SBGR and depending on the perceptions of passengers at other airports, especially if their socio-economic profile differs significantly from those surveyed [13]. The results of this interview survey harmonize with the results pointed out by Martel and Seneviratne [9]. From the user perspective passengers reported several factors influencing the perceived quality of service at the airport terminal. For instance, essential criteria for walkways (movement areas) are

– Information 53 %,
– Distance 38 %,
– Available space 6 % and
– Altering terminal level 3 %.

Within movement areas information is one of most important factors while the availability of seats is essential for waiting areas. By contrast processing facilities are primary determined by waiting time. Due to technological or legal changes the weighting of influence factors for particular terminal processes will vary. With respect to waiting time and capacity values the provided information level is not an immediate measurable quantity.

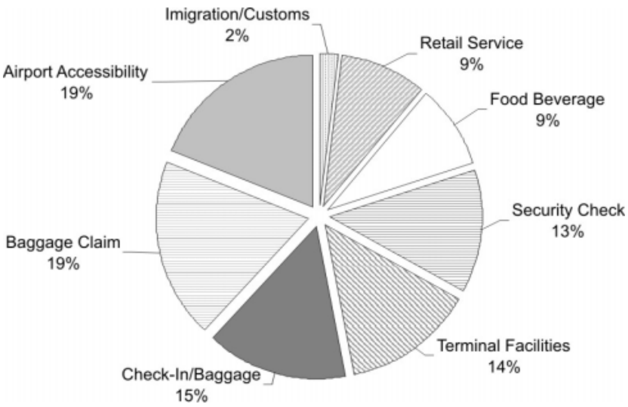

FIG 1. Quality Ranking of Airport Processes [14]

Today passengers are faced with increased legal restrictions for baggage control (hand baggage). The North America Airport Satisfaction Study 2007 [14] showed that baggage claim has the greatest impact on overall quality of service. To ensure the efficient handling of the additional baggage volume by the airport, check-in and baggage claim area have to be improved. Airport managers also try to reduce the perceptive waiting time by managing customer expectations like reviewing waiting times (Hartsfield-Jackson Atlanta International Airport (KATL)).

The LOS is a complex concept with a high number of influencing factors (measurable or perceivable) which is inappropriate to be evaluated with a global system indicator. Important factors for the quality of airport services are exposed by the Global Airport Monitor [2]. The indicator with highest influence on quality of service is the “courtesy/helpfulness of airport staff” followed by the “Ease of finding your way through the airport/ Signposting”. Considering the fact that there are no quantitative performance indicators for guidance systems at airport terminals the next paragraphs will examine the legal and common requirements more closely to deduce systems specifications.

1.2. Aerodrome Requirements

The construction and operation of airports base on several national and international regulations, but these regulations do not include explicit statements about guidance systems. Within the legal scope of Germany there are general requirements which can be derived from the following laws:

– Luftverkehrsgesetz (LuftVG),
– Personenbeförderungsgesetz (PBefG) and
– Strafgesetzbuch (StGB).

By contrast recommendations for the signage in terminals are released by the international organization International Civil Aviation Organization (ICAO) [15] or the national instance German Airports Association (ADV) [16]. The IATA [8], Air Traffic Association (ATA) [17] and the Federal Aviation Administration (FAA) [18] have published several documents on a level of informational guidelines (further detailed discussion by Wachtel [19]). All of these documents have no mandatory character and consist only in descriptive declaration.

– “Airport authorities should consider … diagrammatic maps indicating to passengers their present position… Audio assistance may also be used.” [15]
– “The same color scheme should be used on all such signs in the airport terminal building and, if possible, in all terminal buildings at airports in the same country.“ [15]
– “Consistent use of standard terminology in airports will simplify the process of making the transition from the ground mode to the air mode … for the traveling public.” [8]
– „The use of short verbal messages along with symbols is more effective than the use of symbols alone.“ [8]

The examples listed above point out that the lack of legally binding specifications leads to a spectrum of varying guidance system concepts. Actually, dissimilarities can occur even in one terminal building. Enlarging the capacity of the airport by the reconstruction of terminal areas or the construction of new terminal buildings is often associated with new airport-wide design regulations. Charles de Gaulle International Airport (LFPG) serves as a negative example for the inconsequent application of uniform regulations in the new terminal areas. Colors and shapes of the signs differ according to the terminal area construction date. At several signs at LFPG terminal 3 (extension of former Aérogare T9) is diversely labeled with both the old and the new notation. Furthermore the numbers of counters and doors are not unique; they are multi-assigned depending on the current terminal area.

