Integrating Human Factors into Evacuation Simulations - Application of the Persona Method for Generating Populations

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ABSTRACT

For assessing evacuation dynamics in disaster situations, current approaches of pedestrian simulations increasingly include additional human characteristics. One aim is to assess realistic effects of structural changes of an infrastructure on evacuation behavior displayed by users. Creating agents with supplementary physical and psychological human characteristics and assembling the agents in accordance to the user's population may be beneficial not only to support decision making. The analysis of simulated effects of, e.g., informational strategies will foster crisis and disaster management.

This paper combines knowledge about users in subway systems and highlights benefits of using the Persona method to improve objectivity in the specification of different user types. Persona method is adapted to pedestrian simulation. Using data from the authors´ field studies, personas are developed and implemented for an evacuation simulation. First findings suggest that including personas into pedestrian simulation influences the results with respect to the required safe evacuation time (RSET).

Keywords

Persona method, pedestrian simulation, preparedness, human factors, evacuation.

INTRODUCTION

This article results from a cooperation of researchers from different research domains: Researchers of software engineering, psychology and pedestrian simulation integrated their knowledge to build personas of relevant evacuees in subway systems. Apart from the theoretical discussion, the fusion of research perspectives was an additional challenge. A common language was necessary to bridge the different researchers´ points of views and the theories of each research domain, and to enable a shared understanding of data and options for this kind of implementation. Further research will be conducted to gain further knowledge by this cooperation.

The Persona method is a descriptive model describing users' needs, behavior and motivation (Cooper et al., 2007). Persona method has its origin in user-centered design and marketing and is adapted to pedestrian simulation. Personas are not real people but they represent a powerful tool to represent users in a design process. Personas usually are presented in a narrative description and are based on research work and ethnographic studies taken the respective end-user of a product into account. In this paper, the data is taken from field studies in a subway system in Germany.

The aim behind creating Personas, and as a result to build up successful products, is to design not for a variety of users but rather to specify your product with regard to specific needs of a specific type of group of individuals (according to Cooper (2007)). Personas can help to keep the users' perspective in focus of a development process. This knowledge is used as a foundation for plans to create products whose form, content, and behavior is useful, usable, and desirable, as well as economically viable and technically feasible to the end-users in focus.

Personas are to reveal all relevant user types of a product, e.g. originally Persona was used for the product of software. In this paper, instead of designing a software the Persona method is used to account for behavior in interactive environment systems with the goal to assess the "product: Evacuation design in subway systems". By means of Personas, all relevant characteristics of possible occupants of a subway system are to be integrated, in order to answer the following questions: What are relevant physiological and psychological characteristics of occupants for an evacuation scenario? Which characteristics need to be implemented in pedestrian simulations in order to receive realistic evacuation times? Which occupant characteristics have to be considered for effective evacuation design of subway systems?

In the following the consecutive and mandatory steps to create personas according to Cooper (2007) are described in the context of simulation. This process includes the identification of relevant human characteristics of pedestrians. Secondly, it is highlighted which occupants of a subway infrastructure are clustered into subgroups thereby forming separate personas. The personas are specified using data in an evacuation scenario in a subway station. In a third step, the Persona method is utilized for generating occupant scenarios. It is implemented in pedestrian simulation demonstrating the application by using JuPedSim (Kemloh Wagoum, 2015). The subsequent simulations are also conducted with JuPedSim. Based on the results, it is discussed which improvements can be reached using Persona and how efforts can be minimized by creating subsets of personas, e.g. according the purpose of a simulation.

HOW TO CREATE PERSONAS

The process to create personas is described in Cooper (2007). The complete approach to create personas includes seven steps (Cooper (2007), p. 97ff). In the following part of this chapter the different steps are presented and one additional step is suggested, if personas are to be used for the purpose of evacuation design in subway systems rather than in software design (see also Ontology of Personas Ontology in the References).

STEP 1: Identify Behavioral Variables

Cooper (2007) lists three kinds of individual variables: I. geographic variables (as part of demographic variables) II. demographic variables, and III. behavioral variables. The process of constructing personas is focused on the behavioral variables because they are more useful in the description of interactions with a product. Thus, based on data and information gathered on the desired end-user behavioral variables are to be identified.

Nonetheless, for the purpose of this paper, all three individual variables are introduced first:

I. Geographic Variables

For a desired product, a specification of the setting in which personas act is highly relevant. In this paper, the persona is not meant e.g. to sit in front of a computer using a software but to be an occupant in a subway system. The subway system is located in Berlin, Germany and the person has to evacuate from the latter. For the evacuation design in subway systems, also the location of a persona within the subway station is relevant. The location may also address the reason for being within the infrastructure (e.g. shopping, commuting) and further qualities of the environment (e.g. visibility, walkability, availability of oxygen, availability of lifts), both in general usage and especially during evacuation (e.g. if stairs are blocked by debris even an unhandicapped persona may not be able to evacuate on her own). Therefore, this consideration of geographic variables differs from the original approach of Cooper (2007). Thus, these variables have to be considered separately from the demographic variables.

