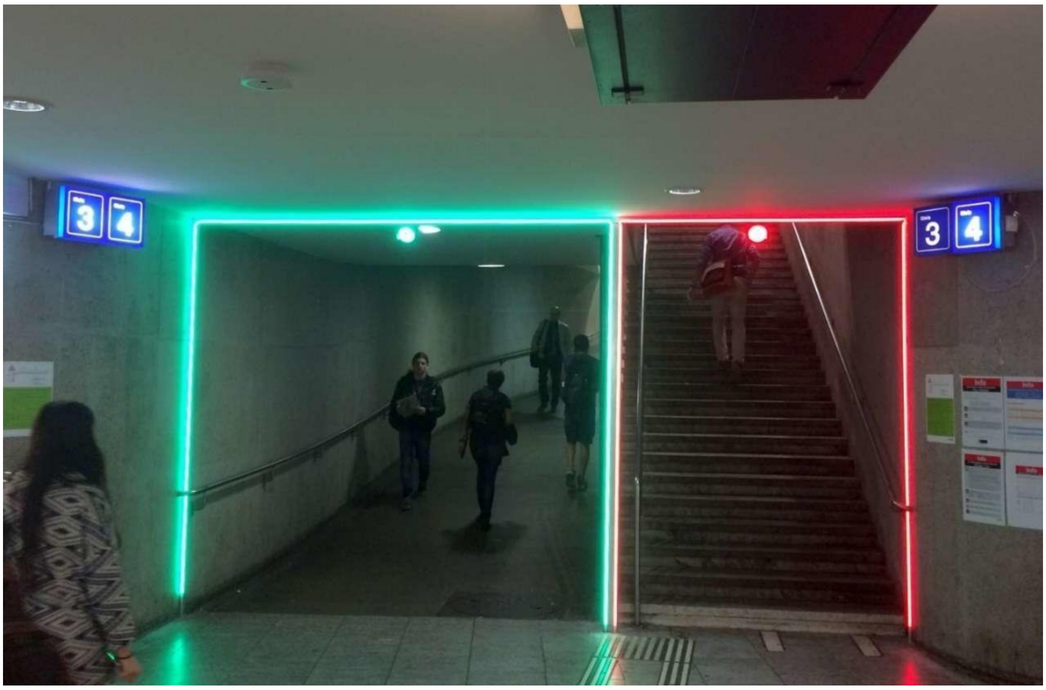

Pedestrian management strategies for improving flow dynamics in transportation hubs

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Abstract

Forecasts predict a strong increase of the demand of public transport facilities in the next decades, close to doubling the number of users in the "Arc lémanique" area. This increase in demand can lead to congestion and poor level-of-service inside transportation hubs. The aim of this paper is to develop control strategies which aim at guiding pedestrians in hubs and improving the flow dynamics. The objective is to guarantee adequate level-of-service throughout the infrastructure. This is achieved by influencing the locations pedestrians dwell while waiting or the activities they perform before or after using a public transport mode. Not only are "hard" strategies developed (barriers for example) but "soft" strategies like information or advertisement are also used. These measures are coupled with a dynamic assignment and demand model to simulate the effect on pedestrian flows. To quantify the impact of such management strategies, a simulation framework is developed and the results are compared to real-life data collected in the train station of Lausanne. Through this framework, pedestrian control measures can be tested and validated before being implemented in practice, and the impact of such decisions can be maximized, furthermore the performance of the facility is improved.

Keywords

Pedestrian dynamics, management strategies, transportation hub

1 Introduction

Multiple indicators point towards a significant increase of the pedestrian demand in transportation hubs for the next decade. This evolution has multiple sources. Not only is the number of passengers using public transport increasing, but technological improvements allow the public transport operators to increase the frequency of the services as well. Furthermore, the diversification of the hubs themselves, restaurants and shops are now common, creates a secondary source of pedestrian demand. On the contrary to the demand the infrastructures (providing the supply) only rarely evolve. To significantly increase the capacity of transportation hubs and satisfy the new pressure, major construction work needs to be accomplished and this takes decades to complete. The combination of the aformentioned considerations will lead to saturated infrastructures providing users with low experiences and possibly dangerous situations.
To prevent such problematic situations from occurring, proactive measures should be taken. Nevertheless, some events impossible to plan ahead for, or which take place extremely rarely, cannot be addressed, this even with careful design. To solve this issue, simulation tools are commonly used to evaluate planning strategies in order to determine whether they are efficient. Within the context of transportation hubs, in particular train stations, only few frameworks are available for simulating management strategies for pedestrians (outside of emergency evacuation which is vastly covered). On the other hand, the last 20 years has seen the publication of many models describing the movements of pedestrians, and this at multiple levels. The range between microscopic (or agent-based) simulators up to macroscopic (flow-based) models has been extensively covered. In a similar way, multiple studies have proposed methodologies for characterizing the activity scheduling of pedestrians.
As already mentioned, to our knowledge frameworks which combine pedestrian movement models with activity scheduling used for simulating planning policies are scarce. Therefore, we propose such a framework by combining recent models from the field of pedestrian behaviour modelling and we integrate a novel controller which manages multiple management strategies tailored specifically for pedestrians. In this paper, we focus on the development of the framework required for integrating all the components. The second element which is investigated concerns the possible management strategies which can be applied in train stations. As proposed by Berlonghi (1995), we follow the naming scheme were "management" strategies are proactive whilst "control" policies are reactive. Although our aim is primarily at the conception of proactive strategies, the classification is not always rigorous as no clear cut can be made in some cases.

