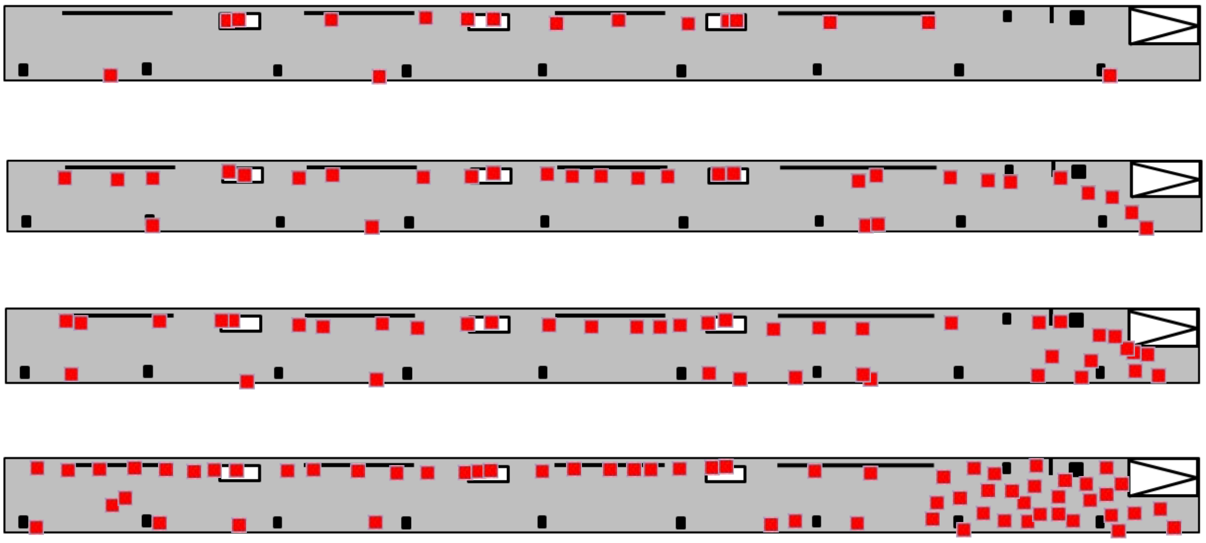

Distribution of passengers on railway platforms

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Abstract

Railway platforms are used simultaneously as walking and waiting areas. These two functions cannot easily be separated in space, as they can alternate with time. Up until now, the evaluation of the capacity of platforms was mainly done by considering the whole platform area without further considering the real distribution of waiting and walking areas. But in reality, the distribution of passengers along platforms is strongly uneven.

The aim of the work was to get a better understanding where passengers tend to wait on railway platforms and what are the main influences for this behaviour. Therefore, manual observations were performed at two railway platforms in the city of Zürich (Zürich Wiedikon and Zürich Stadelhofen). In order to determine the effects not related to the station layout but to specific trains, several observations were made for the same platform. These observations were done for different rail lines, but also for the same rail line at different times.

The observations showed that the waiting area distribution changes with an increase of passengers on the platform and with the time to the next train departure. At first, areas next to obstacles and walls were used for waiting. Typically these are the areas along ramps and stairs, walls and columns and other features where it is possible to lean against. Shortly before the train arrival, when the amount of passengers on the platform is higher, the areas next to the platform entrances are heavily used for waiting. As a result, the platform areas are classified according to their local pedestrian densities for a different overall amount of people on the platform. These results can be used as a first approach for the design of pedestrian facilities and the evaluation of pedestrian density on railway platforms.

Keywords

Railway platform – pedestrian distribution – waiting area

1. Introduction

Compared to other pedestrian facilities, railway platforms have different characteristics as they are used simultaneously as walking and waiting areas. These two functions cannot easily be separated in space, as they can alternate with time. For design purposes, this constant change in the space distribution has to be considered. In addition, pedestrians are not evenly distributed along the platform, but have preferred waiting and walking areas. Also, the safety aspect is important for these facilities as passengers should not enter the hazard zone next to the railway tracks. For the design of railway platforms it is therefore important to consider the preferred waiting locations. Otherwise people might tend to wait at locations reserved for walking and thus hinder passenger circulation. This work aims at describing the waiting location of pedestrians along the platform. This shall give a deeper understanding on the passenger flow at railway platforms and thus allow a more efficient and comfortable design. In addition, this information might help to avoid spots with high pedestrian densities on the platforms which lead to safety critical situations due to people avoiding the crowd and walking to close to passing trains.

To solve the conflicts between pedestrians waiting and walking, a complete segregation of these activities is done at some platforms. This can be achieved else by having distinct waiting and walking areas on the same platforms or on each side of the train, or by having gates preventing people to enter the platform before the arrival of a train. In this work only platform types are examined, where there is no physical or organisational division between waiting and walking areas, hence allowing pedestrians to move freely at the whole platform.

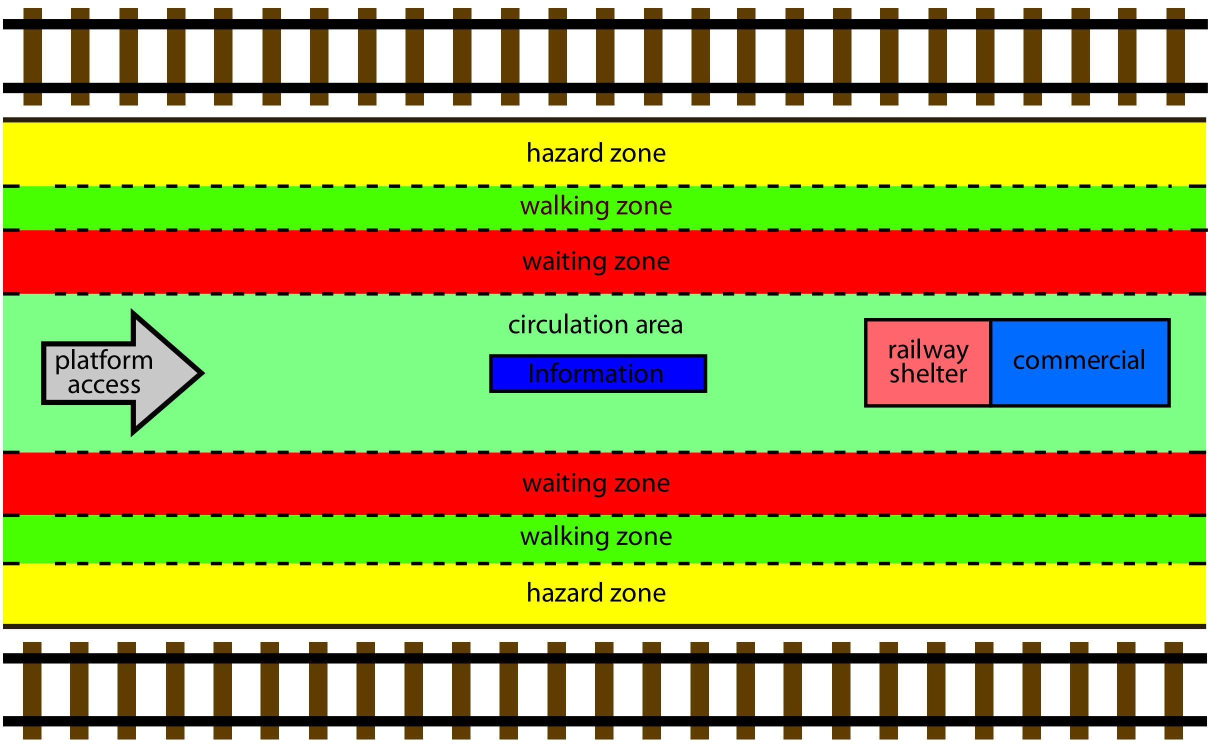
There exits only few literature about the design of railway platforms in terms of capacity and quality. Information about the methods used can be found in design guidelines used in different countries and in some research studies. Usually they use a general approach without considering the exact waiting behaviour in space and time. The following paragraphs will summarise the main points of the approaches used.