II. Demographic Variables

Cooper (2007) lists the name (suitable for a specific persona), age or gender. Further important demographic variables for the usage of personas for evacuation are: height, weight and walking speed of the respective user. Moreover, the personas general group membership and family status influence reactions and behavior during evacuation. Furthermore, the profession or occupation is considered relevant, as this might influence perceived tasks during evacuation, e.g. paramedics might feel obliged to support harmed occupants; safety staff from the infrastructure may give directions before leaving the station; a shop owner may close down before leaving his/her shop. Another demographic variable is nationality, due to the fact that cultural norms and the procedures regarding evacuation may influence and determine acceptable behavior, e.g. following others, acceptance of support by others, aspects of proximity, or gender roles.

III. Behavioral Variables

In order to cover all types of behavior, Cooper (2007) distinguished between five different kinds of behavioral variables: a) activities, b) attitudes, c) aptitudes, d) motivation, e) skills. The authors adopt the same distinction except for the description of aptitudes (see Table 1 below).

Activities refer to what the user does (frequency and volume). For personas in the context of evacuation these activities include:

- Primary reason for presence in the station (e.g. shopping, commuting, under passing the street level), which may depend on the time of day (e.g. opening hours of shops; peak hours for commuters).
- Target: targets could be "local goals", e.g. a specific shop, exit, or platform. Targets may, on a more global level, refer to the ICE-Phases (cf. e.g. Gwynne and Kuligowski, 2010). For the subway station this would refer to: Ingress from street level, Circulation inside the station on distribution level with shops and/or platforms, and Egress from the subway station to the outside/ towards street level. This second differentiation is relevant because evacuation simulation usually assumes a maximum of users that is egressing. In reality, people do not egress immediately; some may continue to circulate to their local goal, as others might ingress the station (see e.g. Gwynne et al., 2016; Künzer, 2016; Pretorius, 2015).
- Additional activities added to Cooper´s (2007) concept by the authors are group affiliation (how much is a persona attached to other people), and (perceived) group coherence (in how far is a persona accepted as part of a group). Linked to the more general status of group membership as part of demographic variables, affiliation refers to the accompanying group/ family in the context of the product.

Attitudes refer to how the user thinks about a product domain and technology. For the product: Evacuation design in subway systems, attitudes are differentiated into the following aspects (each of them defined on separate dimensions – including the dimensions on the left or right, a persona can occupy only one (intermediate) characteristic on each continuum):

- Affective State: Feeling, Mood, Emotion, perceived safety in the station, fatigue
  - Perceived safety: not safe at all ⟷ very safe
  - Emotion: fearful ⟷ fearless
  - Perceived level of fitness: exhausted ⟷ well rested
  - Tiredness and fatigue: tired/ unconcentrated ⟷ awake/ concentrated

Aptitudes refer to the education and training of a user and the capability to learn. Because it is hard to determine the knowledge about evacuation in general (How am I supposed to act?) and the application of this knowledge (How will I act?) this differentiation is only partly relevant for the implementation. Due to methodological constraints, scientific insights in aptitudes of people during evacuation are missing. For the purpose of building personas for evacuations, capabilities of occupants are subsumed under Cooper´s (2007) skills-category, even though he lists capabilities originally under aptitudes. Furthermore, in the authors´ field studies there was a discrepancy between "participants´ statements on what they would do" and "the behavior they displayed during a \`pseudo´-evacuation during the field studies". The psychological distinction of capabilities (could act like this) and skills (applying the knowledge in order to act) are adopted instead.

Motivation refers to why the user is engaged in the product domain. For the product of evacuation different aspects are described on individual dimensions:

- Strategies and preferences: Strategies of wayfinding/ route choice/ obeying to orders, ...
- Application of different strategies for route choice: even if not done consciously, people apply certain strategies to find the safest route (e.g. Andresen et al., 2016); the route choice "no strategy" would be inappropriate and can be considered closest to the following "trial and error":
  - Trial and error: low ⟷ high
  - Shortest path: low ⟷ high
  - Quickest path: low ⟷ high
  - Avoid jamming: low ⟷ high
  - Following exit signs: low ⟷ high
  - Take next possible way up: low ⟷ high
  - Follow other persons: low ⟷ high

- Well-known paths: low ⟷ high
- Obeying to orders: low ⟷ high
- Obedience: disobedient ⟷ obedient