This article is structured as follows: the next chapter contains a review of pedestrian behaviour models and management strategies. Chapter 3 then contains a description of the framework which will be developed, including a brief description of the various management strategies which are considered. Then, chapter 4 presents an overview of the case study which will be used to evaluate the suitability of the framework. Finally, chapter 5 concludes the paper.

2 Literature review

Three important aspects need to be integrated together in order to develop a framework which is capable of simulating the impact of management strategies in train stations. This section contains a literature review of these main topics.
Firstly, the management strategies (actions) themselves need to be examined, secondly the movements of pedestrians must be clearly defined both from the tactical level (activity scheduling) and the operational level (pedestrian movement/assignment models) and finally, an overview of existing integrative frameworks is done.

Management strategies There are many different management and control strategies which can be applied, some of them being context specific. Some affect the movement of pedestrians directly while others impact the choices pedestrian must make. During special events (concerts, sports events) organisers have used information in many different ways to manage crowds. Informing visitors about points of interest via social media (Zomer, 2014) or physical signposts guiding pedestrians towards specific locations (Abbott and Geddie, 2000) are some examples of measures which can be taken.
Within transportation hubs, management strategies tend to focus on controlling the pedestrian's movements rather than acting on their desired routes or activities. Some actions for controlling the pedestrian's movements are for example the usage of gates (Bauer *et al.*, 2007), avoiding contact between counterflows (Campanella *et al.*, 2015), improved intersection design (Helbing *et al.*, 2005) or even forcing people to use moving walkways. Nevertheless, information has also recently been used: one example is by providing information concerning the train's stopping position (van Roij-Lubsen, 2016) which can significantly improve the boarding and alighting processes (van den Heuvel, 2016).

Pedestrian activity scheduling & movement models There has been many developments in recent years concerning pedestrian movements models and activity scheduling for pedestrians. The spectrum of models for simulating pedestrian movement is wide and the choice of a model depends on the application.
Three categories are commonly used for describing pedestrian movement models: microscopic, macroscopic and mesoscopic. The first group models pedestrians explicitly (often called agents). Pedestrians then interact with each other and the environment and "walk" towards their goal by avoiding obstacles. Some examples of this group of models is the social force model (Helbing and Molnár, 1995), the next step model (Antonini *et al.*, 2006) or the cellular automaton (CA) model (Blue and Adler, 2001). At the other end of the scale we find macroscopic models, where

the pedestrians are aggregated into flows. Two important modelling approaches are found. The first uses a system of PDEs to represent the flow of pedestrians (like in fluid dynamics) as in Hoogendoorn *et al.* (2014) or Algadhi and Mahmassani (1990). The second class of continuum models does not depend directly on a system of PDEs for describing the crowd motion but more on observations of the phenomenon taking place and are often call cell transmission models (CTM). As the name suggests, these models also rely on a discretization of space into cells (Hänseler *et al.,* 2014). Finally, mesoscopic models lie in between microscopic and macroscopic models and borrow concepts from both of them (Hoogendoorn and Bovy, 2000). For an in depth comparison of different models see Duives *et al.* (2013), and for macroscopic models specifically see Hänseler (2016).
Activity scheduling commonly encompasses the analysis of the full planning phase before performing some activity: what activity is going to be accomplished, in which location, what are the start and end times for the activity and finally with which mode and what route (Ettema *et al.,* 1993). Many studies have investigated activity scheduling at the urban level or the household location, see Danalet (2015) for a recent overview. Nevertheless, few studies have focused on activity scheduling inside -or around- pedestrian facilities. In Liu *et al.* (2014), nested logit structures are used to model the activity pattern of departing travelers in airports. As the authors focus on activity patterns, which does not include precise start and end times, such a framework would need extending towards activity scheduling. Some key elements impacting location choice in airports are emphasized in Kalakou and Moura (2014). Visibility is a critical element. Finally, in Hoogendoorn and Bovy (2004), the authors develop a model describing the route choice and activity scheduling of pedestrians inside a train station. A simple pedestrian kinematics model is used for predicting the future positions of pedestrians which is used in the framework for simulating the activity schedule.

Integrative frameworks A framework for controlling LOS in a pedestrian infrastructure is presented in Zhang *et al.* (2016). The walkable space is represented in two ways: firstly as a graph, and secondly each link of the graph is modelled using cells. The upper level is used for estimating an optimum density based on a desired LOS as objective. The cell transmission model is required for guaranteeing an even load on each link. The control variables used to enforce this uniform load is pedestrian velocity. The model imposes the same pedestrian density on each link which can be suboptimal when considering transportation hubs as the demand presents very high spatial and temporal fluctuations.
Similarly to the previous study, a macroscopic pedestrian movement model was used to assess and design the strategy for controlling the opening and closing times of access gates to metro stations (Bauer *et al.,* 2007). The scenarios were based on special events where the demand significantly exceeds the daily operation's demand.