Orientation in multifaceted buildings (airport terminals) with complex structures is constricted if airport managers negate their own rules and disregard the main idea of guidance recommendations: “Standardization, Continuity, Simplicity, Location and Directional Signs, Visibility“ [8].

1.3. Guidance System Components

Passengers should realize signs as a part of their environment with additional information to understand the surrounding and the ability to guiding them to their destination. Signs should provide clear, unambiguous answers to three questions [20]:

1) Orientation - Where am I and where am I going to?
2) Navigation - How will I get there?
3) Information - How will I know when I have arrived?

Signage helps to explain the facility, so guidance system signs have to have a recognizable methodology by means of perceivable and identifiable features. Misinterpretation of the presented information due to different individual understandings should be excluded.

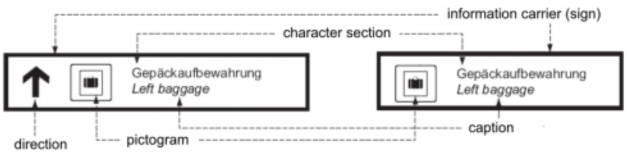

FIG 2. Alignment of sign components, Wenzel [21]

The application of short, explicit and catchy statements or symbols is preferred to the use of proper names, technical air traffic terms or company logos. Considering the diverse groups of persons within the airport terminals, characterized by differentiated profiles (age, cultural descent, country, familiarity with the environment) signs should have international standardized labels (English) as well as significant graphical symbols (pictogram).

1.3.1. Graphical Symbols

A pictogram acts as self-contained sign component because information is transmitted to the general public without the barrier of languages. Non-verbally provided information has to be independent of expert system knowledge [22]. In addition to labels and pictograms direction arrows can be part of the sign (see FIG 2). In the following figure (FIG 3) different pictograms for elevators are shown.

FIG 3. Different graphical symbols for elevators

Pictograms should own an evident connection with the associated function and have to be understood intuitively. Due to comprehension tests Easterby et al. [23] illustrated that elevator signs own a high potential of misinterpretation. On the one hand the picture of man and woman is already in use for a different purpose and will be recognized as a symbol for restrooms (Olympic Games '72). The application of distinguishing features (ISO 7001, International Council of Graphic Design Associations (ICOGRADA)) would scale down this disadvantage. On the other hand the directional arrows in the rightmost elevator sign could be mixed-up with the motion direction arrow provided by the guidance system [24]. As this sign option proposed by the Australian Department of Civil Aviation (ADCA) has no explicit reference to an elevator, this abstract symbol is one of the most misinterpreted signs.

Testing the average information content of the pictograms for first aid (listed in FIG 4) points out that approx. 25 % of the interviewed persons had a wrong understanding concerning the right symbol (EC Directive 92/58/EWG). The left pictogram taken from the Austrian Standards Institute (ÖNORM) was only wrongly identified by approx. 14 % [25].

FIG 4. Different graphical symbols for first aid

If graphical symbols are not self-explaining they have to be supplemented with text especially if they carry less familiar functions [1]. In the context of air transport Frankfurt International Airport (FRAPORT) decided to renew the signage symbols. Examples from the so called "Compass" (Communication for Passengers) system are shown in the following figure (FIG 5). The symbols presented in the first row are:

– Departure, Arrival, Stairs Up and Escalator Up

and the second row symbols depict

– Exit, Entrance, Connection Flights & Passengers Only.

FIG 5. FRAPORT AG, pictograms 2006

Whereas the signs summarized in the first row are quite forward to understand the signs from the second row are hardly self-explaining. Particularly the last symbol "Passenger Only" should better be formulated as a negation, marked with a diagonal bar running from top left to the bottom right (in accordance with ISO 7001 [26]).