To determine the quality on platforms expressed in the level-of-service, the time-space concept proposed by Fruin and Benz (1984) for corners and crosswalks was adapted by Grigoriadou and Braaksma (1986). This method allows calculating the level of service for walking pedestrians based on the available space and amount of people waiting for a given period of time. This approach can be used for a preliminary design of the space needed, but is not capable to consider the layout of the platform.

The Transit Capacity and Quality of Service Manual (Kittelson & Associates et al., 1999) distinguishes four different areas on railway platform. In addition to the waiting and walking areas, queue storage areas were allocated to cover the areas used for queuing in front of stairs, elevators and escalators. Dead areas are located where no passenger flow occurs, for example at the end of the platform. For the calculations of the space needed on the platform, the space needed for each of the four areas is calculated. For the total area, a buffer zone next to the tracks is added. In the newest edition of the manual it is also recommended to include space taken up by obstructions such as columns and seats and to provide additional space for wheelchairs, luggage or bicycles if relevant (Kittelson & Associates et al., 2013).

For the Netherlands, an approach was made to divide the width of a platform in several zones (ProRail Spoorontwikkeling, 2005) (Figure 1). Next to the platform edge, a hazard zone is located, to prevent people from walking and standing to close to moving trains. Next to the safety zone, a walking zone is located. This zone includes the tactile paving as guidance for visually impaired people and should be free from obstacles. The waiting zone is situated subsequently to the walking zone. In the middle of the platform a circulation area is provided, which allows people to distribute themselves along the platform. In this area also other functions such as information screens, commercial activities and railway shelters can be located. The circulation area shall be at least 40% of the platform width according to this guideline (ProRail Spoorontwikkeling, 2005).

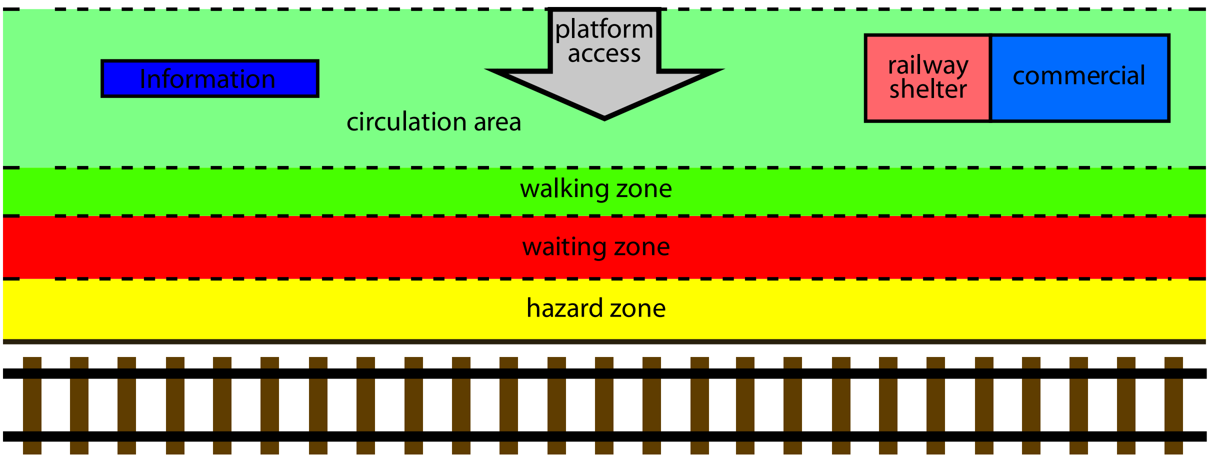
Figure 1 Functional division of a railway platform according to ProRail Spoorontwikkeling (2005)



Source: adapted from ProRail Spoorontwikkeling (2005)

Another concept for the design of railway platforms is published by Network Rail (2011). In this approach, the waiting and walking zone are inverted, thus it is assumed that people are waiting next to the yellow line signalising the hazard zone on the platform (Figure 2). The width of the zones is calculated individually based on the passenger demand for walking and waiting passengers. In addition, minimum values are given for distances between the platform edge and obstacles as well as each of the four zones. The calculation of the width for the waiting and walking zone are done for blocks corresponding to the length of a carriage. The guideline also acknowledges that the zones presented will not exactly be reflected in reality, but there will be sufficient space when the width of all four activity zones is considered in the design.

Figure 2 Functional division of a railway platform according to Network Rail (2011)



TransLink, the transit authority in Queensland, Australia, requires LOS C during peak periods as a minimum quality level (TransLink Transit Authority, 2012). In addition it is recommended to separate walking and waiting areas to ensure free circulation of pedestrians.

For railway platforms in Switzerland, regulations exist for the design of railway platforms (Bundesamt für Verkehr BAV, 2006). They mainly specify the width of the hazard zone in relation to the speed of passing trains and the minimum width of railway platforms. For the platform area it is required to design it according to the future passenger demand. In addition to the regulations, the Swiss Federal Office of Transport published a research report about the design of railway platforms (Bundesamt für Verkehr BAV, 2011). In this work, considerations about minimum dimensions are made based on the space needed for walking, crossing and overtaking other people. Based on the length of obstacles such as ramps and stairs, minimum widths are proposed to prevent people to enter the hazard zone. For obstacle-free areas on the platform a maximum pedestrian density of 0,45 P/m^2 corresponding to LOS C shall not be exceeded. This limit was determined based on the assumption that with increasing pedestrian density the probability of people entering the hazard zone is rising. Using the criteria describing the differences between different level-of-services found in Weidmann (1993), it was concluded that at LOS D the probability of people entering the hazard zone exceeds the acceptable level. In this work also the uneven distribution along the platform was addressed, which has to be included in the design of railway platforms (Bundesamt für Verkehr BAV, 2011). In contrast to the previous literature presented, here the design of railway platforms is not based on the pedestrian quality but on safety aspects.