The effectiveness of some crowd management actions was observed in a real-life situation in Campanella *et al.* (2015), where a Brazilian metro stop offered very poor LOS and possibly dangerous situations during the new-year celebrations. Some management strategies had been planned and used to prevent critical situations while some reactive actions were also used. Qualitative observations where done and compared to operations from the previous years. The authors emphasize the need for an integrative framework including pedestrian simulations for evaluating various crowd management strategies.

3 Methodology

In this section, we describe the key components along with some of the modelling decisions taken for each of them. The first part discusses the various management strategies which we are considering. The second part presents the framework itself while the third and last element presented in this section are the possibilities for measuring the level-of-service of the infrastructure, also known as key performance indicators (KPIs).

3.1 Management strategies

The management strategies can be categorized into two groups based on how a given strategy impacts the pedestrians. This distinction is motivated by the ability for a pedestrian to ignore or not a specific measure. This classification leads to "hard" measures to which individuals are obliged to comply, and "soft" measures where a person can choose to follow the measure or simply ignore it. Within each one of these major groups, several subcategories can be made.

3.1.1 Hard management strategies

Strategies which can be considered as "hard" imply that pedestrians must follow them. Here, we ignore cases where one individual could "break the rules", for example a person who would jump over a barrier. A non-exhaustive list containing the main strategies which will be tested is given below.

Access gates Possibilities to control pedestrian flows with gates already exists in some locations (Bauer *et al.,* 2007). Nevertheless, the control of the gates (when to open and for how long) has rarely been considered as a control variable to improve -or optimize-passenger dynamics inside transportation hubs.

Platform allocation The platform allocation of trains could be adapted to take pedestrian dynamics into account while satisfying the train operator constraints. The key objective of this measure is load distribution throughout the infrastructure.

Flow separation Physical objects can be used to avoid counter flows. Rows of structural columns or publicity boards are only two examples.

Moving walkways An innovative network of moving walkways can be used to move passengers around transportation hubs. Both the direction and velocity of such systems can be controlled. The feasibility of a network of moving walkways in an urban environment is investigated in Scarinci *et al.* (2017).

3.1.2 Soft management strategies

Unlike the previous possibilities of control actions, "soft" management strategies rely on the compliance of individuals towards some information or rule. The complexity added by introducing compliance is significant, therefore to make the framework operational, an initial assumption of full compliance is made. This means that pedestrians always follow the rules or information which is provided.

In-vehicle occupancy By efficiently informing passengers about the vehicle occupancy, they can move around the platform to spread out the load.

Trafic lights Lighting can be used to guide flows. Using a green or red light surrounding the doorways is one example (20 minuten, 2016).

Floor markings Dynamic floor markings can guide people and separate flows inside a hub. These can be arrows or lines for example.

Expected congestion Providing information about expected congestion inside the station and therefore increased travel times can make passengers change PT service, walk to a shop to buy something or move to a waiting area until the desired PT service arrives.

Attractors Attractors like ticket machines, vending machines or kiosks can make pedestrians divert from the shortest path to their destination. Therefore, by intelligently placing these elements in specific locations of the infrastructure the pedestrian dynamics can be influenced.

3.2 Simulation framework

The framework for simulating the application of management strategies requires many different components. In order to give a general overview, Figure 1 contains a graphical representation of the framework with the different elements. The following sections detail these elements. There are four main components: the input, the pedestrian simulator, the controller and the output. The input contains all the a priori information which is needed for running the simulations. The pedestrian simulator takes care of both the pedestrian movement model and the activity scheduling models. The interaction between these components, which can be seen as a demand-supply interaction is also handled here. The controller is the "brain" which decides how the management strategies should be applied. Finally, the output is the set of indicators providing information on the system and a quantification of the impact of the strategy which is evaluated.