The purpose of a guidance system is to deliver essential information to its user. As one aspect signs should attract the passenger's attention and allows for extracting all necessary facts for way-finding. In order to provide a comfortable feeling at each (even perceived) decision point (and in-between) the passengers need to assure themselves of being on the right way to their destination. The distance from one sign to the next differs according to the visibility conditions and complexity of route choice; however the distance should range between 25 m and 100 m [21].

1.3.2. Color Contrast

To exclude confusion between public symbols and safety signs it should be avoided to use similar colors and shapes for both purposes (DIN ISO 3864-1 [22]). As mentioned above, all essential information should be provided

[3] All Japan Airport Terminals Association

to the general public in an efficient way, regardless of the individual expertise. Considering the human sensory abilities, the applied signs must exhibit sufficient contrast to the surrounding conditions making them distinguishable from their ambience and decipherable for the user [27]. An adequate contrast (referred to intensity of light [28]) is obtained by using coordinated colors for fonts and background described in the following table (TAB 3).

[%]	beige	white	grey	black	brown	pink	purple	green	orange	blue	yellow
red	79	85	32	38	7	57	28	24	62	13	82
yellow	14	16	73	**89**	80	58	75	76	52	79	
blue	75	82	21	47	7	50	17	12	56		
orange	44	60	44	76	59	12	47	50			
green	72	80	11	53	18	43	6				
purple	70	79	5	56	22	40					
pink	51	65	37	73	53						
brown	77	84	26	43							
black	87	**91**	58								
gray	69	78									
white	28										

TAB 3. Color contrast, Arthur [29]

A combination of white background and black font (vice versa) exhibits the highest contrast followed by the combination of black and yellow. Two good examples from different airports (Copenhagen and Chicago) are therefore shown in the following figures.

FIG 6. Copenhagen Airport (EKCH)[4]

FIG 7. Chicago O'Hare International Airport (KORD)[5]

1.3.3. Information Alignment

Passengers in terminals possess different motivations for using guidance systems. Corresponding to ADV [16], ATA [17] and the American Institute of Graphic Arts (AIGA) [30] destinations provided by the system are subdivided in destinations of primary and secondary relevance. Primary destinations are essential for the natural function of the terminal, as check-in, security check or baggage claim. By contrast secondary destinations as shops, elevators or restrooms neither have a direct influence to terminal operations nor are exclusive airport facilities. They may only have certain relevance from the overall system perspective. Rules and regulations as well as hints for forbidden actions do not represent a part of the guidance system.

In addition to the use of well-design symbols and unambiguous captions at sufficiently contrasted signs the arrangement and accentuation of the presented information is another important influence factor for the human perception. For this purpose particular types of information could be linked to a special background color. Based on this intention Mijksenaar [1] drafted a new signage concept for Amsterdam Schiphol Airport (EHAM). Before 2002 the yellow background was used for operational (primary) targets whereas offered services showed green background (restrooms). This two color scale was extended by a third color. Afterwards primary information (check-in, gate) was provided by yellow signs (FIG 8).

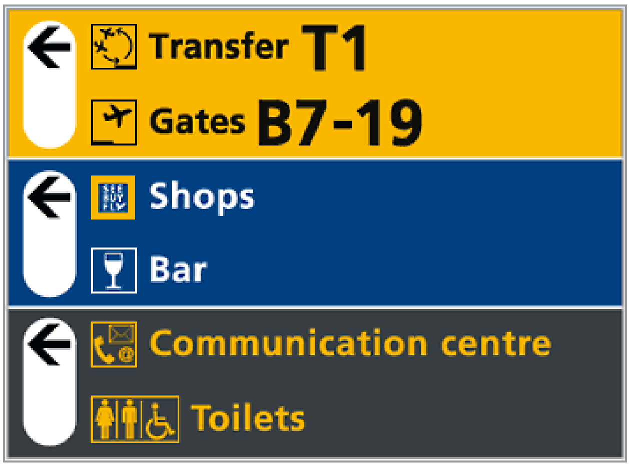

FIG 8. Amsterdam Airport Schiphol (EHAM)[6]

Shops and restaurants were integrated as part of the guidance / way- finding system and equipped with blue background color. Secondary targets like waiting areas received anthracite background whereas green was now consistently coupled to the escape-route system. A similar concept is currently used at Charles de Gaulle International Airport (LFPG, see following figure FIG 9). but with a slightly different color set (yellow → orange, blue → green, anthracite → black).

