Modelling of train-induced pedestrian flows in railway stations

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PRELIMINARY DRAFT

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Abstract

With the predicted double in number of train passengers in the "bassin lémanique" over the next 20 years, pedestrian demand in train stations is going to increase significantly. Elements like train timetable stability, comfort and safety of pedestrians are at stake. To ensure safe and efficient movement of pedestrians within train stations, increasing our knowledge in pedestrian flow propagation is essential. Research has been lead on embarking and alighting of pedestrians in strain stations, but as far as we know little work has been done on train induced pedestrian movements correlated to the train timetable.

Each train movement induces flows of pedestrians who travel through the station. These groups of densely packed passengers (either heading for a train or disembarking from one) can cause congestion. In both cases critical situations can occur: for loading passengers waiting areas must be sufficiently large, whereas for pedestrians getting off trains the facility's throughput capacity must be sufficient. Bottlenecks are one of the critical components in this respect as they are responsible for important delays in pedestrians travelling through the transportation hub. In order to thoroughly understand passenger movements, a timetable based model is developed at first to estimate parameters to fit train-induced pedestrian flows between platforms and platform access ways (arrival and departure flows). Secondly, distribution of pedestrians between access ways leading to the platforms is analysed. Finally, the model is used for prediction of the previously mentioned flows. Only train timetables and rough estimates of the number of boardings/disembarkations at the station are required to obtain reliable predictions of passenger flows.

Data driven analysis and modelling of Lausanne's train station (Gare de Lausanne) is done as a case study. This analysis is based on the train time table and pedestrian tracking data. By combining these two data sources, dynamic estimation of the pedestrian demand is possible, which can help accurate dimensioning of access ways in Lausanne's station.

Acknowledgement

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Keywords

Pedestrian flows, train station, timetable

1 Introduction

Many public facilities concentrate pedestrians in confined areas. This is especially true for public transport hubs, amongst which train stations hold a dominant place. Any large train station with many trains servicing the infrastructure will have thousands of passengers using the facility inducing complex pedestrian interaction. Access ways to platforms attract most of the pedestrians since they serve the primary function of such infrastructure: using trains. The large number of entrance/exit possibilities to stations also induces complex flows with many different origin-destination possibilities.

Pedestrians will interact with the infrastructure but also the other passengers: from the same train, waiting on the same platform, in the access ramps to leave the platform and then in the rest of the walkways of the station. Platform organisation should be analysed, pedestrian-pedestrian interaction is not the only source of hindrance in a station. If many benches, trash bins or structural elements cover the platforms, passengers will have trouble moving around.

Being able to model pedestrian movement throughout any public facility is primordial for designing, or modifying, such buildings. Understanding the links between each of the elements interacting in train stations can improve general knowledge on this field.

2 Literature Review

The link between train timetables and pedestrian flows is weak as of today. Many studies analyse pedestrian interactions, platform arrangements or full station analysis but only little research has been lead on the link between time table and pedestrian flows. A detailed literature review can be found in Hänseler *et al.* (2014) highlighting this under-analysed link.

3 Model

One aspect which is poorly analysed is linking pedestrian interaction models to global station models. By focusing on the dependency between pedestrians flows and the train time tables, this missing link can be partially completed. Pedestrians can either be attracted to platforms to take trains, or as trains arrive in the station many passengers are unloaded into the station. By considering trains as independent events, a general model for train-based events can be developed.

Train movements within a station will induce pedestrian flows. Such flows specifications will depend on the station's configuration -or facilities-, the train type, time of arrival and many more parameters. Assuming the flows are observed in a specific area of a station, these can be described by a sum of train based functions with train-specific parameters (M independent trains) like arrival -or departure- time t_m, number of passengers linked to the movement of this train Q_m and a set of parameters γ_m specifying the function f. The observed pedestrian flow $\tilde{y}$ can be modelled with the following:

$$\tilde{y} = \sum_{m=1}^{M} f(t; \gamma_m, t_m) + \varepsilon \tag{1}$$

Adapting the function f allows modelling of different phenomena in specific parts of a train station. It can be cumulated pedestrians flows, arrival rates or densities for example.

4 Case study: Lausanne's main station

Given the proximity of Lausanne's station to EPFL and the large amount of available data, considering this train station as a case study was a natural choice. The station's configuration (figure 1) is ideal since the flows of pedestrians are well contained in both underpasses (PU, for pedestrian underpass). Also, on many tracks (3 through 9) passengers must use one of the access ways to take a train or disembark from one, hence they can be easily counted and tracked. Unlike the aforementioned tracks, platform 1 is directly accessible from the main hall and has many different exit/entrance possibilities making it difficult to track pedestrians. Again, platform 70 is also different since only few trains use it and it has direct access without going through the station's facilities. Both underground walkways (PUs) give access to pairs of platforms: 3&4, 5&6 and 7&8.