The combination of safety and comfort aspects was examined in another study (Weidmann et al., 2013). In this work it is proposed to link the level-of-service to a certain time interval, as the accepted density is linked to the exposure time. Therefore the level-of-service for waiting areas was linked to different densities depending on the safety relevance of the facility. For facilities directly adjacent to public transport lines or car traffic, lower densities were proposed for the same level-of-service. As there is no physical barrier between the pedestrian facility and the nearby safety relevant activities pedestrians can walk freely into safety critical areas. For the design of mixed used facilities, such as railway platforms, the area is virtually divided into walking and waiting areas. For each of these areas the level-of-service is computed. For the division of the facility into waiting and walking areas it is recommended to place waiting areas at locations where waiting people are expected and to keep virtual walkways in direct connection between origin and destination of people walking.

Summarising the design principles found in literature it can be concluded that only limited information is available on the exact distribution of pedestrians on railway platforms. Up until now, the evaluation of the capacity of platforms was mainly done by considering the whole platform area without further considering the distribution of waiting and walking areas. Usually the platform area was divided virtually in waiting, walking and other areas and the space demand was calculated for each of these areas separately. Still, these approaches do not provide information about the exact location of waiting areas. Especially when designing highly used facilities with severe space constraints, the existing design principles are limited.

2. Method

It is assumed that the location, where pedestrian are waiting on a railway platform is influences by several parameters. These can be divided into parameters depending on the individual pedestrian and his route, the location of the platform accesses and the platform layout (Table 1). The focus of this work was to generally describe the distribution of pedestrians waiting on railway platforms and the influence generated by the facility. Hence influences based on the characteristic of the pedestrians were not considered separately.

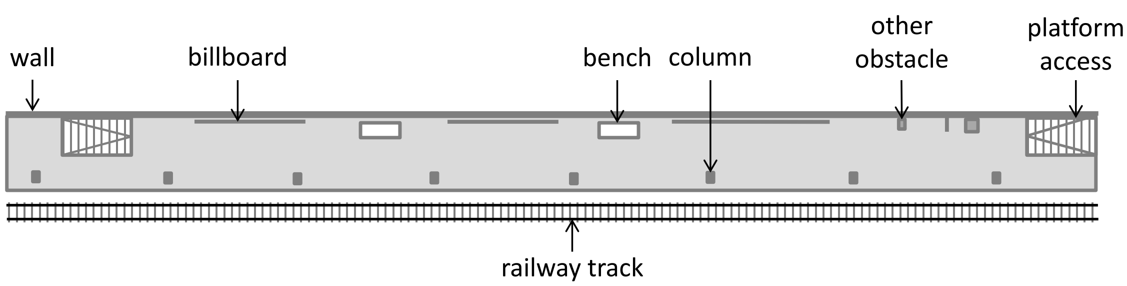
Table 1 Potential influences on the distribution of pedestrians waiting at platforms

Group	Influence	Expected behaviour
Pedestrians	time of pedestrian arrival relative to the train arrival	Pedestrians arriving longer before the arrival of a train tend to distribute themselves more along the platform.
	Trip purpose	Commuters arrive shortly before the train arrival and wait exactly at a location optimised for short walking distances at their destination and next to the doors of the train.
	Age	Children and elderly people chose their waiting position for other reasons than adults.
	Group size	Groups show different behaviour than single passengers.
	Total number of pedestrians	Pedestrians at the platform influence the waiting location of new accessing pedestrians
	Weather conditions	The weather conditions influence the distribution of passengers between covered and uncovered platform areas
Platform accesses and surrounding	Location of station building in relation to the platform	The location of the station building influences the main pedestrian flow accessing the platform
	Location and number of platform accesses	The platform accesses will strongly influence the distribution of passengers along the platform
Platform layout	Platform type	Side and centre platforms will show different waiting behaviour
	Platform dimensions	The platform dimension determine the total waiting area available
	Location and number of columns and other obstacles on platform	Columns and other obstacles are attractive waiting locations especially when it is convenient to lean against.

To describe the pedestrian distribution on the platform, manual observations were made at selected railway stations. As it is assumed that the distribution of waiting pedestrians will change with increasing overall pedestrian density, the observations were made each two minutes. These intervals were set in relation to the expected train arrival, so that the observations correspond to the time of the train arrival, two minutes prior to the train arrival and each two minutes earlier.

To characterize the layout of railway platforms a scheme was used including the most important features found on railway platforms (Figure 3). First, this scheme was used to describe and compare different station layouts. Afterwards it was used for data collection, as the location of pedestrians waiting are recorded using these schematic sketches.

Figure 3 Station layout scheme



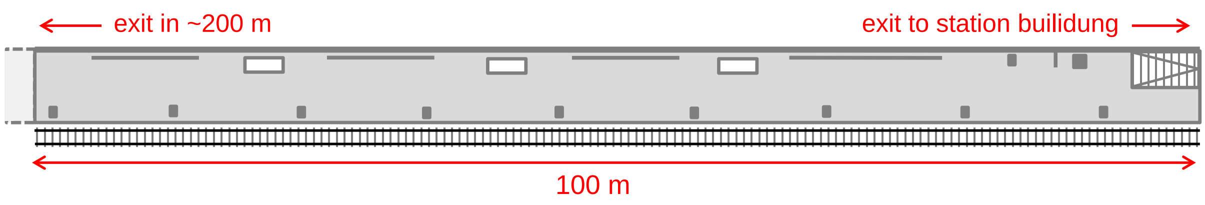
3. Case Study

For the case study two different railway stations were selected based on the relevant influence factors proposed. Zurich Wiedikon was chosen as a railway station with simple geometry with average passenger demand. Zurich Stadelhofen on the other hand represents a railway station with high passenger demand and several platform accesses. Both are railway stations only frequented by suburban trains.

3.1 Zürich Wiedikon

Zürich Wiedikon is a railway station in the city of Zurich consisting of three tracks and two platforms. On average, about 8000 passengers per workday are using this station (Regierungsrat des Kantons Zürich, 2013). The observations were done on platform 1, a side platform with a width of about 6 m (Figure 4). The area of the platform used for observation is covered and has one entrance leading to the station building. On the other end of the observation area the platform continues for about 200 m where another exit leads to the street level. Next to the tracks a line of columns is located on the platform. At the back of the platforms billboards and benches are aligned. Additionally there are only some small obstacles next to the exit.

Figure 4 Schematic layout of observation area on platform 1 in Zürich Wiedikon



The data collection in Zürich Wiedikon was done at the 4th and 11th April 2014 for two respectively one and a half hours in the evening. This allows comparing data from same trains at different days for the same time and at different times on the same day.