FIG 9. Charles de Gaulle International Airport (LFPG)[7]

[4] Picture by D. Bowman
[5] Picture by E. Fish
[6] Picture by P. Mijksenaar
[7] Picture by D. Monniaux

Regarding to the color contrast table (TAB 3) the chosen colors at LFPG exhibit less contrast quality compared to EHAM. The variable use of the green color for way-finding targets instead of emergency exits can result in profound misunderstandings. Due to this reason Frankfurt Airport (EDDF) decided to change the applied colors (FIG 10) and modernize the whole signage system.

FIG 10. Frankfurt Airport (EDDF), 1970th[8]

Conventional signage concepts base on ceiling mounting of all necessary signs. As an example for an alternative way of presenting information the terminal at Dresden airport (EDDC) is mentioned. It is a free-standing building with no supporting pillars inside. Due to this special characteristic the signs are arranged at floor level (FIG 11). For the benefit of human perception horizontal alignment is preferred by the airport operators instead of the vertical information sectioning. At EDDC the primary information is presented at the middle whereas the secondary and concessionary information is presented aside with different labels and inverted colors at the top. Passengers perceived the logic of the parted information not on the first view, because of no background color differentiation as mentioned in FIG 8 (EHAM).

FIG 11. Information board at floor level (EDDC)[9]

For handicapped passenger orientation and navigation inside complex buildings is still a difficult task. Several orientation advices are presented at visually perceivable signs. Without influencing existing systems of way-finding a subsidiary guidance at floor level provides additional benefit for visually handicapped persons. According to EDDC an orientation guide at the floor (grooved tiles) leads from the underground train station directly to the information center at the arrival level (FIG 12).

FIG 12. Floor signage (EDDC)[9]

1.4. Guidance System Installation

Planning a guidance system implies considering the psychological human factors as well as the existing building infrastructure and architecture. To create an elementary and well-defined system the following specified steps have to be accomplished by the operator (see [1]).

- Overview of all accessible system points and creation of flow charts with all possible routes between these points.
- Differentiation between primary process information and (additional) secondary information
- Removing of all parallel routes and preventing a high number of turnarounds. Creation of aggregate main paths with marginal redundancy.
- Categorization of all information elements (information alignment) and usage of adequate colors, lighting and other design elements to emphasis the messages.

Each step of the planning processes of an airport-wide guidance system could be supported by a computer simulation, for instance compiling a list of recommended sign position or testing the sign-network with individually operating persons (agents). Boundary conditions for sign locations are visibility/perception range, designation of all required (recommended) destinations and minimum (maximum) distance between the signs. In this context basic computer simulation concepts are presented in the following chapter.

2. SIMULATION ENVIRONMENT

The development of the simulation is subdivided in two parts. In the first part common graph theory approaches are presented for developing and analyzing the routing/way-finding network. This approach considers the aggregation of direct point-to-point connections (source-destination) to an applicable route structure. In the second part this route structure is optimized by using a multi-agent system [31, 32].

In the first stage the terminal building is transferred to a logical model. This model contains every primary and secondary destination. If the logical structure of the building is generated, all possible connections between the referred destinations are set up. A simple logical model is shown in the following figure (FIG 13). The terminal is subdivided into public and non-public area separated by the security check.