Data sources In these pedestrian areas a tracking system is installed by VisioSafe (for further details about the tracking data) which is capable of following pedestrians from the bottom of the access ramps to the entrance/exits of the PUs. Cameras cover about 60% of the area and the rest is extrapolated from trajectories. In the present analysis only the pedestrian's entrance and exit timestamps into the PUs are used, the rest of the tracking data is not considered. A selection of seven days is done based on the train timetable "normality". The morning peak hour (7h00-8h30) is analysed for each of these seven days.

The other important data source is the effective train timetable. Supplied by SBB, the precise arrival and departure times of each train is available. This data is primordial to analyse the link between train-induced pedestrian flows and the train timetable as clearing of platforms only

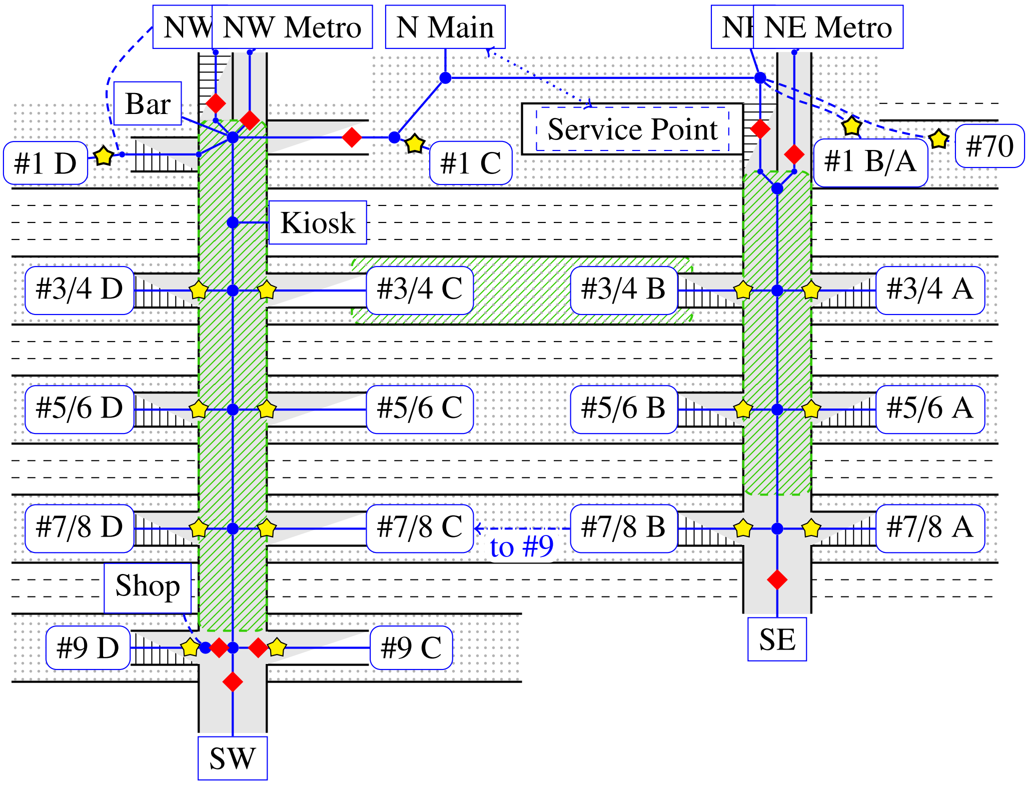


Figure 1: Schematic map of Lausanne's train station. Yellow stars indicate the location if the sensors which are used for recording the time stamps used in this study. (from Hänseler *et al.* (2014))

takes a few minutes in Lausanne and train movements naturally have a few minutes of variation. For validation and prediction purposes, travel survey data is needed. Two sorts are available which need to be merged to have a complete data set of estimates. The first, most reliable of both, is annual averages of passenger movements in and off from trains, the latest estimation dates back to 2010: HOP_{2010}. The second, up-to-date but not reliable, is train specific estimations. In some trains, either automatic systems or train employees, (partially) count the number of passengers in trains from which estimations of the number of (dis-)embarking passengers are extrapolated: $FRASY_{2013}$.