3.2 Zürich Stadelhofen

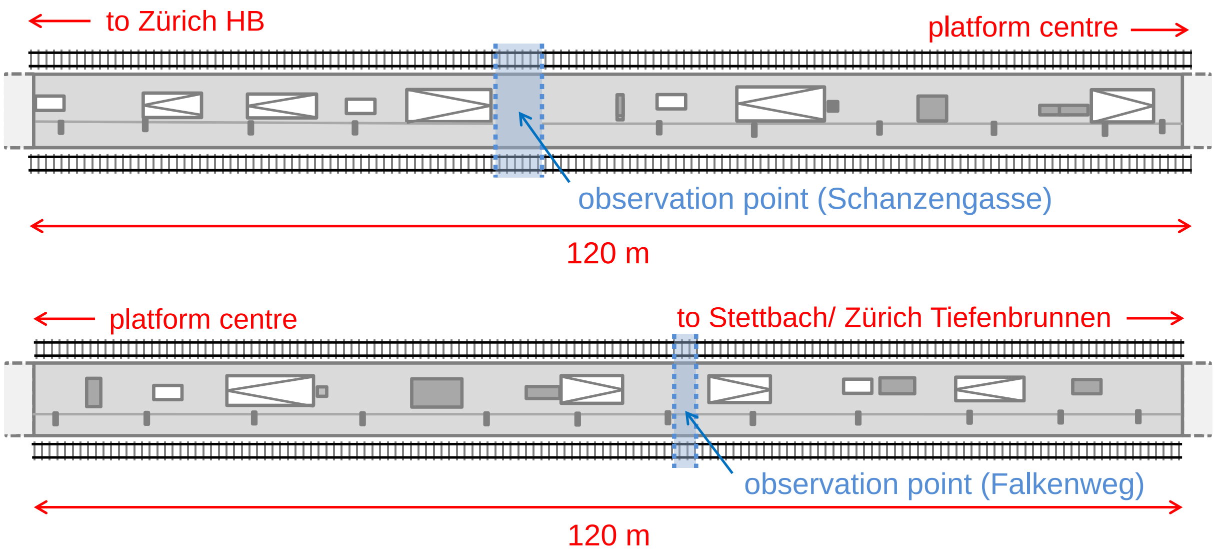
Zurich Stadelhofen is another railway station in Zürich. With about 76000 passengers per workday the passenger demand is about 10 times higher than in Zürich Wiedikon (Regierungsrat des Kantons Zürich, 2013). The station consists of three tracks having one centre platform and one side platform directly connected to the surrounding city (Figure 5). In Zürich Stadelhofen the centre platform, between track 2 and 3, was used for the observations. This platform can be accessed using several entrances connecting the platform to the existing underpass and to a walkway above the station. The width of the platform is about 10 m.

Figure 5 Zurich Stadelhofen (view from Schanzengasse)

The observations in Zürich Stadelhofen were done from the two bridges situated above the railway station (Figure 6). From there it was possible to undisturbed observe wider parts of the platform even at higher pedestrian densities. On the other hand, the view to some areas on the platform was blocked by columns and other obstacles. Therefore, most of the observations at this location were only made for the side of the platform next to track 2.

Due to the amount of passengers present at the station it was also not possible to cover the whole observation area at the same time. To ensure sufficient data quality, smaller parts of the observation area were selected at the same time for data collection. Compared to the observations in Zürich Wiedikon it was also not possible to determine the exact train arriving, as the headway time in Zürich Stadelhofen is short and short delays made it impossible to distinguish between subsequent trains. The observations were therefore made each two minutes without considering the train schedule. Due to the short headway times the passenger flow to subsequent trains is overlapping in time. Thus the influence of the arrival time on the waiting location cannot be determined in this setting.

Figure 6 Schematic layout of observation areas on platform 2/3 in Zürich Stadelhofen



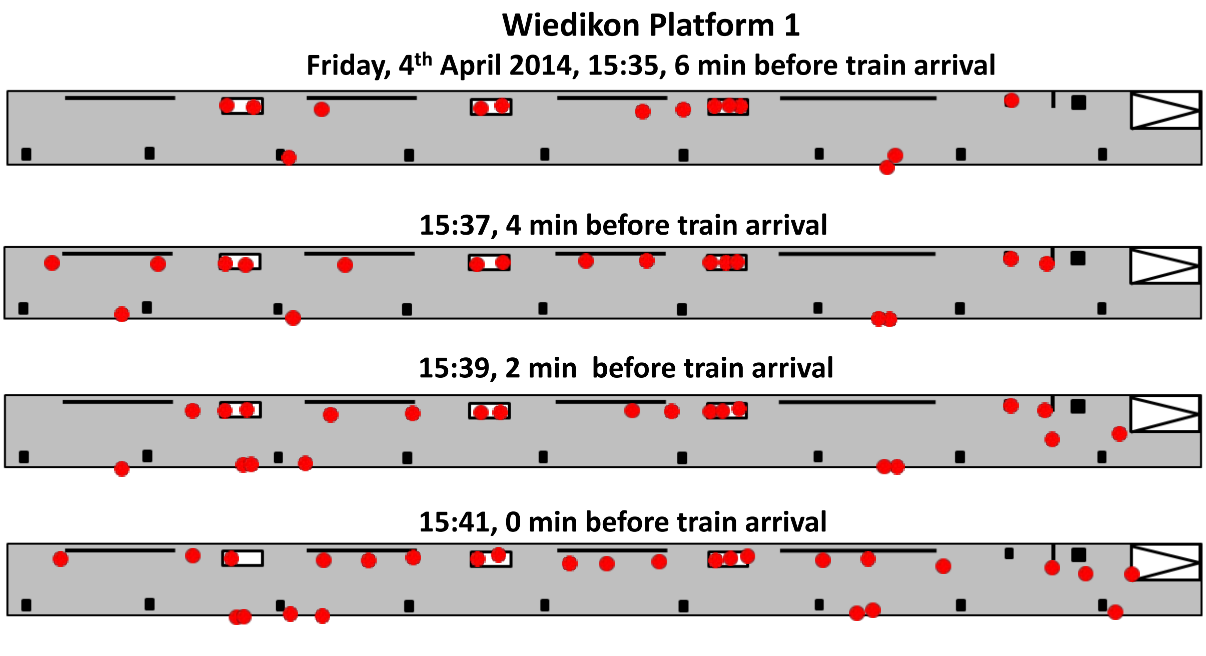
4. Results

To analyse the results of the observations, the waiting positions of individual pedestrians were digitised. Based on the observations made at the railway stations and the collected data, several conclusions can be made about the behaviour of waiting pedestrians at railway platforms. At first the main findings for each of the railway stations used for the case study are presented. Afterwards the influences proposed in Table 1 will be discussed.