- Cooper (2007) distinguished three different types of goals to characterize a baseline of a persona: experience goals, end goals and life goals. In relation to the context of the product “Evacuation design in subway systems” the original aim of the goals have to be changed slightly. Persona should feel as comfortable (or as safe) as possible during an evacuation (experience goal). Personas should be aware of upcoming problems along their evacuation route (end goal) and succeed the evacuation process (life goal). These overarching goals are similar for each persona but strongly differ in the details. In the context of evacuations experience might play a crucial role and therefore the experience goals are the focus of this paper. A Persona may have an experience goal: e.g.: never did anything happen, thus I will not evacuate instantly and continue what I am doing presently (shopping, waiting for/ boarding a train). The defined continuum is:
  - Continue to do present activity ⟷ evacuate (reestablish safety, control)

Skills are a user´s capabilities related to the product domain and technology. The authors specified this aspect for this research as:

- Physical resources (is a person able to participate in evacuation: general fitness, health, physiological characteristics, special need/ disabilities):
  - Needs support (by others or technology) ⟷ evacuates by him/ herself
- Generalized knowledge (knowledge about and experience with evacuations; subway systems, …):
  - Low frequency of use of subway systems ⟷ high frequency of use of subway systems
  - Unexperienced with subway evacuation ⟷ very experienced with subway evacuation
- Local knowledge (specific knowledge on and experience with evacuation from subways, with the subway station (geometry, location of lifts), with safety in subways)
  - No local knowledge ⟷ complete local knowledge

STEP 2: Map Interview Subjects to Behavioral Variables

Based on the identified variables and insights about the user of evacuation routes, a mapping of demographic and interview data from previous research in line with the behavioral variables is conducted. One example for positioning individual people on a continuum for individual local knowledge (behavioral variable: skills) is shown in the figure below (cf. also Schäfer et al., 2014). Passengers with the same level of local knowledge may later be subsumed in the same persona.

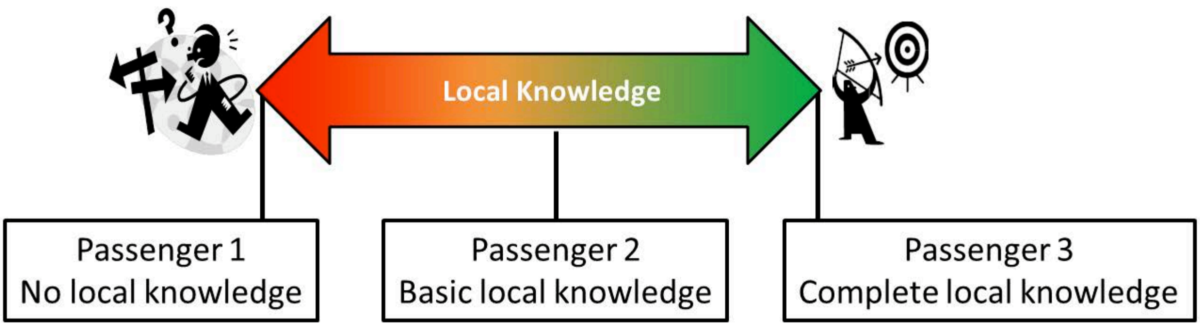

Figure 1. Classification of Passenger Types on a Continuum for Local Knowledge

STEP 3: Identify Significant Behavioral Patterns

In order to identify behavioral patterns, insights about the combination of different variables were necessary, e.g. evacuation strategies arise due to a walking disability of a respective person and therefore limit the scope of action for the person or the need for help in an evacuation due to the disability. For a useful pedestrian-level simulation model, identifying significant behavioral patterns should furthermore include aspects such as identifying which paths are usually taken or used by users when entering the infrastructure. Users may be familiar with these paths and may preferably use them in case of an evacuation. Apart from using interviews, data can be gathered by observation of users´ behavior within an infrastructure.

STEP 4: Synthesize Characteristics and Relevant Goals

Step 4 synthesizes characteristics and relevant goals of a persona. Attributes were combined to specify and detail the different personas from the data gathered. Sticking to the behavioral variables mentioned above, a certain persona is described through a combination of variables of Step 1 (see Table 1).

Table 1. Overview of demographic and behavioral variables and further attributes of three personas.

Variables/ Characteristics		Personas:		
		Peter Elderly, with walking stick	**Johanna** commuter	**Anna** School child, not yet young adult
Demographic Variables	Nationality	German	German	German
	Age	71	45	12
	Gender	male	female	female
	Group membership	individual	individual	individual
	Family status	married	solid relationship	single
	Profession	retiree	banker	student
Behavioral Variables – **Activities**	Primary reason for presence in the station	commuting between home and shops	commuting between work and home	commuting between school and home
	Group affiliation	low	low	low
Attitudes	Affective state	fearful	rested, in a hurry	fear and curiosity
Motivations	Strategies and preferences	well known path	shortest path; quickest path	follows other people; well known path, trial and error;
Skills	Physical resources	needs help (escalator, lift; due to walking stick)	evacuates herself without help	might need help

STEP 5 to STEP 7: Check for Completeness and Redundancy, Expand Description and Designate Persona Types

After the identification of relevant combinations of variables, the behavioral pattern and the conceptual design of the personas are checked for redundancy and completeness. Given that in the course of an evacuation, individual characteristics could change, e.g. a group could fall apart or be separated; the individual may now be regarded as a different persona with other attributes. By looking at the phases following the initial request to leave the station, further attributes and possible combinations of them were added creating additional personas.