Train-induced pedestrian flows As trains arrive -or leave- the station, pedestrians are either emptied into the station or attracted to a platform. For platforms 3/4, 5/6 and 7/8 these flows must pass through either of four access ways linking the PUs to the platforms. Analysing the timestamps at the bottom of the access ramps highlight two different types of flows:

- unloading or inbound or disembarking flows: passengers arrive in the station in a train
- loading or outbound or embarking flows : pedestrians come to the station from outside to take a train

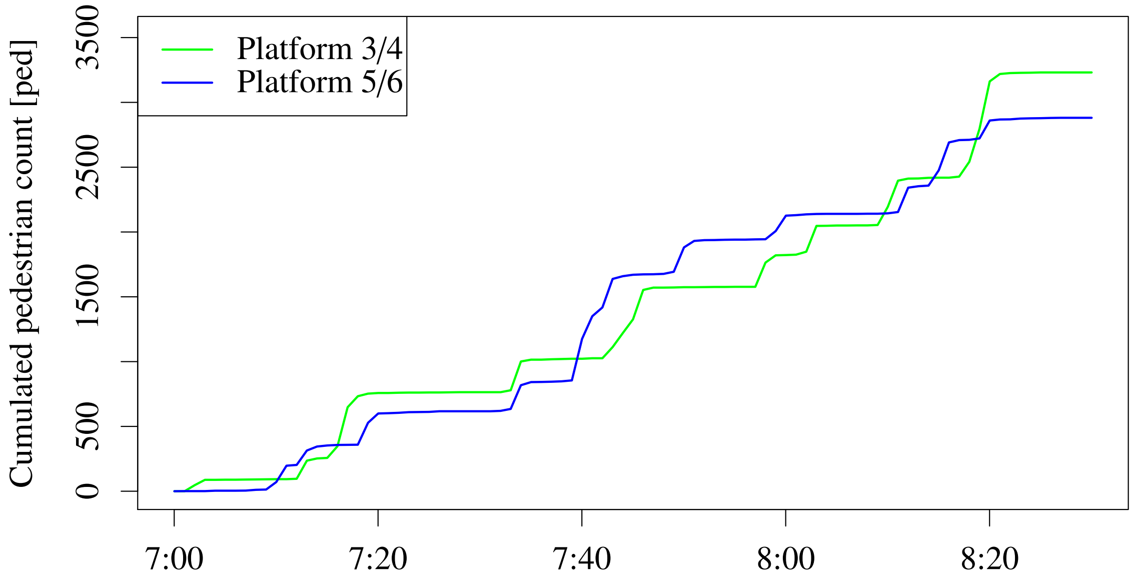
The separation must be made since they present two clearly different behaviours when considering the cumulated pedestrians counts at the bottom of the access ways (figure 2). The unloading flows present a well-defined step-like curve whilst the loading flows present a quasi constant curve. Inbound pedestrian flows are critical from a facility's throughput capacity since dense groups of passengers suddenly enter the walkways and can create congestion. On the other hand, outbound pedestrians will fill up platforms while they wait for there train. This can be critical with the increasing capacity of trains since people must be not risk being pushed off from a platform.
To be able to model these train-induced flows, expressions for these observed flows need to be developed. Considering trains as independent events allows the modelling of unloading flows by a train-based sum of step functions. Unfortunately, this approach is not conclusive for loading flows as the correlation between the train timetable and the flows is not clear.