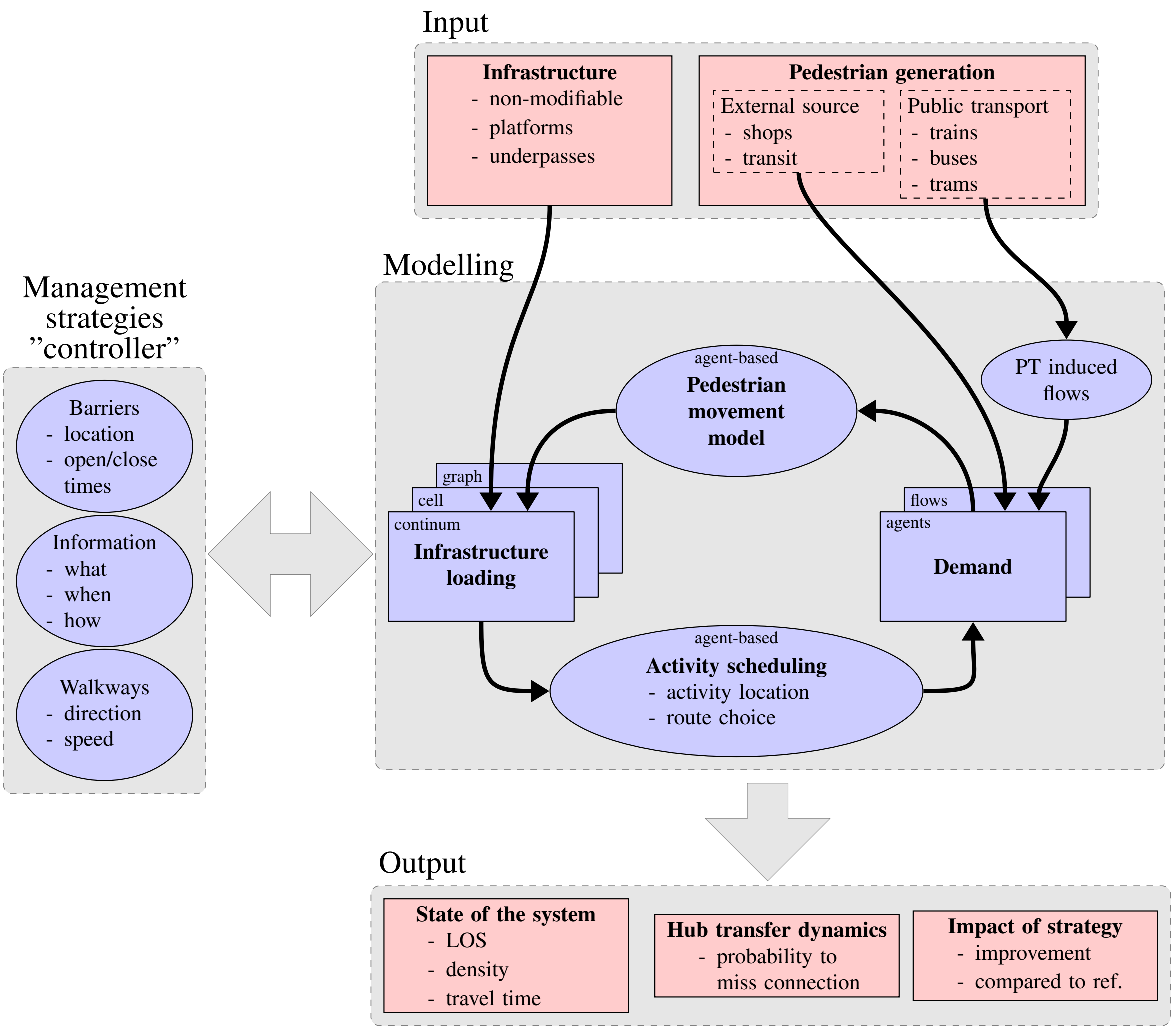

Figure 1: Schematic representation of the framework to simulate the impact of management strategies inside transportation hubs. Round shapes indicate models (pre-existing or to be developed) while the rectangular boxes indicate data or state variables.

Pedestrians have three levels of decisions to take (Hoogendoorn and Bovy, 2004). The top level is strategical, and defines the reasons for accomplishing a journey, in both time and space. The intermediate level defines the activity scheduling, it is the tactical level. Here, the sequence of activities to be performed during the trip and the route choice are chosen. Finally, the lower level is the operational decisions. The walking behaviour choices and local collision avoidance are taken.

3.2.1 A priori requirements - Input

The requirements for modelling and performing simulations of pedestrians flows can be split into two groups. Firstly, information concerning the infrastructure is needed for specifying the physical walking space which pedestrians can use, this aspect is input for the "infrastructure loading" state, see Figure 1. Secondly, knowledge about the pedestrian's desired trips is naturally needed for defining where and when individuals move, this later becomes "demand" onces the raw data has been processed.

Infrastructure Different modelling scales require different representations of space. For microscopic simulators the infrastructure is either discretized into cells or considered as continuous space. When macroscopic simulations are performed, the physical space is commonly represented as networks which contain aggregate information (for example length and width of corridors). These different representations naturally lead to varying details in the results produced by the simulators: more detail leads to higher precision but at a cost. The computational burden increase with disaggregate models is significant and can be prohibitive.

Since some key performance indicators (KPIs) are computed on an aggregated representation of the infrastructure while others use continuous representations of space, two different representations are used for the framework. Both a continuous space and graph-based representation will be used. This parallel formulation is also required as route choice and activity scheduling models can require graph-based formulations while disaggregate movement models require a continuous or cell-based space representation.

One key aspect of the infrastructure specification, for any representation, is the "fixed" topology. All components which are specified cannot be moved or controlled. Some elements which would not be defined here are gates, moving walkway speeds or the location of ticket machines for example. Although these elements are contained in the infrastructure, they should be able to be controlled by the management strategy controller.

Pedestrian demand When focusing on transportation hubs, people arrive into the simulation's scoop from two distinct possibilities. The first category is pedestrians arriving from public transport systems (trains, trams, buses or metros) and the second category is people arriving from outside the hub.

One critical aspect concerning arrivals from the PT network is the transition from a passenger riding a train to a pedestrian inside the hub. This is addressed in Hänseler *et al.* (2017) and Molyneaux *et al.* (2014) with the concept of "train induced flows", abbreviated TINF. Although the original framework was designed for trains, it can be extrapolated to all PT vehicle types.

Pedestrians entering into the scoop of the hub on foot can have various motivations. People either come to use some PT service, use some facility present (shops or restaurants) or can simply use the hub as a walking facility.

3.2.2 Pedestrian simulator

As emphasized in section 2, many models exist to simulate pedestrian walking behaviour and activity scheduling. Therefore we shall use pre-existing models for these two parts of the framework. This section describes the core components of the pedestrian simulator.