Consequently, in step six according to Cooper (2007), an expanded description of attributes and behaviors was formulated. Per definition, the identified groups are thus clearly separated from each other as personas. In the seventh and final step the persona types are designated and now receive a name. Ideally, a sketch or even a picture of that persona is added to it´s characteristic variables. Three different examples for personas for the given subway station can be found in Table 1, containing an overview of demographic variables and behavioral variables and further attributes for each of the three personas. For limitations in the length of the table, only a selection of variables and attributes is presented here.

STEP 8: Implementation of Personas

The "translation" of personas into a machine-readable format is included in the work of Cooper (2007). Depending on the intended use in a computer software, the description of the personas has to be transformed for a direct use in an application. Different types of formats exist with deviating semantic richness. An ontology contains a very high semantic richness and is able to cover many aspects of a persona (cf. Ontology of Personas in the References). At the same time the choice of the semantic richness depends on the software application as it might not be able to handle the semantic richness of the personas originally defined. The following figure (from McGee and Greer, 2009) demonstrates the various possibilities.

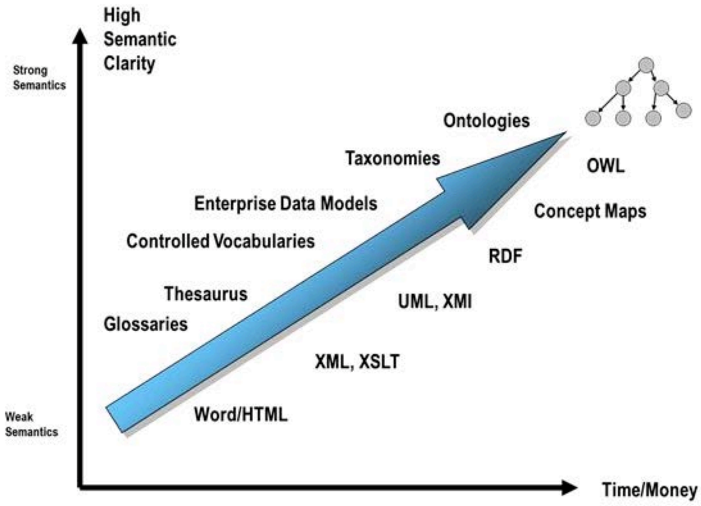

Figure 2. Overview of Machine-Readable Formats with Rising Semantic Richness

Regardless of the timely efforts, an ontology described in a web ontology language (OWL) would be a desirable form for describing semantically rich personas in a machine-readable format. The work of Negru (cf. References for URL) shows one realization of the Persona domain in an ontology. By this he follows the definition of Goodwin (Goodwin, 2005) to clarify his understanding of personas: A persona is regarded as a user archetype which can be used to "help guide decisions about product features, navigation, interactions, and even visual design". Even if the purpose of the ontology differs from the purpose of the authors of this paper, it helps to find solutions for the translation process from narrative to formal descriptions, to finally use the persona in pedestrian (evacuation) simulations.

For demonstration purposes, selected personas with limited behavior patterns were used in the case study described in the next paragraph.

CASE STUDY

The implementation of the persona method into a pedestrian simulation will be demonstrated based on a rather simplified evacuation analysis conducted for a subway station. For this purpose, the JuPedSim framework is applied. In order to focus on selected research topics, the intention of the latter is to provide scientists with an open-source software environment, which supplies the basic utilities for pedestrian simulation. The framework currently consists of JPSeditor (setup of geometries), JPScore (computation of trajectories), JPSvis (visualization), and JPSreport (post-processing). Further reading is provided in (Kemloh Wagoum, 2015).

Geometry and Scenario

The following simulation study refers to an existing subway station in Germany, which is the centerpiece of the current ORPHEUS research project (cf. references for homepage URL). The station consists of two platform levels and one overlying concourse level, which also comprises retail spaces (see Figure 3). It is noteworthy that all egress paths towards the surface traverse the concourse level. The latter is connected to the surface by five staircases (exits: A, C, D, E, G). The surface is predominantly covered by an intersection of two arterial roads including multiple bus stops and one tramway station.