5 Specification

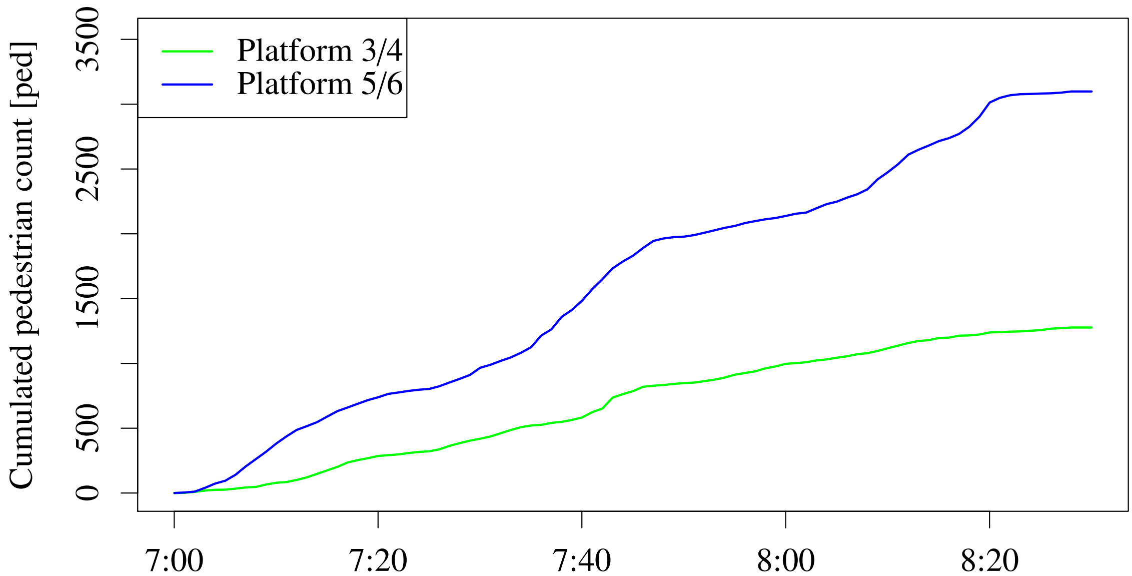
Visualization of the timestamps of pedestrians reaching the bottom of the access ramps to platforms highlights the difference between unloading and loading flows (see figure 2). With such different behaviours, distinction between loading and unloading flows must be made. Given the difference between the - apparent - random arrivals on platforms to take trains (loading flows) and the well-defined step-like unloading curves, two different models need be defined. The first, for disembarking flows consists of a piecewise linear function, whilst the second for embarking flows is a linear model. Ideally outbound flows would present a similar behaviour as inbound flows, but the large discrepancy motivates two different models.

5.1 Unloading flows

For the shape function f in 1, a piecewise linear model is used as suggested by the data and other researchers modelling the same problem (Lavadinho, 2012), the number of parameters required to define the function is kept to a minimum. Nevertheless, this function yields close results with descriptive parameters which are meaningful for analysis. The disembarking flow capacity rate for one train m is α_m, graphically this corresponds to the slope of the middle section of the piecewise linear function. The number of disembarking passengers from a train is Q_m, the time taken for the first passenger to be detected is s_m and t_m^{flow} the time taken for the pedestrians to empty the platform. Figure 3 illustrates all the parameters.



(a) Inbound (unloading) cumulated pedestrian count on 6^{th} February 2013. Clear step like functions are visible. Each vertical line indicates a train arrival on the corresponding platform.



(b) Outbound (loading) cumulated pedestrian count on 6^{th} February 2013. Unlike the unloading curve, no clear pattern stands out.

Figure 2: Train induced pedestrian cumulated counts in Lausanne's train station. Only platforms with reliable tracking data are presented.

$$f = \begin{cases} 0 & t < t_m + s_m \\ \alpha_m \cdot t \quad \text{for} & t \in (t_m + s_m, t_m + s_m + t_m^{flow}) \\ Q_m & t \geq t_m + s_m + t_m^{flow} \end{cases}, \quad t_{flow} = \frac{Q_m}{\alpha_m} \tag{2}$$

Inserting (2) into (1) returns

$$\tilde{y} = \sum_{m=1}^{M} f(t; \alpha_m, Q_m, t_m, s_m) + \varepsilon \tag{3}$$

Multiple parameters are defined for the piecewise-linear step function which require some more detailed explanations (Fig. 3). The train arrival time (t_m) and number of disembarking passengers (Q_m) are self-explanatory, unlike the last two (s_m and α_m).
Since the passengers are detected at the bottom of the ramps and stairs leading up to the platforms, there is a so-called "dead time" between the train arrival time stamp and the first pedestrians who are detected. This time lapse will depend on the distance from the train doors to the exits ramps, the counter flows also influence the time taken for pedestrians to walk down the stairs (and ramps). This dead time parameter is assumed to follow a normal distribution.
The capacity flow rate (α_m) suffers from the counter flows even more so than the dead time (s_m), the second element influencing the capacity flow rate is the number of access ways which are used. For long trains passengers will disembark along the whole platform, whereas shorter trains will concentrate pedestrians in the middle access ways. Instead of using the length of trains directly, since large trains can unload only few passengers in some cases, the number of disembarking passengers is considered.