Moving pedestrians As the objective is to model the impact of various management strategies which affect both the movement of pedestrians and their activity scheduling, an agent-based movement model is used. Although the computational cost is higher and the calibration of the model requires reliable data, the capabilities of modelling interactions with ticket machines, kiosks or gates motivates the choice of a disaggregate model. The increased detail also favors such a disaggregate model.

Although recent extensions have been made to the original formulation of the social force model (Helbing and Molnár, 1995), we decided to use it as our first pedestrian movement model. Future work will include implementation of a more advanced model. The input to this model is individual pedestrians (agents) which their own socioeconomic characteristics and their origin/destination locations and times.

Activity scheduling Although activity scheduling can address different levels of decision making (strategical or tactical), most decisions the management strategies will impact are tactical. Some strategic decisions can also be influenced. For example, the arrival time at destination can change if a pedestrian chooses to use a different PT service.

A model similar to Hoogendoorn and Bovy (2004) is used for simulating the activity scheduling of pedestrians. Multiple different categories of activities are considered: buying a ticket, waiting, shopping or eating are only some of the numerous examples. The model formulation is utility based. The model maximizes each pedestrians utility (the opposite of a generalized cost) by choosing the order and timing which is the most provides the most utility.

Network loading & demand interaction Their exists strong interactions between two key elements presented in Figure 1: demand and infrastructure loading. The demand (i.e. pedestrians) puts pressure on the infrastructure (network) which must be able to satisfy this pressure and allow individuals to walk to their desired locations. Each pedestrian chooses a predefined route to follow. Nevertheless, this route can change depending on factors such as congestion or public transport track assignment for example. To close the loop, congestion depends on the pedestrians' route choices. In the static case, this setup leads to a fixed point problem to solve. For further detail on such interactions, we refer to Ben-Akiva *et al.* (2002) where a similar framework was used for vehicular traffic.
As we are interested in a dynamical system, no static equilibrium is searched. On the contrary, each pedestrian "continuously" evaluates the shortest to his destination and can dynamically decide to change route if congestion is expected. Considerations about the amount of information available to pedestrians will impact the decisions. Some possible choices include full information (pedestrians know the congestion levels in all the infrastructure), full information with history (knowledge on past congestion levels is also available) or only information on the field of vision of the pedestrian.

3.2.3 Management strategies

One of the contributions of this study is the development of management strategies as a controller, in a similar way to Febbraro *et al.* (2004) where controllers are developed for traffic flow management. Actions for controlling pedestrian movements will impact the pedestrians in different ways. By controlling which areas can be reached by pedestrians, with gates for example, pedestrians must update on short notices their route as their planned route might not be available for some time. Such updates will impact the pedestrian movement model (section 3.2.2), and by propagation will also change the activity scheduling decisions. Strategic placement of ticket machines will make passengers plan ahead their routes and the order in which the activities are performed can be influenced. In this case, the activity scheduling is updated (section 3.2.2) which will in turn affect the movement model.
In order to integrate the management strategies into the pedestrian simulator, a "feedback control" system must be designed. The objective is to conceive as simulator which can dynamically react to the level-of-service inside the hub.

3.2.4 Output

The results from the framework presented in Figure 1 are two-fold. On one hand there are classical results indicating the state of the system (density or level-of-service for example) and on the other hand there is an indicator representing the impact of the management strategy which is evaluated.

State of the system Classical indicators are used to evaluate the state of the system from a pedestrian's point-of-view. Many indicators exist in the literature and they can be extended to take the passenger's needs into account. The notion of passenger-centric indicators is introduced to emphasize the need for indicators which take the passenger's needs into account, and not the operator's ones.

Evaluation of the strategy Using the various KPI which are defined in section 3.3, the impact of a given management strategy is measured by comparing the KPI before and after adding management strategies.

3.3 KPI

In order to quantify the improvements management strategies can bring, adequate indicators of the pedestrian dynamics taking place inside a hub need to be defined. Here, pedestrian dynamics should be interpreted in large sens. Indicators such density, travel times deviation from free flow speed or transfer success are considered.

3.3.1 Passenger oriented

Many service indicators are designed from the operator's perspective, such as punctuality or commercial speed (Pticina, 2011). Nevertheless, the user's experience is critical when assessing the quality of service a hub provides. Therefore a list of passenger-centric indicators are used to measure the effects of the various management strategies which are tested.

Density One classical but still very important indicator is pedestrian density. Computation of pedestrian density is far from trivial as space needs to be discretized, and this discretization will impact the resulting density values. A recent approach is the usage of Voronoi diagrams Nikolić and Bierlaire (2014) which provides a time-varying solution but is computationally expensive. More traditional solutions require a fixed discretization into cells.
A simple proxy for density is accumulation, which is straightforward to compute. We keep track of the number of people inside a delimited area. Although this approach does not yield precise results, it is very easy and cheap to compute.

Travel time In congested areas, the walking speeds of pedestrians usually decreases, hence the travel time will naturally increase. These variations can be very costly for passengers who must catch connections if the planned walking time is short as they could miss their connections. For example, Figure 2 present the differences in travel times between two time intervals. During the first one low demand takes place (7:19 to 7:25) while during the second interval a significantly higher demand takes place (7:39 to 7:45). When considering the histograms of travel times, it is clear that the travel times increase for pedestrians making the trip during the interval when high demand occurs.