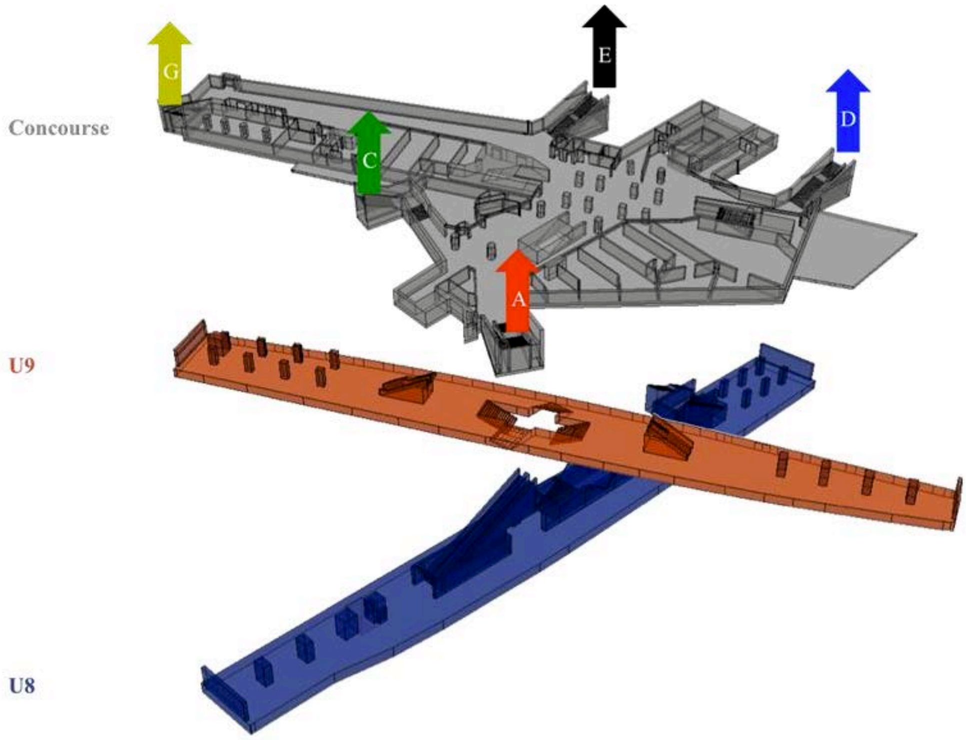

Figure 3. Subway Station Consisting of Two Platform Levels and One Concourse Level

The focus of this study is set to the population characteristics. Hence, additional considerations regarding the occupant scenario have a simplified extend. It is assumed that an evacuation alarm is triggered via the public address system (loudspeaker announcement). With regards to protective active decision model (Kuligowski, 2016), no further evacuation cues e.g. staff intervention, behavior of others, or traces of fire, gas or explosives are considered.

Population Generation and Implementation of Personas

Pedestrian simulations are commonly set up with representative populations, whose major characteristics (walking speeds, body sizes etc.) are described by distributions. In order to put emphasis on both heterogeneity and the dynamical composition of populations, the major objective of this study is to describe the latter by a bottom-up approach. For this purpose, the above-mentioned formulation of personas has been condensed to a set of three personas (see Table 1) including parameters, which can be yet implemented into pedestrian simulations (see Table 2). Please note that these specifications represent a very simplified excerpt out of the analyzed field data [e.g.: 12, 13]. As the pedestrian simulation considers male and female in equal proportions of the population, and because gender did not matter significantly for the findings from previous field studies, a persona with identical characteristics is assumed for both male and female regardless of the gender specification in Table 2.

Table 2. Preparation of Personas for Pedestrian Simulation for the Specific Subway Station

Commuting persona Variables/ characteristics	Anna	Johanna	Peter
Age-group, gender	Youth, female	Adult, female	Elderly, male
Walking speeds μ / σ [m/s] Plain/ upwards stairs	1.6 / 0.3 0.86 / 0.26	1.48 / 0.3 0.80 / 0.26	1.07 / 0.2 0.58 / 0.25
Shoulder width [m]	0.3	0.42	0.38
Pre-movement times [range in s]	[90, 180]	[0, 180]	[180, 240]
Preferred exits of subway station	A, C, E	Shortest path A, C, E	Shortest path

Having available these personas, the information is then transferred to machine-readable format, which is XML in this study. The subsequent step is to generate populations out of the latter. In principle, this process has been split up into three steps: (1) composition, (2) relative passenger load, and (3) population size.

Initially, the population composition has been defined by constraints regarding the fractions of the personas throughout the daytimes. Unfortunately, there is only few data available about population composition ratios and the latter heavily depends on the location, demographics or adjacent infrastructures (see e.g. Spearpoint and MacLennan, 2012). In order to account for these uncertainties, upper and lower temporal constraints have been defined as exemplary shown in Table 3. These assumptions were based on the qualitative findings regarding the general passenger mix in public transportation provided in (Weidmann, 1994).

