The Human, the Built Environment and the Technology: Identifying Key Configurations for a User-Friendly Wayfinding System at Transport Hubs

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Abstract. Neither an entirely analogue nor an entirely digital wayfinding system can meet all user requirements for navigation and orientation in a complex transport hub (such as a railway station, a metro station or an airport). This paper presents considerations on a holistic, barrier-free and user-friendly wayfinding system at transport hubs by describing wayfinding elements provided through humans, the built environment and specific technologies. For each of the three mentioned categories, a detailed set of wayfinding elements (morphological field) is compiled. Environmental elements include signs, plans or landmarks while technology-based elements consider any form of wayfinding support on mobile devices (such as smart phones, tablets or watches). Human-related support in wayfinding represents classic forms of personal information or personal assistance by passengers or employees. In order to integrate the user perspective and the complexity of different user requirements, an additional set of user groups (such as people with visual impairments, people with hearing impairments or people with mobility impairments) and their wayfinding-specific requirements is composed. With a focus on intersecting the identified wayfinding elements and the user-specific wayfinding requirements, a Morphological Analysis is conducted. This methodological approach represents a multi-dimensional, non-quantified method for delineating key configurations of wayfinding elements that cover the widest range of user-specific requirements in orientation and navigation at transport hubs. Based on the Morphological Analysis, recommendations for a holistic, barrier-free and user-friendly wayfinding system are formulated. The elaborated recommendations form the basis for a feasible implementation strategy of future wayfinding systems at transport hubs.

1. Introduction
In order to navigate and orientate within a transport hub (see chapter 2.1), visitors can use a wide range of navigation and orientation aids provided through the built environment, humans and certain technologies. Since neither a purely analogue nor a purely digital wayfinding system can meet all individual customer requirements, this paper is not dedicated to analysing the most suitable analogue or digital indoor wayfinding system. The paper intends to develop a comprehensive overview of environmental, technological and human-based navigation aids. The target is to describe an implementation strategy for a practical, barrier-free and user-friendly indoor wayfinding system with specific regard to transport hubs. Since a well-considered interplay of analogue (e.g. signs, colour, contrasts, tactile guidance system, architecture) and digital navigation and orientation aids (e.g. apps, interactive maps, info terminals) can produce the best possible wayfinding solution for a large number
of different user groups, it is important not to jointly consider analogue and digital navigation systems. This particularly applies to multifunctional buildings such as transport hubs (see chapter 2.1). Nonetheless, developments in the field of indoor wayfinding systems mainly focus on the establishment of stand-alone solutions.

Günther and Jöst (2016) [1] define general requirements for digital wayfinding systems. First and foremost, the high reliability of the respective systems must be guaranteed. The more complex the functional scope of a wayfinding system, the more extensive the maintenance and updating (e.g. of data) becomes and the more difficult ensuring the reliability of the system will get. The reliability of a digital wayfinding relates to the reliability of the implemented algorithms for position determination. Therefore, this report provides a presentation of technological processes and methods for data generation and position determination (see chapter 2.4).

Providing a variety of user-friendly functions (see chapter 2.2) may raise the customer's willingness to actively use a digital wayfinding system. For example, user-friendly functions include audio functions in the form of acoustic verbal instructions, vibrations, the availability of the system to operate in several languages (e.g. translation function) or barrier-free routing functions. Additionally, a digital wayfinding system should provide an appropriate information level about the spatial components existing at a transport hub (e.g. representing the station’s infrastructure on an interactive map where levels of detail vary depending on the zoom level).

According to Seumenicht (2008) [2], it is important to ensure uniformity when designing an analogue wayfinding system. A uniform design increases the recognition degree of wayfinding elements. A sufficient contrast between analogue wayfinding elements and the built environment must be ensured (via colour, pictograms, font, lighting, monolingual or bilingual texts, alignment etc.). The main characteristics for implementing an analogue wayfinding system are:

- Uniformity
- Perceptibility
- Readability
- Arrangement

Based on an extensive and user-oriented analysis of wayfinding elements provided through built environments, humans and specific technologies, this paper aims to describe an implementation strategy for a barrier-free, user-friendly and practicable wayfinding system at transport hubs.

2. Methodical approach

2.1. Classification of transport stations

In this study, transport stations are classified as presented in table 1. The further focus is on transport hubs as, by nature, their configuration and multifunctionality lead to the highest complexity for indoor navigation and orientation.