[8] Picture by FRAPORT AG
[9] Picture by M. Schultz

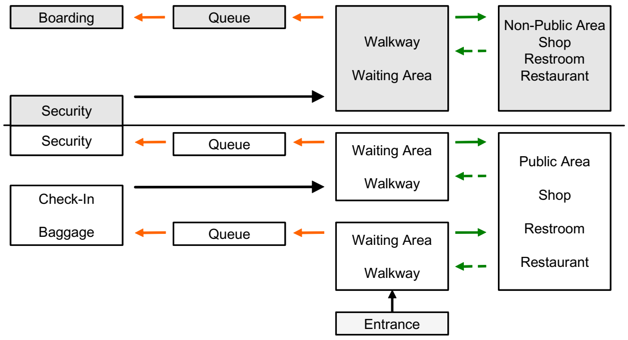

FIG 13. Simple logical process chart

Entering a primary process is often coupled with accessing a queue. Before accessing the queue passengers may choose between primary and secondary facilities. The decision depends on the remaining time. The first requirement for passengers is to reach the check-in in time, because many airlines close the check-in counter 30 min before the scheduled time of departure. The arrival time of passengers depends on several factors, like individual expectations and experiences regarding terminal processes as well as the travel motive (business, leisure) and travel distances. For this reason departing passengers arrive at the terminal in the range of 2.5 hours to 30 min before scheduled [33, 34]. If passengers have finished the required departure procedures they are free to spend their time for different activities until boarding [35].

The remaining time is the difference between scheduled time of departure, current time and the minimum time for all remaining processes (including current process, see equation (1)). The minimum time includes the process and queuing time of all necessary primary facilities as well as the walking time between the facilities.

(1)
$$t_{remain} = t_{STD} - t_{current} - t_{min,\ current\ process}$$
$$t_{min,\ current\ process} = \sum_{p=current}^{P} (t_p + t_{p,\ queue}) + \sum_{p=current}^{P-1} t_{p,\ p+1}$$

Frequent and business travelers usually minimize their inevitable airport time whereas other passengers tend to considering extra time. An appropriate LOS and well-defined guidance instructions consequently induce short process times. If the available time budget exceeds a sufficient level a substantial increase of consumption activities by the passenger takes place [35]. In the simple logical process chart (FIG 13) decision points are located at the walkways. Generally the passenger follows the intended (major) terminal paths for an undisturbed journey. At each decision point the passenger has the ability to extend his scheduled path depending on the time budget.

Against the background of airports as highly competitive market segments and the justified claim to self-financing the secondary/concessionary facilities become more important. With increasing time budget the sophisticated signage of these retail areas advances to a competitive benefit.

2.1. Route network development

Without considering concessionary facilities all routes connecting the primary arrival and departure facilities are created [19]. In this process the terminal design and geometric characteristics are considered as well as the maximum capacity of the path sections and LOS measures. As a result a directed graph representation of the terminal (see FIG 14) can be used for further network analysis and optimization [31, 36]. In the network vertices (circles) represent facilities and edges (arrows) are the connection in-between. According to the intention of optimization the edges have different weightings. In a second step edges are split by adding a decision point (grey square) with connection to the retail area (rectangle).

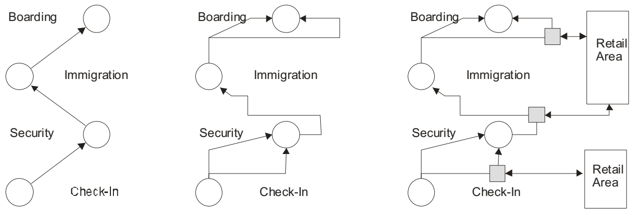

FIG 14. Stepwise network development

Optimizing the route network denotes finding a balance between the concession revenue and the passenger expectation by means of adequate service quality. In this context Hsu et al. [35] points out that the extension of airport capacity without the increasing of available space and unchanged LOS (space) yields to required extension of processing facilities areas. The new space allocation leads either to diminishing concession areas or decreasing LOS at these facilities. The above solution results in suboptimal sales revenue.

Using virtual passengers (agents) the provided network environment is applied to evaluate the actual route specification and the effect of terminal changes. With the simulation approach the weighting of all edges is determined at every time step among any system condition (actual flight schedule, forecast, terminal upgrade or current capacity overload). The actual weighting factors are considered in the objective function to continually improve the desired intention.