Table 3. Excerpt of Percentage Constraints for Population Composition throughout the Day

Daytime / Age	Youth		Adult		Elderly	
04:30 am	0	10	90	100	0	0
08:00 am	10	30	60	80	1	10
10:00 am	1	10	1	20	60	90
...						
05:00 pm	20	30	60	80	1	10
11:30 pm	0	10	80	100	0	10

The above-mentioned constraints have been used for the generation of so-called candidate designs in the following step. In this respect, a candidate design is generated with a randomized Dirichlet routine. The latter yields three random numbers, whose sum equals one and every number describes the percentage of a particular persona. Initially, 5,000 candidate designs are generated, while each of the latter represents a unique course of population compositions throughout the day. In the next step, it is checked if the candidates comply with the above-defined constraints. The routine is completed if 50 candidate designs are found, which are compliant for the entire daytime. The achieved variability in terms of population composition is illustrated in Figure 4.

The variable compositions introduced above have to be conjunct with a certain assumption about the overall passenger load in the next step. The latter could potentially be prescribed by a fixed population size whereas only the composition is varied. However, in the special application of a subway station, we know that there are certain relationships between population size and composition. In this respect, a literature review revealed some basic findings about the average course of the passenger load throughout a day. Regarding the latter, Weidmann (Weidmann, 1994) observed a double peak structure when summarizing multiple German studies. He furthermore concluded that approximately 12% of the daily passenger load occurs during the peak hour in the morning. For demonstration purposes, the daily course of the relative passenger load applicable for Hamburg has been utilized as shown in Figure 4.

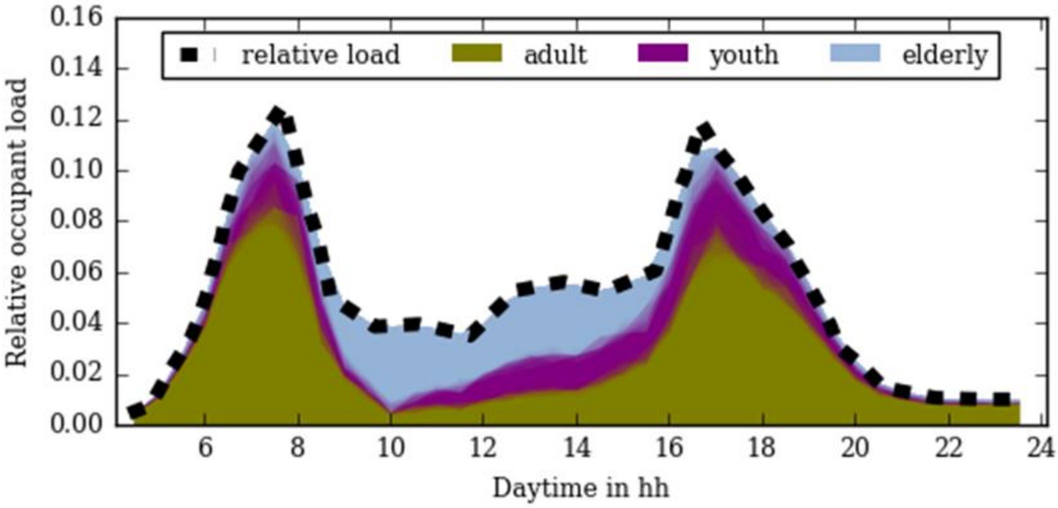

Figure 4. Daily Course of Relative Passenger Load Constituted by Variable Populations

Since the passenger load is resolved in half hour steps, the 50 candidate designs consist of 50 x 40 = 2,000 different constellations, which cannot be entirely incorporated into the simulation. Thus, a k-means clustering has been applied to the candidate designs in order to derive 100 population clusters. The identification of these clusters has been optimized with special emphasis on variability and passenger load. The general purpose of these clusters is to aggregate similar candidate designs (e.g. early morning and late night) and focus the computation on highly variable sub-domains (e.g. the peaks).

In order to specify the total population size, the proposed workflow has been conjunct with the current traffic data applicable for the investigated station. In this respect, approximately 90,000 passengers use both subway lines serving the station (City of Berlin, 2014). In order to account for both the assumed daily course and increasing passenger numbers, the total passenger number has been increased by a surcharge of 20% yielding 108,000 passengers per day. The latter number represents the integral surface below the curve describing the daily percentage load. In turn, the peak hour yields approximately 13,000 passengers. Regarding one particular event within this period, three served tracks and twelve arrivals per hour result in 375 passengers per train. Moreover, additional 30% have been assumed on the platforms. This assumption is based on a technical guideline applicable in Germany (TRStrab BS, 2016) and is in good accordance with the findings of field studies conducted in the station (Hofinger et al., 2016). It is noteworthy that these numbers represent the maximum load. In case of population clusters representing less frequented daytimes, the latter are reduced accordingly.

With regards to the final design of experiment, the introduced population clusters serve as the single system parameter in this study. Additional parameters (e.g. detection time, alarm time) may be incorporated for a more comprehensive analysis. However, in this case, we will introduce no further variations. The generated population clusters yield 100 occupant scenarios, whereas each of them is computed with 15 realizations.