Unloading flow fit

Least squares is used to fit the model to the data. Comparing the recorded timestamps with the fitted curve over the entire time interval (7h00-8h30) is difficult due to the small residuals, hence one portion is magnified to explain the limitation of the model. Figure 4 presents a global view of the data set and focuses also on the limitation of the model: simultaneous train arrivals. When two trains arrive on adjacent tracks in a small time interval, flows get mixed up and by looking at the data only one event can be distinguished. One of the piecewise train steps will degenerate in such case to yield a closer fit, from a least-squares point of view.
In case of multiple events, the degenerated estimates are discarded (considered as outliers) since

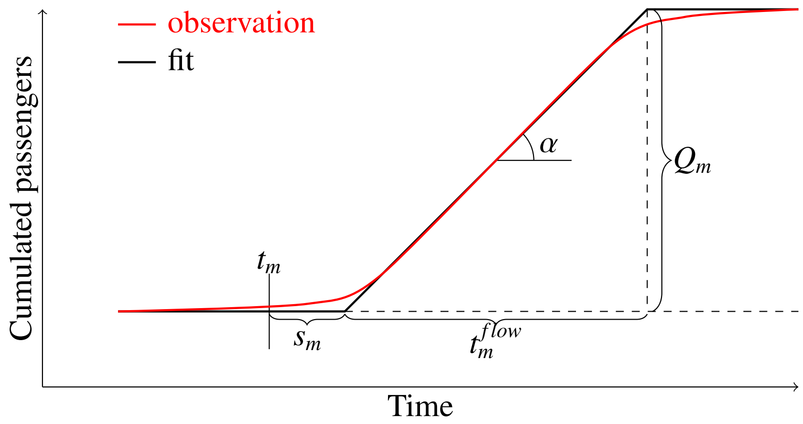


Figure 3: Definition of the parameters used in the piecewise linear step function. Each train induces flows (red curve) which can be modelled by a piecewise linear model (black)

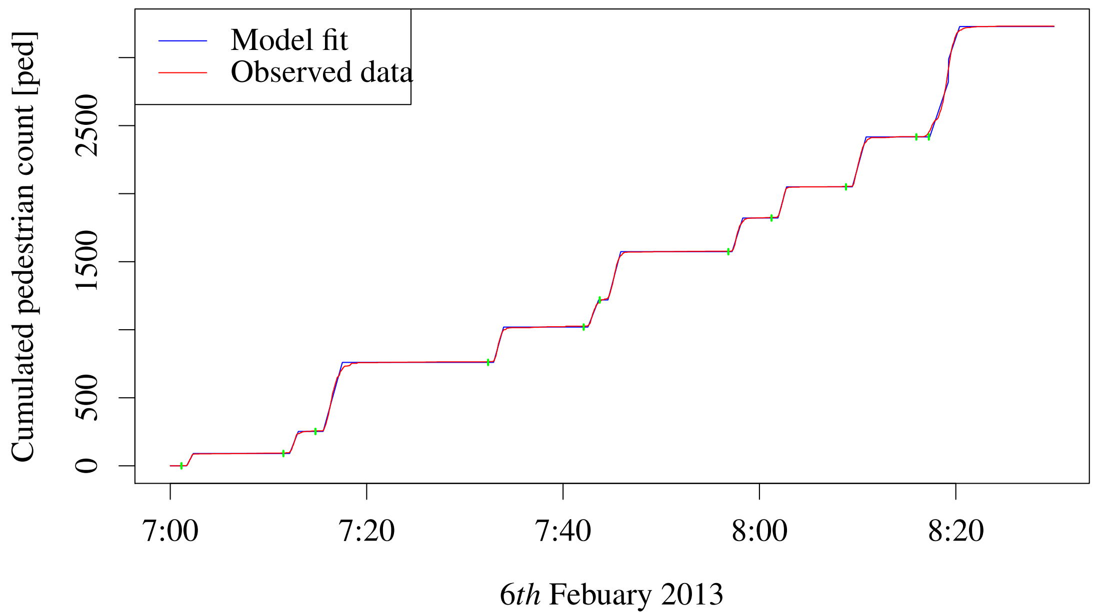
they will influence the models fitted with the parameter estimates. Comparison between the total number of disembarking passengers and SBB travel surveys validate these estimates (Hänseler *et al.* (2014))).