4.1 Zürich Wiedikon

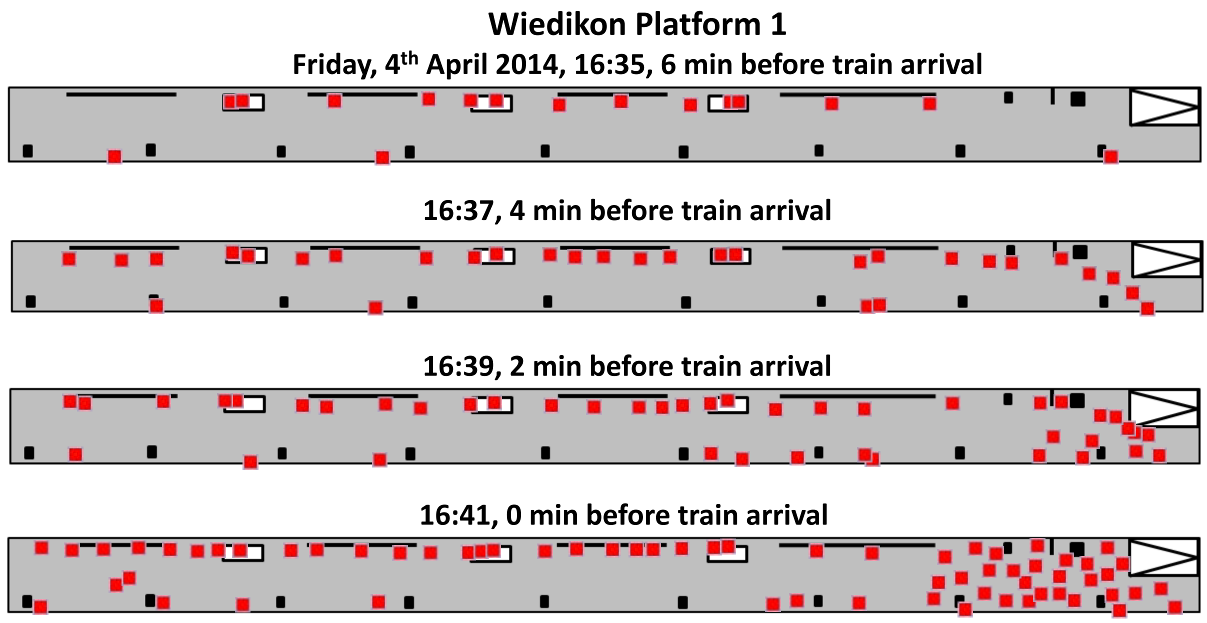
As expected, the overall amount of pedestrians at the observed platform in Zürich Wiedikon is low to medium. As there are usually almost no pedestrians waiting on the platform after the departure of a train it was possible to study the behaviour of pedestrians who can freely choose their waiting location.

Figure 7 Distribution of pedestrians waiting at platform 1 in Zürich Wiedikon during non-rush-hour



At low densities, mainly present during non-rush-hours, the pedestrians primary wait next to the railway tracks near the columns and at the back of the platform next to the wall (Figure 7). In the middle of the platform, where there are no obstacles, the space is used for circulation. During the rush-hour it was observed that pedestrians accessing the platform shortly before the arrival of the train tend to stay close to the platform access and do not circulate around much further (Figure 8). Similar to less crowded situations on the rest of the platform the waiting areas used are situated next to obstacles and the back wall.

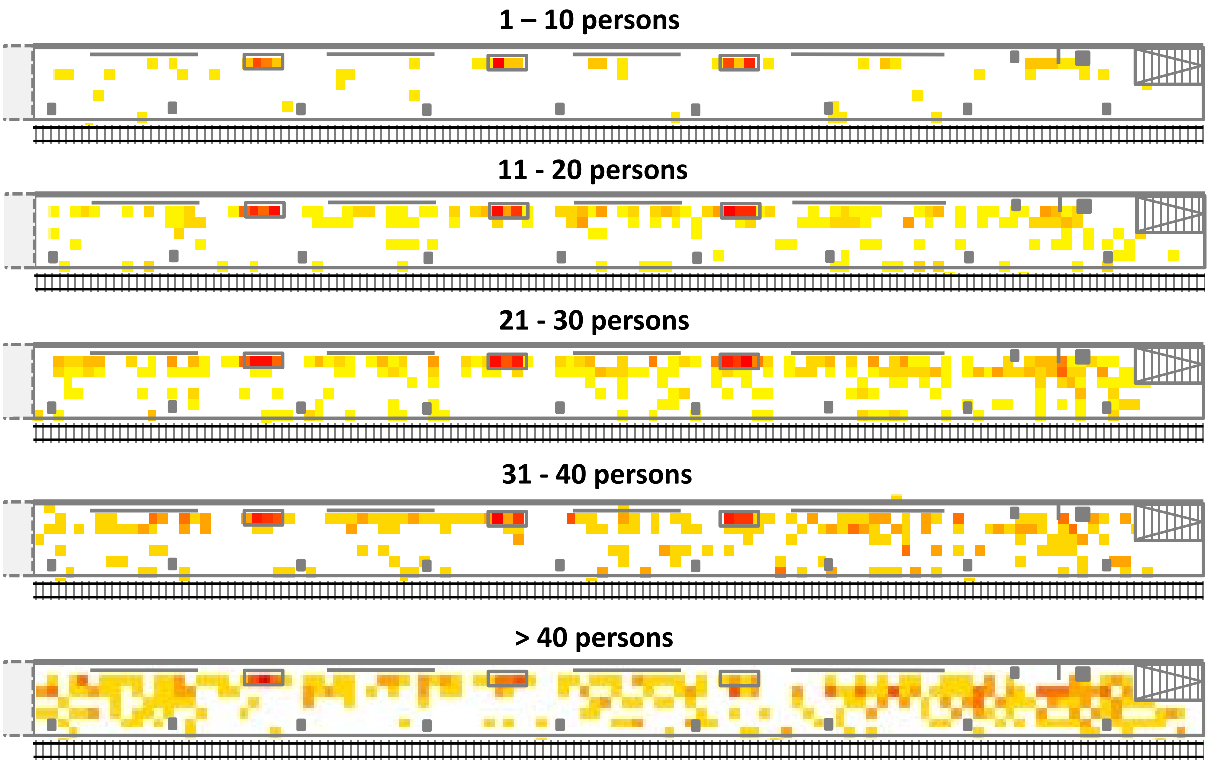
Figure 8 Distribution of pedestrians waiting at platform 1 in Zürich Wiedikon during rush-hour



In Figure 9 the superposition of observations including the same number of pedestrians are shown. Here all observations are gathered having a similar total amount of pedestrians. Successive observations without train arrivals in between were then removed to reduce the interdependency of the observations. Subsequently the data was superposed to show the distribution of waiting pedestrians at different total densities.

It can be seen that when up to 10 pedestrians are present at the platform, the waiting locations are mainly situated along the wall at the back of the platform and next to the columns. With an increase in total density pedestrians are more distributed across the whole platform area. In general, the back of the platform is more crowded than the rest of the area. The data also clearly shows that the benches are used most.