Results

Without doubt, there are many other relevant observables when analyzing pedestrian dynamics. However, in the frame of this study, the impact of heterogeneity and temporal dynamics will be investigated based upon the required safe evacuation time (RSET). For each scenario, the latter is calculated as the 95th percentile out of all realizations. In this respect, Figure 5 provides the correlation between the occupant numbers, which are induced by the particular population clusters and the resulting evacuation times.

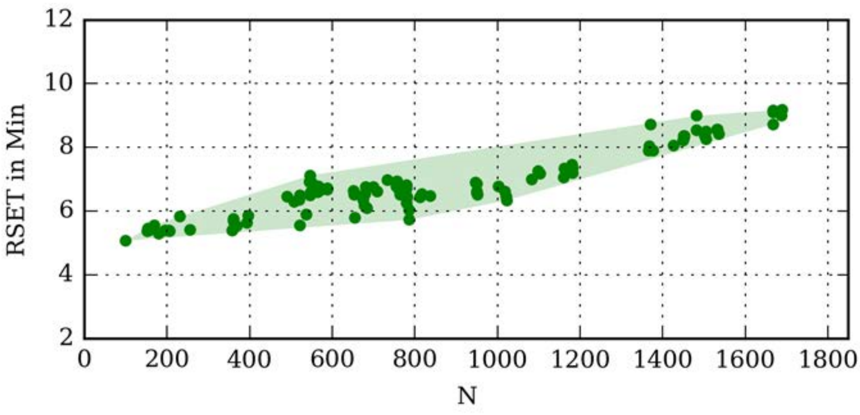

Figure 5. Relationship between Occupant Number and Required Safe Evacuation Time

As expected, increasing occupant numbers yield higher evacuation times. However, the results show remarkable fluctuations; especially in the range from approximately 500 to 800 occupants. This range represents the passenger loads that occur in the off-peak hours, which are rather variable in terms of population composition. Interestingly, these fluctuations yield a certain plateau of RSET, which potentially can result in similar evacuation times despite variable occupant numbers in a range from 500 to 1,100 occupants. Moreover, occupant numbers greater that 1,000 appear to yield less scattered results. On the one hand, this finding may correspond to the fewer sampling points. On the other hand, it is also related to jamming, whose occurrence then establishes as the system's main determinant.

Persona method may be generally applied to simulations for evacuation. These situations are likely to cause stress (e.g. due to a perceived danger) in users of an infrastructure which has an impact on the individually perceived options to act and in consequence on human behavior. Applying Persona method has the potential to fully account for this behavioral and emotional characteristics and motivation of people in evacuation scenarios, thereby creating more human-like agents for pedestrian simulation. Persona method at the same time can be applied to different kinds of scenarios: Specific evacuation scenarios that are likely to occur are evacuations initiated by a (false) alarm. In these situations the users of an infrastructure may not perceive an immediate threat to their lives or personal well-being. If fire and smoke are the cause for an evacuation, the kind and density of smoke may influence the reaction time as well as the walking speed.

CONCLUSION

Human factors offer a wide range of psychological models to describe human beings in interaction within different settings and scenarios. Compared to this variety, pedestrian models do not yet include the same range of individual parameters, neither on a tactical nor operational or strategic level.

In order to integrate more human-like agents for pedestrian simulation and to sample representative populations, the Persona method could serve as a striving force to focus on further individual human factors aspects. Successfully integrating the relevant characteristics and subgroups of users of an infrastructure as personas allows assessing realistic behavior, e.g. of passengers displayed during evacuation or when given information by an organization or agency. Decision makers can use this approach to prepare for crisis or disaster management.

In this paper Personas were selected to represent subgroups of the populations inside a German subway station. Not only the variation in the proportions of these subgroups was taken into account for pedestrian simulation but also their respective psychological and physiological characteristics were combined to form different personas.

The results of the case study gave proof that it makes a difference to include personas into evacuation simulations, as displayed by means of the required safe evacuation time (RSET). Regardless of this effect, further research is necessary. Additional personas could be defined and implemented, representing subgroups of the overall (subway-user) population, e.g. subway staff with guidance authority.

Applying Persona method to evacuation simulation revealed both benefits and shortcomings. For the presented product: Evacuation design in subway systems, the Persona method offered a useful approach for selecting individual human aspects for modelling pedestrians and to improve objectivity in the specification of different user types. However, the implementation of personas for this novel context of pedestrian simulation was limited and required the definition of an additional step 8 to the Persona method proposed by Cooper (2007). This step 8 was added by the authors and specification of categories of the Persona method was necessary. The Persona method may impose further restrictions for use in domains other than software designs. It may be vague with respect to the identification of relevant "target-user" parameters (e.g.: Does it matter if the user wears a striped jacket?). Overall, applying Persona method still appears a promising approach potentially improving occupant scenarios and the sampling of representative population for pedestrian simulation.