Shift parameter evaluation

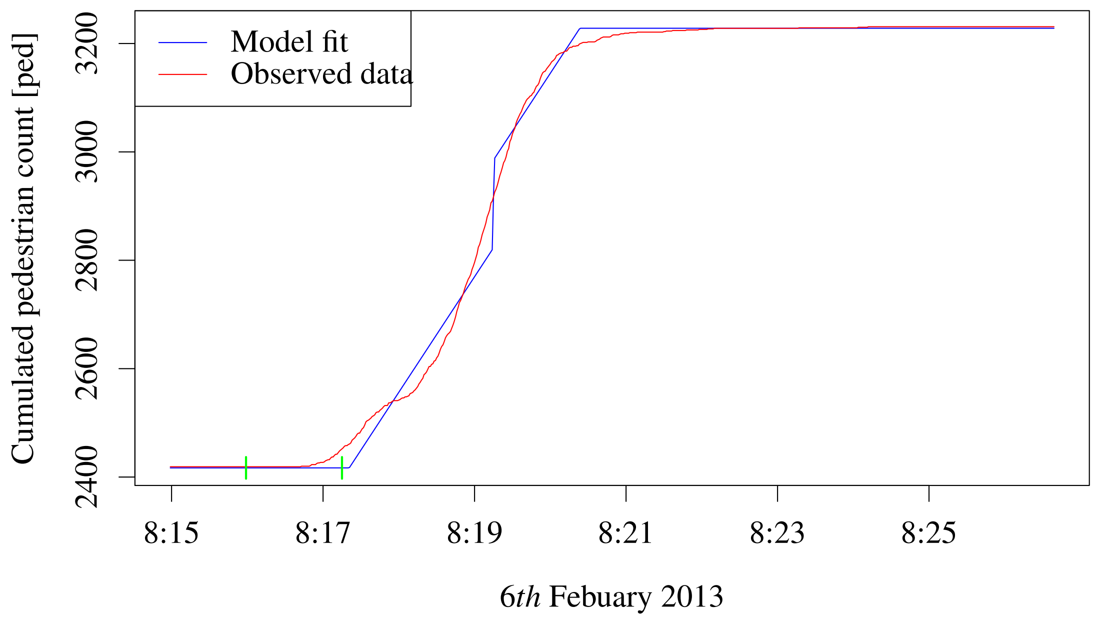
The "dead time" parameter is certainly the hardest to interpret since various different phenomena influence the values obtained from the estimation framework.

- distance from train doors to detector
- counter flow up the ramp (reduces walking speed)
- train arrival timestamp

Time taken for passengers to reach the sensor at the bottom of each ramp will depend on the train door-top of ramp (or stairs) distance and the length of the ramp (or stairs) itself. Upper and lower boundaries (depending on the closest door position) of the time taken to walk this distance can be calculated based on Weidmann (1992). The horizontal distance of the stairways is about $10m$ and an rough estimation of the distance between train doors and the top of the stairs is also $10m$. Since the horizontal travel speed descending stairs is $0.44m/s$ and the walking speed on flat ground is $1.34m/s$, an approximation of the time taken to reach the sensors is $\frac{10}{0.44} + \frac{10}{1.34} = 30.2s$. Such basic approximation is perfectly in keeping with the modelled dead time parameter mean of $38.0s$ and standard deviation of $12.8s$.
The previously calculated approximation ($30.2s$) do not take into account any counter flow which, in some cases, will influence significantly the time taken to walk down the access way. The last unknown phenomenon concerns the time stamp indicating the arrival of each train.



(a) Overall comparison of the fit between the model and recorded data. Discernible differences only appear at the start and end of flows from platforms.



(b) When two trains arrive at the same time on two adjacent tracks, distinction between flows from each train is impossible. At least one of the estimated values of the unloading flow capacity is unrealistic. The number of disembarking passengers must be considered together and only then do the values make sense.

Figure 4: Comparison between the observed data and the model fit for 6^{th} February 2013. Short vertical green lines indicate the arrival time of a train.