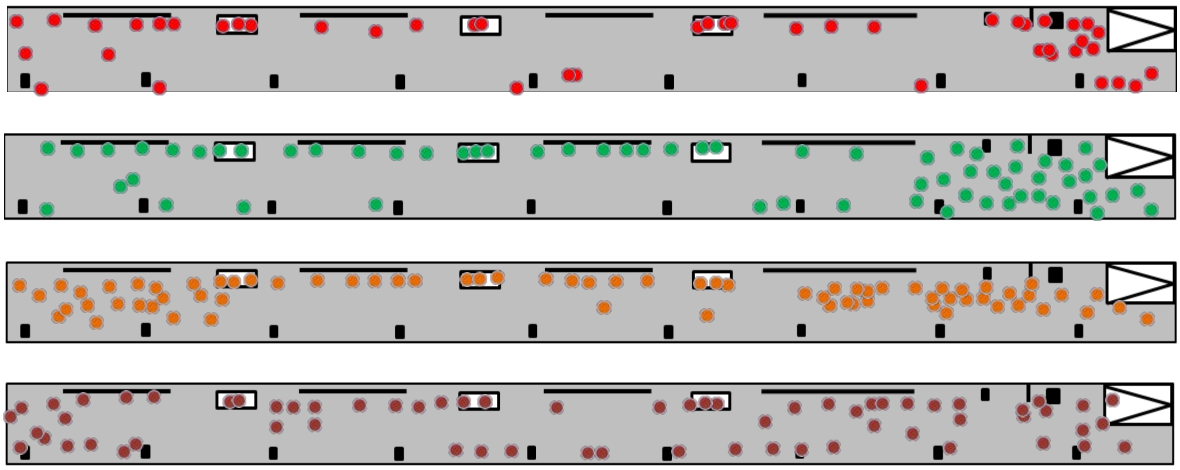
Figure 9 Superposition of observations made at same total numbers of pedestrians in Zürich Wiedikon



Higher densities are also observed at the sides of the platform close to the accesses. Due to the limited amount of data available, the influence of the higher density cannot be separated from the influence of the time to the next train arrival. Both influences might lead to the observation that pedestrians wait close to the entrances. As the density increases until the train arrival, observations with higher densities are only made shortly before the arrival of the next train.

In Figure 10 observations of the passenger distribution close to the train arrival are shown, where more than 50 pedestrians are waiting on the platform. In all these cases the back of the platform and the benches are used for waiting. There can also be a crowd waiting next to the entrance identified, but the shape and size of this crowd is different between these observations.

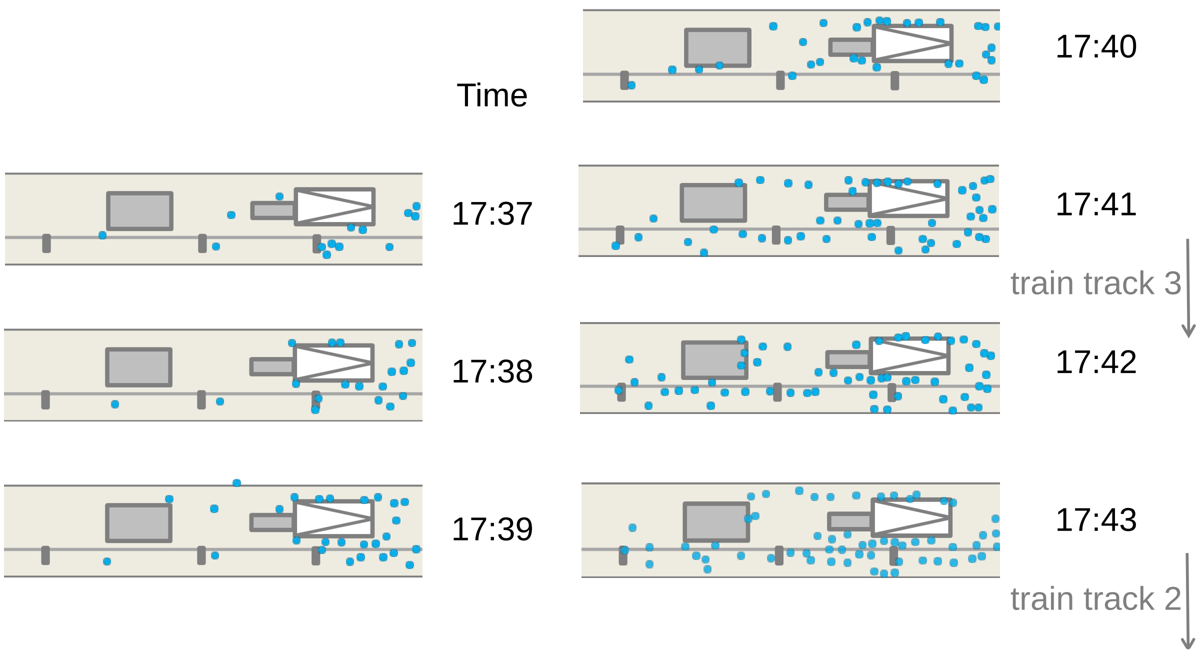
Figure 10 Observations with more than 50 pedestrians on the platform 1 in Zürich Wiedikon



4.2 Zürich Stadelhofen

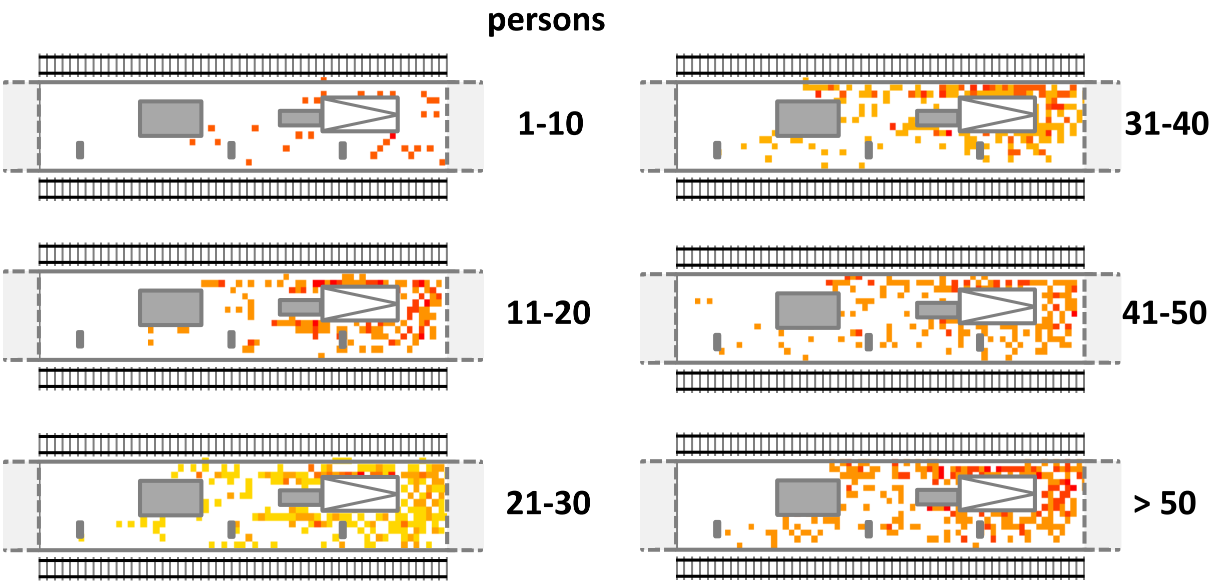
In Zürich Stadelhofen considerably higher pedestrian numbers were observed. To be able to manually gather the data also during the rush-hour, smaller platform areas were observed at these times. In Figure 11 the distribution of pedestrians waiting at the platform during rush-hour is shown. It can be seen that the distribution of pedestrians along this stretch of the platform is highly uneven. In the queuing area in front of the platform access and along the railing on the side of the stairs there are considerably more pedestrians than further away from the entrance. In contrast to the situation in Zürich Wiedikon the trains arrive with a short headway time, hence the pedestrians usually do not wait for a long time on the platform. This might be a reason why pedestrians do not walk further to convenient waiting locations but stay close to the access.