2.2. Virtual passenger simulation

To test the established guidance system (route network) an individual-based simulation system is used. Each virtual passenger has to implement thee functional elements: a sensing system, a planning system and a transaction system [37]. The sensing system provides essential environmental information, which is transferred into an inner model of the environment. The interpretation of the model data in conjunction with previous experiences and actual objectives yields an individual decision. In consideration of available alternatives and the surrounding conditions a plan will be generated to realize the target figure. The task of the transaction system is to implement the generated plan by executing precise operations. The described process sequence is generally known as Sense-Plan-Act (SPA) concept [3]. A graphical representation is shown in the following figure (FIG 15). (see [38])

A simulated subject that implements all the above listed features is called an agent. In this context corresponding agent definitions announced: "anything that can be viewed as perceiving its environment through sensors and acting upon that environment through effectors" [39] with the capability of flexible and autonomous action [40]. Flexible actions are responsive to environmental changes, being proactive due to opportunistic and goal-directed behavior, and social by means of interactions with other entities [41].

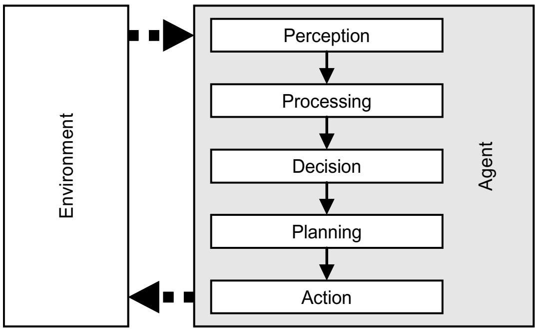

FIG 15. Extended Sense-Plan-Act concept

The developed simulation [31] represents a multi-agent system in which every agent has access to a common knowledge base (terminal processes). Agents gather environmental information during the simulation and their actions influence other agent's behavior (decisions) [42, 43]. The simulation environment fulfills major characteristics of multi-agent system [44]:

– agents posses (incomplete) information and limited perception areas
– agents posses the capability of problem solving
– no global system control, data are decentralized
– asynchronous computation

The implemented components of the extended SPA concept are successively explained in the next paragraphs.

Perception

For evaluating guidance systems the perception of human beings is reduced to the visual sensors. If the guidance system is extended (e.g. with audio messages), also the modeled human perception has to be extended with audio-visual sensors. The visual perception can be subdivided into a horizontal and a vertical component. At the pictured perception areas (FIG 16) individual limitations are shown. To recognize an object it has to be in a vertical range of ± 15° and a horizontal range of ± 62°. Additionally, attention should be paid to the following facts. The head is normally inclined to the floor by 10-15°, so the vertical range has an additional variation.

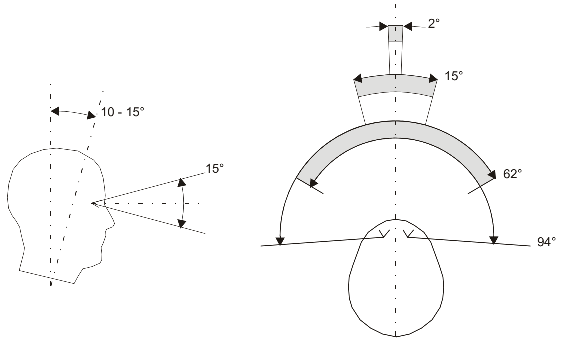

FIG 16. Perception areas[10], Bokranz [45]

[10] See also DIN 33414 E / Part 1, DIN 33402

The horizontal visual range is subdivided in several areas. One eye has a visual range of approx. 160° whereas the intersection area of both eyes has a range of approx. 120°. Objects which are inside this sector are recognized in three dimensions. Furthermore, humans are able to clearly identify objects (as text) if they are located near the focal point (± 2°). The range between ± 15° is an area with particular attention adjacent to an area of peripheral visual perception (± 94°) [46]. Information gathered by the agents is additionally tagged with the corresponding perception area.

Processing

The perceived environmental data is transferred to a conceptual representation (mathematical model) for virtual humans. A model reduces the reality with focus on the scientific intention to a manageable environment with explicit factors and relationships (structures) [47]. The central idea of modeling concepts is the reduction of complexity. In this context the simulation model represents an explicit state and describes this state in details [48].

The main model concept is the individual interaction via social attraction and repulsion forces [49]. By implementing this interaction approach observed macroscopic characteristics (self-organizing effects: row formation, oscillation at bottle necks, etc.) are reproduced. According to the heterogeneous personality (employees, passengers, well wishers, and visitors) agents have different personal profiles. These profiles are fundamentally categorized by citizenship, language, knowledge of the environment, culture attitudes, assertiveness and the general individual physique. Strategic behavior components have to take into consideration as well, like activity and destination choice or path choice to reach the activity areas [50].