Walking speed Each person generally has a desired walking speed, which is dependent on socio-economic variables (Chattaraj *et al.,* 2009). One indicator of congestion is the discrepancy between the desired free flow speed and the actual walking speed of pedestrians.

3.3.2 Transfer dynamics

Important transportation hubs are used by passengers not only as access or egress points to the PT network, but also as a place to change services. During this transfer process, pedestrian do not perform the same activities. For example, some people will walk directly to the platform of their connecting train and other will buy a newspaper in between. The choice of activities also depends on the punctuality of the arriving train and the level of congestion inside the facility.
One way to measure the impact of a management strategy can be through the connection success. One intuitive definition is, for each connection pair, the percentage of passengers who managed to catch the connection. Ideally, such a measure should be close to 100%

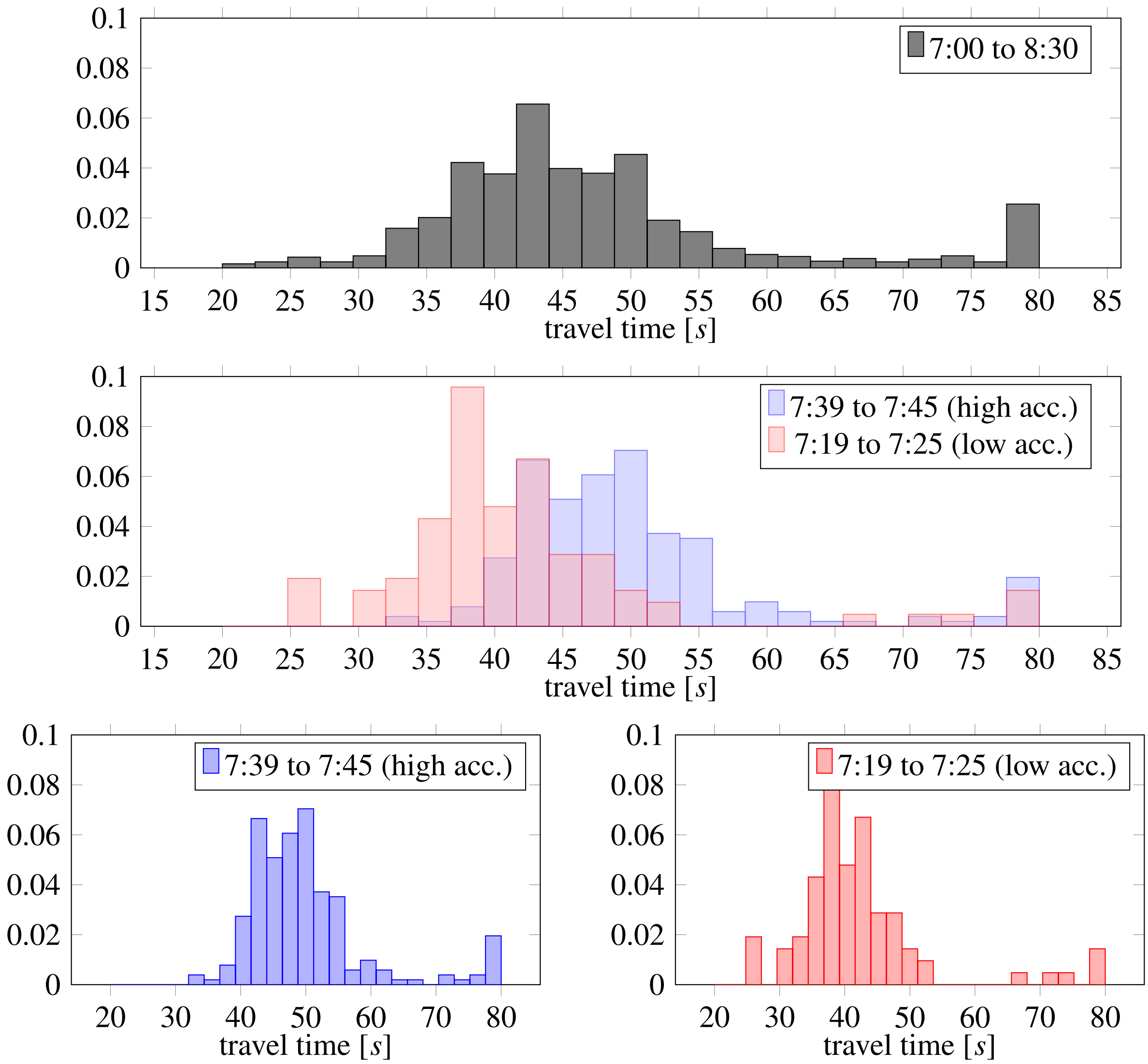

Figure 2: Travel times are affected by accumulation between the "Tekoe" ramp and platforms 3/4. This is possibly the most congested area of the station.

4 Case study

The train station of the city of Lausanne, Switzerland, is used as a case study. Lausanne station is the largest node in the railway network of Western Switzerland, serving 650 arriving and departing trains and close to 120,000 passengers on weekdays (Amacker, 2012). The pedestrian facilities of the station have reached capacity in the year 2010, and a doubling of passenger demand is expected by 2030. For this reason, Swiss Federal Railways (SBB) planned an expansion of the pedestrian facilities by 2020. The station was equipped with a tracking system to collect pedestrian movements in the two underpasses linking the entrances to the platforms.