Figure 11 Distribution of pedestrians waiting at the centre platform in Zürich Stadelhofen during rush-hour (track 2 below, track 3 above the platform in the drawing below)



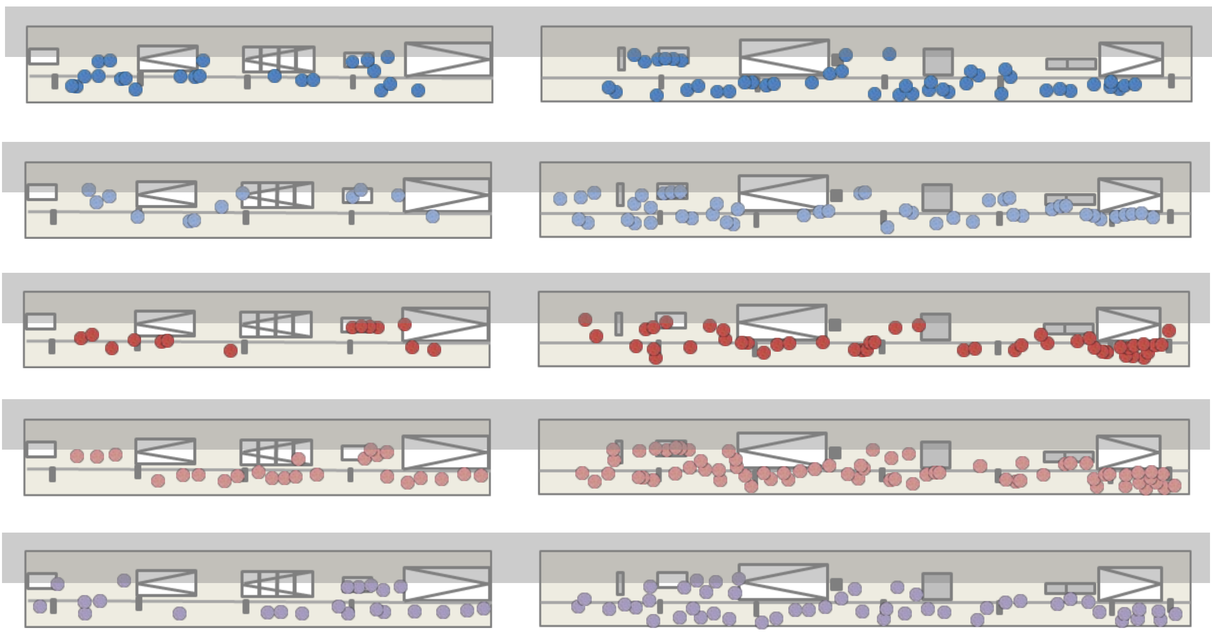
The lack of distribution of pedestrians can also be seen in Figure 12, where the superposition of observations at same densities is shown. It is remarkable that on the side of the platform closer to track 3 (top) the waiting pedestrians are aligned more at the platform edge whereas on the lower half of the platform the pedestrians stay closer to the entry. A possible explanation for this is the asymmetric platform layout. There is more space available close to track 2, thus pedestrians do not need to circulate further but do have waiting areas with acceptable densities close to the entrance. On the top half of the platform there is less space close to the platform access, hence pedestrians do not find suitable waiting areas there. As passengers tend to orient themselves towards their track, they will not use the available space at the other side of the platform.

Figure 12 Superposition of observations made at same total numbers of pedestrians in Zürich Stadelhofen



When observing another part of the platform at high densities, the same behaviour was found (Figure 13). Pedestrians will use railings to lean against whenever possible, but the circulation along the platform is limited. It was observed, that mostly the middle part of the platform is used as a waiting location, as the columns, railings and other obstacles are situated there.

Figure 13 Observations with more than 50 pedestrians in Zürich Stadelhofen

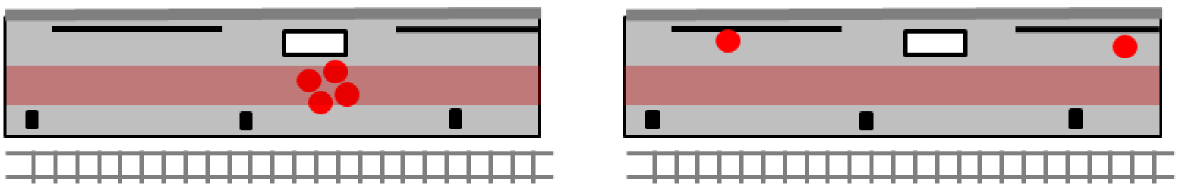


4.3 Pedestrian characteristic

From the proposed influences based on the pedestrians and their characteristic only observations for the time of pedestrian arrival relative to the train arrival, the group size and the total number of pedestrians was made. For the other influences (the trip purpose, the age and the weather conditions) further investigations and other measurement techniques are needed. For the influence of the trip purpose and the age some observations were made confirming their influence, but the underlying data is limited.

Concerning the arrival time of pedestrians relative to the train arrival different behaviour was observed. Pedestrian entering the platform shortly before the arrival of the train tend not to distribute themselves across the whole platform but wait next to the platform accesses. This behaviour confirms the idea that these pedestrians do not need to find a comfortable waiting area but try to reduce the walking distance. As the pedestrian density increases until the arrival of the next train, this influence is hard to distinguish to the influence of the total number of pedestrians on the platform. With an increasing overall density, preferred waiting positions are already occupied or the local density exceeds a certain threshold, hence pedestrians use other waiting locations. It was observed that first locations next to obstacles and walls are used, where it is possible and convenient to lean against. Afterwards other zones are used more frequently, for example areas free from obstacles, which do not interfere with walking pedestrians. Only at higher densities, other areas are used where waiting pedestrians interfere heavily with walking pedestrians.

Figure 14 Waiting location of groups (left) and single pedestrians (right).



It was observed that groups show different waiting behaviour compared to single pedestrians. The distances between group members are usually smaller than between unrelated pedestrians. Also the waiting location is different (Figure 14). Groups tend to wait at locations next to the platform accesses where they do not have to walk longer distances. Therefore they often wait in areas usually used for walking. As this behaviour results in conflicts with pedestrians walking along the platform and thus force them to walk close to the platform edge this influence should be investigated further. In addition other pedestrians will more likely wait there as there are already people waiting.