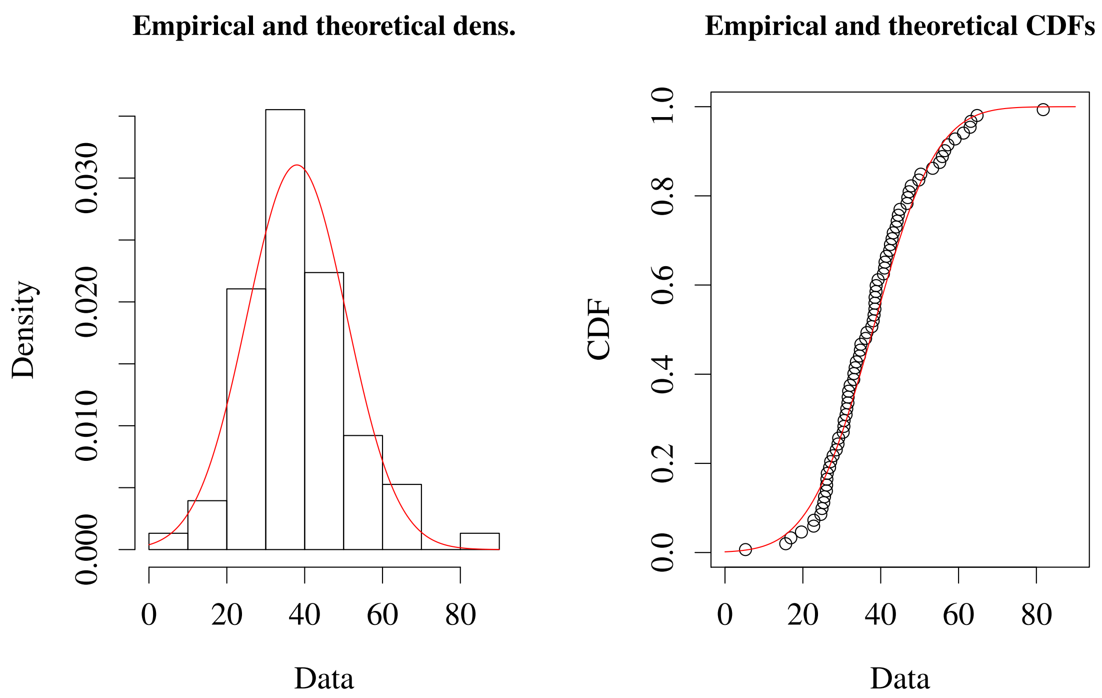


Figure 5: Distribution of the dead time parameter s. The values of s are fitted to a normal distribution mean $=30.2s$ and sd $=12.8s$. Using a stochastic model allows sampling from the specified normal distribution.

This can depend on the driver and since each of them will have their own habits concerning the sending of the arrival signal, this dead time parameter will also depend on this.

Flow capacity rate

Since the flow capacity rate (α) cannot be considered independent from the number of disembarking passengers, an explicit relation $\alpha(Q)$ is developed to link these two variables. The length of the train is not the best variable to use since ling trains could be empty in Lausanne, instead the number of disembarking passengers is considered. The more passengers disembark from a train, the higher the odds are that they will use all four access ways to leave the platform. Since the flow capacity rate is considered together for all four access ways, the higher the use of the outside ramps is, the higher the flow capacity rate will be. Of course the flow capacity rate is limited, for trains with many passengers disembarking saturation will occur. The access ways maximum throughput capacity is one of the limiting factors of the station in Lausanne.
To take into account this flow capacity rate dependency, a piecewise linear model is specified. Until a critical number of passengers the flow capacity rates increases, then reaches a maximum

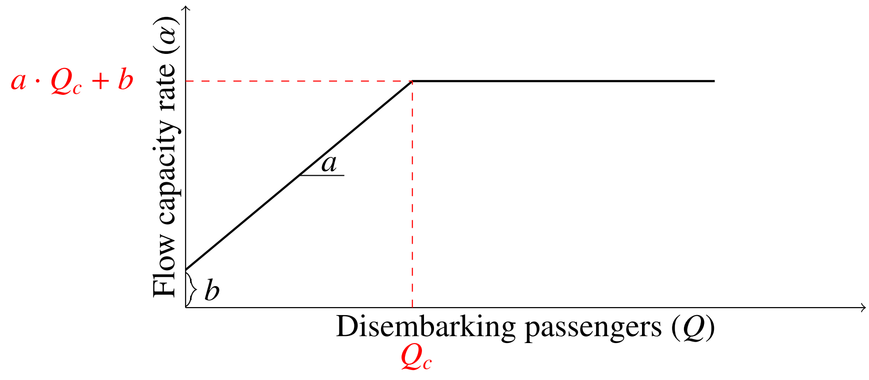


Figure 6: Definition of the parameters used in the model for the flow capacity rate. The assumption is made that the flow capacity rate is linear until an upper limit is reached corresponding to the facilities limits.

value: the flow capacity rate doesn't depend on the number of disembarking passengers once the facilities capacity is reached. This model is illustrated in figure 6. The critical number of disembarking Q_c and two shape parameters a and b are required to define this piecewise linear model for the flow capacity rate. The residuals are fitted to a zero-mean normal distribution to obtain a stochastic model for the flow capacity rate (α) based on the number of disembarking passengers (Q).

$$\alpha_{det}(Q) = \begin{cases} a \cdot Q + b & Q < Q_c \\ a \cdot Q_c + b & Q \geq Q_c \end{cases}, \text{ with } \quad \alpha_{prob}(Q) = \alpha_{det} + \mathcal{N}(0, \sigma) \tag{4}$$

The flow capacity rate which is modelled is for all access ways together. To analyse the specific ramp effective capacity the distribution of passengers between access ways must be modelled. This can be achieved by considering the ratios of pedestrians using each possible exit way from the platform.