Transport hubs as multifunctional buildings are related with specific navigation and orientation-related challenges such as:

- Complexity of the building and path structure
- High (international) visitor flow
- Different length of stay
- High passenger and visitor frequency
- Passengers and visitors not being familiar with the place
- Mixed use (shops, restaurants, mobility offers etc.)
- Combination of different modes (e.g. metro, bus, train, plane)
- Susceptibility to malfunctions in operation (e.g. delays) or infrastructure (e.g. malfunction of an escalator or elevator)
Table 1. Classification of transport stations

| Criterion                  | Unimodal Transport Station | Multimodal Transport Station | Multimodal Transport Hub |
|----------------------------|----------------------------|----------------------------|---------------------------|
| Complexity of Orientation  | low                        | medium                      | high                      |
| Functionality              | Connection (mobility function) | Supply (bakery, provisions etc.) | Activity (entertainment) |
| Keyword                    | move                       | combine                     | experience                |
| Design                     | barrier-free               | not barrier-free            | barrier-free              |

2.2. Wayfinding elements provided through built environments, humans and technologies

Navigation and orientation aids at transport hubs can be provided through the built environment, humans and technologies. Identifying the wayfinding elements of these three categories leads to the compilation of a so called morphological field on Morphological Analysis [3] can be applied (see chapter 2.5). Figure 1 represents wayfinding elements offered by the built environment. They include static (signs) and temporary (advertisement) objects.

![Figure 1. Wayfinding elements of the built environment](image)

Personal information and personal assistance are common possibilities within transport hubs to help people find their way or destination. Human interaction can respond to different senses (seeing, hearing, feeling). Thus, individual and personal support corresponds to a special form of navigation and orientation aid. Personal information and assistance can either be provided by passengers and visitors or by the operating staff. With regard to the design of a user-friendly wayfinding system at a transport hub, it is essential to deal with the topic of personal information and assistance as they take up a significant amount of time from passengers, visitors or the operating staff.
In combination with a specific wayfinding app, digital devices such as smartphones, tablets, interactive terminals, smartwatches or even smart glasses offer flexible, adaptive and user-friendly navigation and orientation aids. The unique feature of digital devices is the ability to combine environmental information with digital information. There exist various solutions for wayfinding apps all of which providing a number of different functions. As part of this study a number of wayfinding functions for digital devices is identified (see table 2).

Table 2. Wayfinding functions for digital devices

| Wayfinding function | Example |
|---------------------|---------|
| Display function    | Interactive maps representing points of interest (POI) |
| Routing function    | Barrier-free routing for individuals with disabilities showing routes free of protruding objects which could not be detectable by an individual with visual impairment using a cane |
| Audio function      | Voice announcement for routing instructions, alarms or destination confirmation |
| Quicklink function  | Button generating a direct connection to the operational staff at the transport hub |
| Feedback function   | User-feedback on the individual experience at the transport hub |
| Vibration function  | Haptic routing instructions in the form of vibrations |
| Query function      | Real time information on the transport system and station infrastructures |
| Notification function| Push notifications about changes in timetable (e.g. delays) |
| Transition function | Transition from indoor to outdoor |
| Translation function| Translation of signs in foreign-language into the individual mother tongue |
| Assistance function | Augmented reality or individual support by an avatar |

2.3. Evaluation of navigation and orientation aids

The wayfinding elements provided through built environments, humans and technologies are examined individually with use of the following framework (table 3).

The evaluation leads to the following conclusions concerning wayfinding elements of built environments, humans and technologies.

The majority of environmental navigation and orientation aids are classical and static aids (e.g. classic signs and floor plans). Dynamic content can be implemented by landmarks, dynamic passenger information, dynamic guidance with LED strips, dynamic signs, interactive and digital maps or intelligent signs. In order to guarantee uniformity, it is useful to apply environmental navigation aids (static and dynamic) throughout the entire transport station on the basis of a corporate design concept. Environmental navigation aids that address all users (i.e. all of the criteria listed in table 3) are intelligent signs (because of their wide functionality) and landmarks (because of their diversity). Therefore, the implementation strategy for a user-friendly wayfinding system includes a clear recommendation for the development of a landmark-based orientation system (see chapter 3).

In addition to tactile information systems (e.g. tactile signs, tactile ground information, tactile handrails, tactile building plans), all forms of signs (including intelligent signs) are suitable for barrier-free design. Moreover, acoustic signals, LED lamps, dynamic guidance with LED strips, colour-coded plans and colour coded areas provide added value for barrier-free design of transport hubs.
Personal assistance and information is a flexible and individual wayfinding possibility. The target of a user-friendly wayfinding system is to ensure the availability of personal assistance at transport hubs. However, some aspects of personal assistance and information may partially be adopted by digital devices offering customisable wayfinding functions (see chapter 2.2). Therefore, it is crucial to implement various wayfinding functions in digital devices. Generally, the described wayfinding functions represent an added value for all user groups (if implemented successfully and customisable). In the development of a barrier-free, user-friendly and practicable wayfinding system, it is advisable to combine a large number of these functions in a single wayfinding service.