RSET was the initial performance measure of the case study, in order to highlight the effects of integrating additional human characteristics (here by implementing Persona method). However additional processes during an evacuation are equally important, e.g. acts of helping behavior or seeking information, which could point to necessary changes in the design of the infrastructure, in return fostering safe, smooth and quick evacuation. In order to investigate effects of different evacuation scenarios (e.g. evacuation initiated by fire or explosions) and of different types of infrastructures (below or above ground), psychological human factors aspects defined for personas (e.g. cognition, emotions, motivation in the variables presented above) need to be included into pedestrian simulations in more detail. When transferring personas into a machine-readable format, an ontology using a web ontology language (OWL) would potentially capture the full semantic richness of the personas. This richness could then be used for implementing more exhaustive personas into pedestrian simulations. At the same time pedestrian simulation, e.g. the framework of JuPedSim used by the authors, should be extended to integrate additional personas´ characteristics apart from mainly physical variables. Whether or not, it is worth the effort of including personas (e.g. for a sub-population) or an additional variable of a persona (e.g. route choice strategies other than shortest path) in evacuation simulation depends on the objective of using a pedestrian simulation. One objective in the case study described is to prepare organizations for guiding users of an infrastructure along escape routes smoothly. Depending on the initial scenario for disaster management, further psychological mechanisms might have to be taken into account while others may turn out irrelevant for creating and implementing novel personas for simulation purposes.

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REFERENCES

Andresen, E., Zinke, R., Hofinger, G., Chraibi, M. and Seyfried, A. (2016) The Impact of Perception and Wayfinding on Pedestrian Movements, *The 8th International Conference on Pedestrian and Evacuation Dynamics 2016,* Hefei, China, 290-298.

City of Berlin (2014) Berliner Verkehr in Zahlen 2013 [Berlin Traffic in Numbers]. Report, Senatsverwaltung für Stadtentwicklung und Umwelt.

Cooper, A., Reimann, R. and Cronin, D. (2007) *About Face 3: The Essentials of Interaction Design*. Indianapolis, IN, Wiley Publishing Inc.

Goodwin (2005) in: https://articles.uie.com/perfecting_personas/.

Gwynne, S. M. V., Hulse, L. M. and M. J. Kinsey (2016) Guidance for the model developer on representing human behavior in egress models, *Fire Technology 52, 3*, 775-800.

Gwynne, S. M. V. and Kuligowski, E. D. (2010) Application Modes of Egress Simulation. In Klingsch, W. W. F., Rogsch, C., Schadschneider, A. and Schreckenberg, M. (Eds.), *Pedestrian and Evacuation Dynamics 2008,* Springer, Berlin Heidelberg, 397-410.

Hofinger, G., Zinke, R., Künzer, L., Schröder, B. and Andresen, E. (2016) Human Factors in Pedestrian Simulation: Field Studies in Underground Stations, *The 8th International Conference on Pedestrian and Evacuation Dynamics 2016*, Hefei, China, 41-48.

Kemloh Wagoum, A. U., Chraibi, M., Zhang, J. and Lämmel, G. (2015) JuPedSim: An Open Framework for Simulating and Analyzing the Dynamics of Pedestrians, *3rd Conference of Transportation Research Group of India*.

Kuligowski, E. D. (2016) Human Behavior in Fire. In Hurley, M., editor, SFPE Handbook of Fire Protection Engineering, book section 58. Society of Fire Protection Engineers, 5th edition.

Künzer, L. (2016) Myths of Evacuations, *FeuerTRUTZ International*, 1, 8-11.

McGee, S. and Greer, D. (2009) A software requirements change source taxonomy, *Fourth International Conference on Software Engineering Advances 2009*, 51-58, IEEE.

Negru, S. (2014) Personas Ontology in OWL API version 3.4.2: http://owlapi.sourceforge.net http://blankdots.com/open/personasonto.owl.

Ontology of Personas at: http://vowl.visualdataweb.org/webvowl/index.html#personasonto.

Orpheus-research project (2016): http://www.orpheus-projekt.de.

Pretorius, M., Gwynne, S., and Galea, E. R. (2015) Large crowd modelling: an analysis of the Duisburg Love Parade disaster, *Fire and Materials*, 39, 4, 301–322.

Schäfer, C., Zinke, R., Künzer, L., Hofinger, G. and Koch, R. (2014) Applying persona method for describing users of escape routes, *The 7th International Conference on Pedestrian and Evacuation Dynamics 2014*, 636–641.

Spearpoint, M. and MacLennan, H. A. (2012) The effect of an ageing and less fit population on the ability of people to egress buildings, *Safety Science*, 50, 8, 1675–1684.

TRStrab BS (2014) Technische Regeln für Straßenbahnen – Brandschutz in unterirdischen Betriebsanlagen. Bundesministerium für Verkehr und digitale Infrastruktur.

Weidmann, U. (1994) Der Fahrgastwechsel im öffentlichen Personenverkehr [Passenger Throughput in Public Transportation]. PhD Thesis, ETH Zürich.