4.1 Empirical data

The tracking data consists of detailed individual trajectories. For each individual, space-time coordinates are available for their trips performed in the pedestrian underpasses (PU). Furthermore, other data sources are available:

OD flow data Flows are available for the two pedestrian underpasses, in which a tracking system is installed. This sensor system allows to simultaneously track the trajectories of pedestrians across space and time. Origin and destination zones are identified in each underpass, and OD flows can be calculated.

Link flow data Ten links of the pedestrian walking network are equipped with sensors that provide directed link counts with a resolution of one minute. To account for sensor saturation, observations are post-processed using a quadratic correction function.

Traffic condition data Pedestrian trajectories obtained from the aforementioned tracking system allow the computation the prevailing speed, density and accumulation in pedestrian underpasses. Accumulation is defined as the number of pedestrians present in an area at a given point in time.

Train timetable and ridership data The actual arrival and departure times and the assigned track are known for each train. An average estimate of boarding and alighting volumes is available from ticket sales data, within-train surveys, and infrared-based counts at train doors. These estimates date back to the year 2010 and are increased by 15% to reach the estimated level of the year 2013. The boarding and alighting volumes are modeled as random normal variables with a standard deviation equal to 19.2% of their mean.

Other demand data For the sales points located in PU West, an estimate of the number of customer visits is available.

Infrastructure data Detailed building plans containing the dimensions of all relevant pedestrian facilities, and the exact location of all parts of the monitoring system are available.

Among the introduced data sources, the OD flow (trajectory) data provide the richest information. VisioSafe SA has deployed 64 sensors to capture the behavior of people. Sensor technology is based on infrared light captors that detect silhouettes and track pedestrian trajectories. Each sensor extracts the precise 3D locations of every pedestrian on the ground and tracks them across time. The topology of the installed network of sensors is illustrated in Figure 3. The sensing technology being used is privacy safe. No private information is extracted, such as images that would enable to identify people.

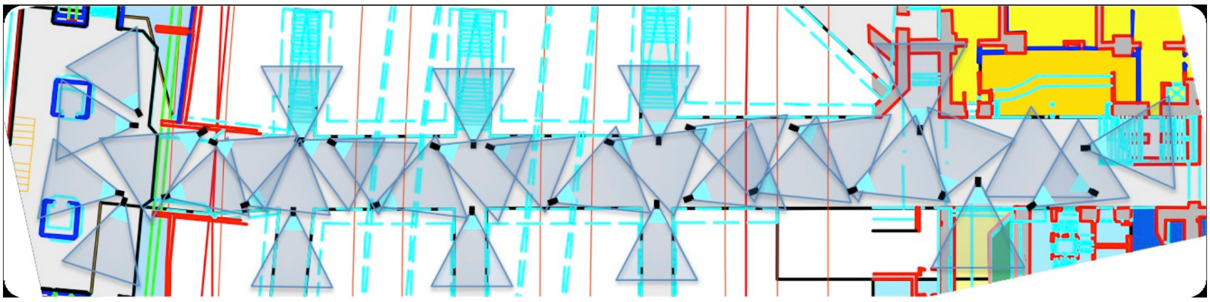

Figure 3: System of sensors installed in the western pedestrian underpass (PUW) of the actual Lausanne train station (Lavadinho, 2013).

4.2 Infrastructure

It is planned to use the available data and infrastructure of the current Lausanne train station to develop and calibrate the hub model. This case study is also used to test simple control strategies. At the end of this developing phase, it will be applied on a larger case study: the new Lausanne train station planned by 2020. This more complex case study offers the possibility to test and evaluate more sophisticated control strategies. In the following, we introduce the two case scenarios.

Current Lausanne train station Lausanne railway station is the largest train station in the French-speaking part of Switzerland. Figure 4 shows a schematic map of the station, encompassing nine rail tracks for passenger traffic (thin dashed lines). At its heart are two pedestrian underpasses (PUs), referred to as PU West and PU East (vertical corridors, indicated in the figure). Platforms are shown as dotted areas. Solid lines represent the walking network of the pedestrian facilities, and dashed curves represent corresponding network links that cannot be shown in the 2D scheme. OD areas are represented by labeled rectangles. Dark rectangles symbolize entrance/exit areas as well as service points within the train station. Rounded rectangles represent platform OD areas, i.e., platform sectors or entire platforms. Pedestrian count sensors are represented by diamonds. The shaded parts in the two pedestrian underpasses represent areas that are covered by a pedestrian tracking system.

Future Lausanne train station Lausanne station expansion is being carried out as part of the Leman 2030 rail expansion project, which is aimed at improving rail services in the cantons of Vaud and Geneva. The expansion is needed in order to meet the projected rise in passenger traffic.

The station expansion involves modifications to the pedestrian facilities, installing extra tracks and extending the existing platforms. In total, EUR 1.1 billion is spent between 2010 and 2020 to enlarge the station. Three new underpasses connecting the platforms and city are planned below the tracks (Figure 5). The width varies between 17 and 19 meters, and shopping facilities are planned. The train station is connected with the urban metro lines, which will be expanded too. In addition, a new exhibition area is planned, and the integration with the city is improved by a new square in front of the south entrance. The expanded Lausanne train station is an appropriate case study for testing traffic flow management strategies. The simulated results can be useful to the facility operator to plan specific control actions and evaluate the level of service and risk in the new station layout.