A comprehensive implementation strategy for a wayfinding system at transport hubs will make use of both, analogue and digital navigation and orientation aids. However, it must be ensured that real-time information about the facilities at the station (e.g. the current condition of the station's own infrastructure) is available either via the environment or individual digital devices.

| Framework for analysing wayfinding elements |
|---------------------------------------------|
| **User** | **Impairment** | **Age** | **Ethnicity** |
| visual impairment | young | monolingual |
| hearing impairment | elder | multilingual |
| physical impairment | | |
| mental impairment | | |
| no impairment | | |

| **Characteristics** | **Advantages** | **Disadvantages** |
|---------------------|----------------|-------------------|
| classic navigation and orientation aid | robust | maintenance-intensive |
| innovative navigation and orientation aid | reliable | update-extensive |
| static information | capable of synchronization | depending on special technology |
| dynamic information | comprehensively installable | selectively installable |

| **Advantages** | **Disadvantages** |
|----------------|-------------------|
| clear | prone to misinterpretation |
| easily perceptible | difficult to percept |
| uniform | not uniform |
| easily accessible | difficult to access |
| customisable | not customisable |

| **Accessibility** |
|------------------|
| Unimodal transport station | barrier-free |
| Multimodal transport station | not barrier-free |
| Multimodal transport hub | |

Table 3. Framework for analysing wayfinding elements
2.4. Technological methods for indoor positioning

To enable indoor positioning and explicit routing instructions on digital devices, different technological procedures and methods exist [5-23]. The aim of this chapter is to provide an overview of sensors and signals for positioning and methods for data generation. Furthermore, it is shown which digital devices are used for data presentation and which forms of data presentation exist (see figure 2).

Figure 2. Technological methods for indoor positioning

2.5. Morphological Analysis

In order to derive an implementation strategy for a barrier-free, user-friendly and practicable wayfinding system at transport hubs, a Morphological Analysis [3] is conducted. Table 4 represents the aspects that are considered within the Morphological Analysis. This methodological approach represents a multi-dimensional, non-quantified method for delineating key configurations of wayfinding elements that cover the widest range of user-specific requirements in orientation and navigation at transport hubs.

3. Results and discussions

The implementation strategy for a barrier-free, user-friendly and practicable wayfinding system at transport hubs consists on the following twelve recommendations (see table 5).

4. Conclusions

Almost all areas of modern life are affected by the ongoing digitisation processes (Batty, 2013) [4]. Traffic, transport infrastructure and thus also transport stations are not excluded from this trend. It can be assumed that this trend will continue and lead to

- data collection and availability (data acquisition)
- development of efficient methods for processing and analysing data (data analysis)
- a better linkage between data (data linking)
- new technologies for interaction, communication and data presentation as interfaces between humans and computers are emerging (data presentation)
### Table 4. Structure for the Morphological Analysis

| Category | Related question | Attributes of examination |
|----------|------------------|----------------------------|
| Context parameter: user | Who am I and how do I get around? | • Impairments  
• Age  
• Ethnicity |
| Context parameter: transport station | What station am I at and how familiar am I with the station? | • Transport stations  
• Familiarity |
| Wayfinding elements | Which wayfinding elements are available and ready to use in order to help me find my destination? | • Built environments  
• Humans  
• Technologies |
| Technological methods for indoor positions | Which technological devices/innovations/processes are used to get me around? | • Sensors and signals  
• Data generation  
• Data presentation |
| Data Sources | Which data are used for the wayfinding process? | • Internal data (transport hub)  
• External data (entire transportation system) |

### Table 5. Implementation strategy

| Nr. | Navigation and orientation aid | Recommendation |
|-----|--------------------------------|----------------|
| 1   | Data interface | Development of a data hub as a central information interface for indoor wayfinding: collection and continuous updating of spatial and transport-related data |
| 2   | Information and wayfinding service | Respective provision of data for the development of a comprehensive information and wayfinding services that guarantees a reliable interplay between analogue and digital components |
| 3   | Interactive maps | Provision of comprehensive, detailed (and interactive) maps (digital and analogue) |
| 4   | Assistance network | Development of a geocoded assistance network |
| 5   | Landmarks | Development and integration of a landmark-based wayfinding concept |
| 6   | Tactile information | Determination and implementation of the optimization potential for tactile information systems |
| 7   | Colour coding | Colour coding of building levels by means of colour-coded signs, doors, areas etc. |
| 8   | Dynamic Signs | Optimization of temporary guidance systems (e.g. for replacement services) with the help of dynamic signage |
| 9   | Labelling | Determination and implementation of the optimization potential of analogue and static labelling |
| 10  | Safety guidance systems | Implementation of safety guidance system with luminescent floor lines, signs and arrows |
| 11  | Light | Implementation of a dynamic wayfinding system with LED strips including options for Visible Light Communication |
| 12  | Assistance function | Development of a user profile-based, intelligent tactile guidance system for impaired people |
These developments are currently taking place at high speed. They can be seen as relevant elements for the further development of user-friendly and barrier-free wayfinding systems at transport hubs. This is because navigation and orientation are two essential aspects in the wayfinding process within a transport hub where acquisition, analysis, linking and presentation all play a role. In the future, opportunities and challenges for wayfinding systems are derived from ongoing digitalization processes, which provides further basis for discussion and research on this topic.

Acknowledgment(s)
This paper has been elaborated on the basis of the project “Indoornavigation” that was funded by the Austrian Railway Association (ÖBB-Infrastruktur AG) and the Austrian Ministry for Climate Protection, Environment, Energy, Mobility, Innovation and Technology (BMK) within the research programme “Verkehrsinfrastrukturforschung 2017”.

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