Decision

Depending on the simulation model an agent can decide regarding to his intention and surrounding conditions. An adequate approach assumed passengers as "adaptive controllers that minimize the subjective predicted cost of walking" [4]. Generally, people have great routine to solve all-day (motion) challenges without even noticing any stress (see TAB 4).

Attributes	Challenge	
	standard / simple	complex /new
Reaction	automatic reaction, reflex	evaluation result, decision process
Characterization	well predictable	probabilistic
Modeling concept	social force model, etc.	decision theoretical approaches, etc.
Example	pedestrian motion	destination choice

TAB 4. Classification of human behavior, Helbing [49]

In combination with a complex or new environment these trained automatic reactions are changing to a decision process. If the stress level is too high persons tend to act instinctively, since there are no experienced behavior solutions. If persons posses completely no information they decide to move to a location where they expect to get additional guidance. Sometimes this seeking process looks like an unpredictable random walk.

Planning

The planning process is directly connected to the decision process. As mentioned above people act rational (under normal circumstances) and maximize their subjective utility (micro-economic approach). Human behavior patterns are subdivided in three different levels: operational, tactical and strategic. The operational behavior component is characterized by immediate /short term interactions with nearby obstacles and repulsion effects to other persons. Being responsive to oblique information is determined by tactical behavior patterns. Typical issues are path information of the guidance system or the way planning to avoid undesirable situations like crowed areas. Strategy is the overall instance (decision process) and is qualify as driving force for human behavior. Inside the simulation environment individual intentions are formulated as quantitative or qualitative objectives. Quantitative means an explicit task: “Go to the check-in number 10b!” whereas qualitative objectives are more like implicit recommendations: “Cumulate information!” or “Find a way out!”.

Action

Finally, the decision and planning process results in a precise operation task. The agent moves inside the simulation environment and performs an environmental change process which can be observed by other agents and may influence their own decisions.

2.3. Animation layer

Further research projects [52] used an animation layer for both consistency checks and graphical representation as shown in the following figure (FIG 17). The motion coordinates of every agent are continuously stored and combined with elementary cuboids (low level) or with sophisticated kinematical models (high quality).

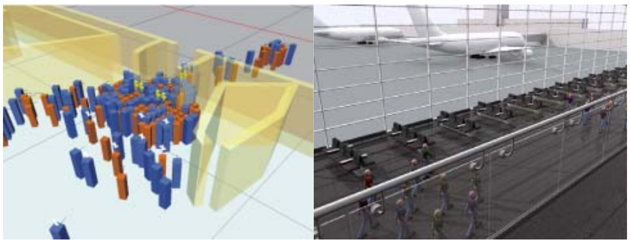

FIG 17. Animation layer for several application

This animation layer is not only developed for effective presentation. Even to reveal basic principles of human behavior visual survey is sometimes an essential part. In this context tagged individuals are traced during the simulation (overview, first person view, etc.) and their decisions become transparent and understandable.

3. OUTLOOK

Guidance systems provide the same information to all passengers. After receiving the information the passenger decides, which information is useful to achieve the individual objectives. For direct addressing the information has to provide via other channels like PDA or cell phone concepts [53]. The application of simulation tools for real environments is an appropriate concept to evaluate the personal and public benefit.

The conceptual design of an extended human perception model is completed and the transfer to a mathematical model is planned for the next period. In addition to the perception model the model for human decision making will be extended by a cooperative component as well. Furthermore, the animation layer will be fully developed to be an adequate tool for agent environments with multi-level diagnostic capabilities.

The human behavior is directly connected to existing and additional offered information. Generally, the static signage provides this information at pre-positioned locations, so passengers have to collect information at given points. The application of environmental depended (adaptive) guidance systems is a potential challenge for future airport terminals. Air traffic has to cope with growing expectations in terms of quality and facilitation as well as safety and security. By introducing adaptive control concepts, agent based simulations represents a promising approach.

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