4.4 Platform access

The location and number of the platform accesses have a strong influence on the distribution of passengers on railway platforms. Especially at high densities and shortly before the arrival of the next train pedestrians stay close to the platform accesses. The queuing areas in front of the platform accesses are thus not only used for pedestrians walking off the platform and queuing in front of the stairs but also for arriving pedestrians waiting for the next train. The density observed in this area is therefore dependent on the available size of this area and on the number of pedestrians entering the platform close to the arrival of the next train.

Their location determines the location of these crowded areas, which are the areas having the highest local pedestrian density in overall crowded conditions. In general more platform accesses result in a more even distribution of pedestrians. In addition it has to be considered that the amount of people using a certain access is strongly linked to their location in the station layout. Usually the station building also serves as the main access point to the platforms, its location therefore influences the amount of people entering the platform at a specific location.

It can be concluded that the influence generated by the platform access has two reasons. Firstly, heavily crowded areas occur for short times in front of them as people do not always walk further away from the entrance. Secondly, their location and number determine the amount of pedestrians using each entrance and hence the total density in the vicinity of the specific entrance.

4.5 Platform layout

As expected, the platform layout has a strong influence on the distribution of waiting pedestrians. The observations showed that there exists a certain rank concerning the preferred waiting location. At first the benches are used. Then locations are chosen, where it is possible to lean against. The places mostly used are the railings next to ramps and stairs as well as around elevators and railway shelters. Closer to the train arrival people occupy these areas less. It was also observed that not all obstacles and walls are used for waiting. Obstacles whose surfaces look dirty are not used to lean against but are avoided completely.

Pedestrians leaning against walls seem to accept smaller interpersonal distances, hence higher densities, than in other areas of the platform. A possible reason for this is that these pedestrians are exposed to the density only linearly.

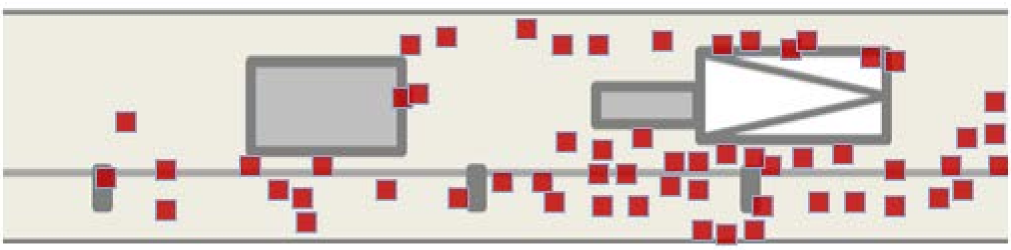
Figure 15 Pedestrians waiting close to obstacles

As can be seen in Figure 16 pedestrians do not only lean against obstacles but also prefer to wait close to them. For example people tend to stand on the side of the benches at the platform but not in front of them. Also the lines of columns on the platform are often used as waiting area. Their location therefore determines the waiting and walking location on the platform.

In this study no further evaluation was made to determine the reason for this behaviour. A potential explanation is that waiting next to these obstacles reduces the conflicts with pedestrians who want to walk along the platform. It seems that up to a certain density the most convenient locations are those where they do not stand too close to other pedestrians and where they do not disturb other people. This behaviour usually leads to an efficient use of space at the platform. Waiting locations which produce considerable interference with other pedestrians are primarily used only at high overall pedestrian densities and close to the train arrival.

The platform dimensions determine the space available for waiting. Still it was observed that not all space is used for waiting or walking. Pedestrians mostly use waiting locations next to the entrance used and next to places, where the train doors will be situated after arrival. Hence the area on the platform where no train stops is not used for waiting. At centre platforms only the side of the incoming train is used for waiting, especially when there are obstacles in the middle of the platform as waiting pedestrian normally face the track of their train Figure 17).

Figure 16 Difference in pedestrian density between the two sides of the platform (Zürich Stadelhofen).



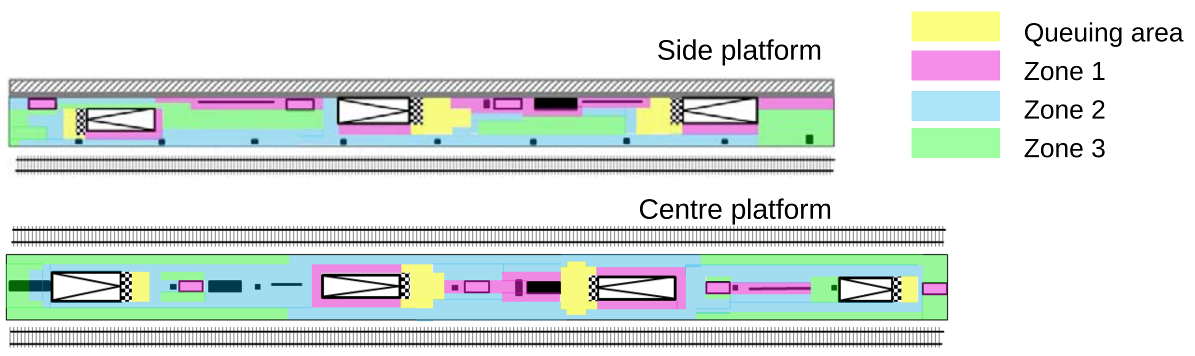
5. Conclusion

The data gathered in this work allowed to identify the most important influences concerning the waiting location used by passengers on railway platforms. The layout of the platform, especially the location obstacles and the size queuing zones next to the platform accesses, was determined as a key factor of the distribution of pedestrians along the platform.

Pedestrians seem to prefer waiting locations where they are undisturbed and do not disturb other people. In general, this behaviour enables and efficient use of the facility. Only at high densities and close to the arrival of a train pedestrian start to increasingly using space needed for walking as waiting area.

The observations done in this work were done manually by marking the location of pedestrians on the station layout. This method was useful to collect data for this purpose. Still this work showed that further research is needed to collect more data on the waiting behaviour. It might be useful to observe the waiting behaviour also on other railway stations with different geometry. Some of the potential influences proposed in this work cannot be determined by only observing the behaviour of the passengers. It is therefore recommended to also include other investigation techniques in further studies.

Figure 17 Preferred waiting locations of pedestrians at railway platforms



The deeper knowledge obtained in this study can be used for the design of railway platforms. Instead of dividing the platform into strips for walking, waiting and circulation, it is proposed to use the knowledge about the preferred waiting positions of pedestrians. In Figure 18 the preferred waiting locations of pedestrians at railway platforms are presented. Zone 1 represents areas where pedestrians prefer to wait. With increasing density these areas get crowded, hence the other zones are used more and more for waiting. Further investigations are then needed to determine the exact densities which will be present in these zones depending on the overall density.

As the amount of data gathered in this study is limited, the results might have several uncertainties. In addition measurement errors can occur at different steps of the data collection. During the observation phase pedestrians might have been missed or placed incorrectly on the map. Also the digitalisation of the data can lead to errors. As the results of this study are mainly qualitatively, it is expected that the main outcomes are not influences by the errors occurring.

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