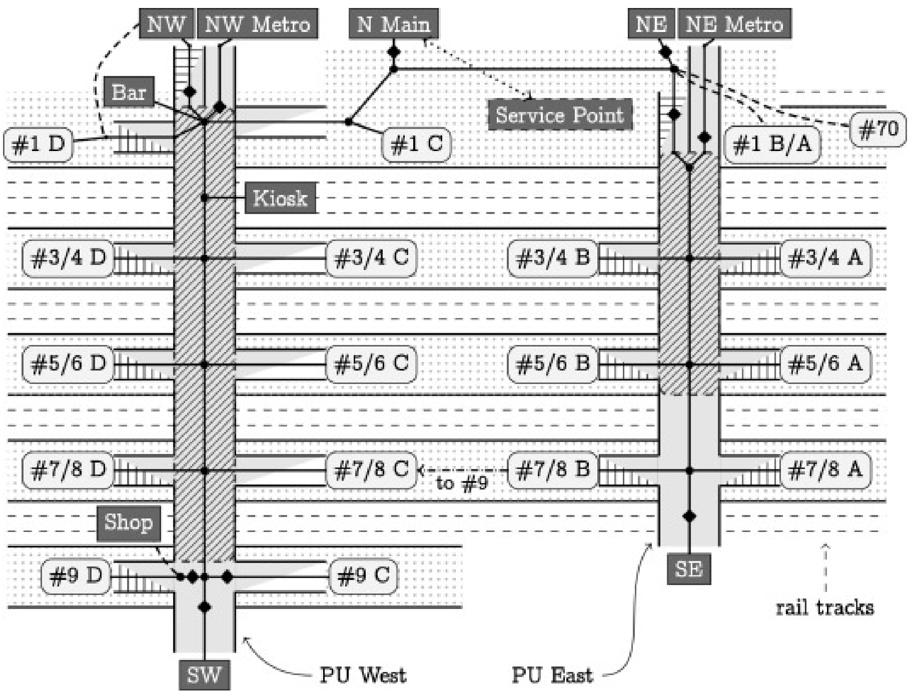

Figure 4: Schematic view of Lausanne pedestrian facilities, with underpasses, platforms and activity locations (Hänseler, 2016).

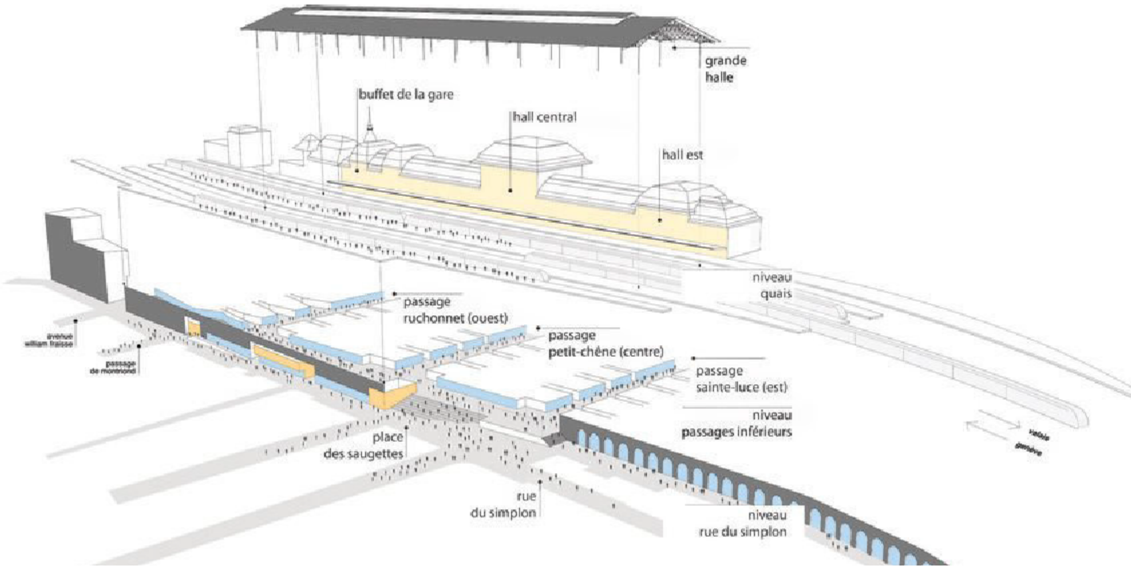

Figure 5: Expansion plan of Lausanne train station by 2020, with three underpasses and shopping facilities below ground (SBB, 2017).

5 Conclusions

In this article we present a new framework for simulating the impact which management strategies can have on the pedestrian dynamics in train stations. To achieve this, a description for integrating the three key components, namely pedestrian assignment models, activity scheduling and management strategies was given. Although this framework is still young, many application such as transportation hub optimization, special event management or large shopping malls can benefit from it.

The next steps require implementation of the various components and the calibration of the models. After the simulation framework is validated, detailed design of the management strategies will be performed. This covers both designing rules for controlling gates for example and more conceptual models specifying where attractors (ticket machines, kiosks, etc) can be located. The final step will be combining the management strategy framework with a mixed integer programming optimization framework.

Acknowledgments

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