Stochastic fit

As mentioned, there are four access ways to platforms 3/4 in Lausanne's train station: three stairways and one ramp. The capacity flow rate of unloading pedestrians is estimated for all four access ways together (distribution between access ways is analysed in section 5.3). Fitting the α-model specified in section 5.1 to the estimates obtained in the previous section leads to figure 7. The numerical results are found in table 1.
Clear correlation between the number of disembarking passengers (Q) and the flow capacity rate (α) stands out until the critical turning point ($Q_c = 333$), as the number of people disembarking from a train increases, the flow rate increases accordingly: the facilities capacity is not reached

Parameter	Value
Stand. dev.	0.74
Q_c [ped]	333
a	1.135
b	0.010
Max rate [ped/s]	4.5

Table 1: Summary of the numerical values of the *alpha*-model fit. A piecewise linear model is fitted to all flow capacity rates, then the residuals are fitted to a zero-mean normal distribution, yielding an estimation of the standard deviation.

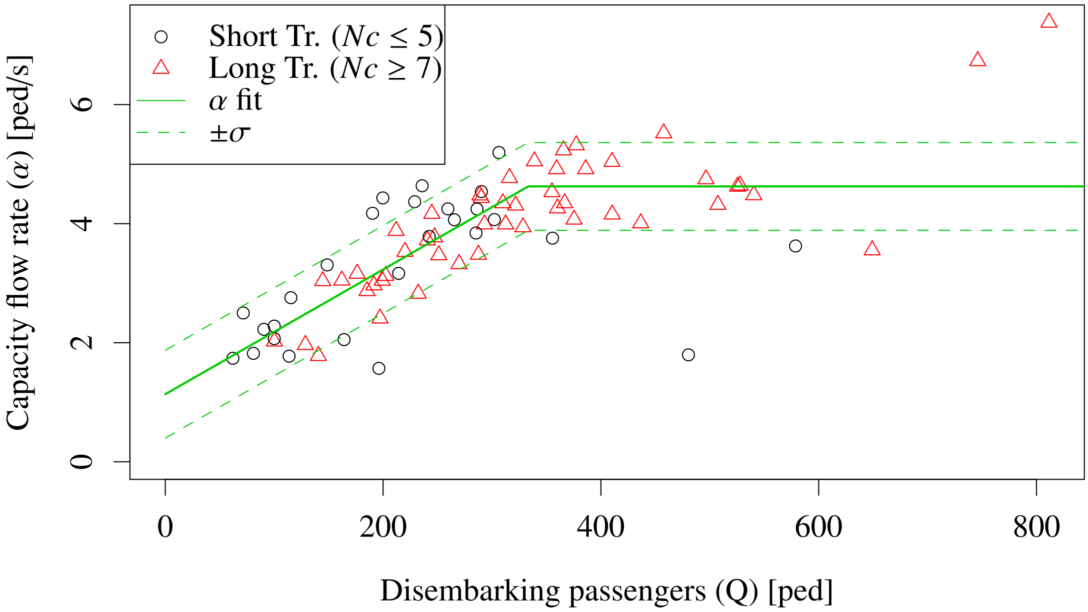


Figure 7: Q-α plot with the fit of the flow capacity rate model to the data points using least squares. With such a model it is possible to sample within the boundaries in order to obtain an estimation of the disembarking flow capacity rate. Red and black data points indicate the train length, until the turning point Q_c no trend stands out, and after this point mainly long trains are present.

for those trains. For larger and longer trains $Q \geq Q_c$ this correlation fades out and the use of a constant value for the flow capacity (α) is justified. The residuals are fitted to a normal distribution yielding the band width of $2\sigma = 1.48$.

In figure 7 red or black colours are used to differentiate between short and long trains. This categorization is not significant in this case except after the critical point Q_c. No trend stands out, hence the unloading flow capacity rate is not train length dependent, unlike the flow distribution across access ways (figure 10).

For comparison, an estimation of the theoretical flow capacity rate is made. Based on Weidmann (1992) the necessary width for having two single-line flows moving in opposite directions without hindrance is $2.2m$. In the case of Lausanne's access ways to platform 3/4, the width of the ramp and stairways is $2.7m$, considering that $1.1m$ (half of 2.2) is used by counter-flow, then only $1.6m$ remains for disembarking pedestrians. In peak hour periods (LOS E), the specific flow rate of descending stairs is $0.56 ped/ms$ and assuming that the ramp has the same specific flow rate as the stairs: $\alpha_{th} = 4 \cdot (2.7 - 1.1) \cdot 0.68 = 4.3 ped/s$. Such a theoretical estimation is in keeping with the estimate of the flow capacity model where the maximum (i.e. limiting) value is $4.5 ped/s$.

5.2 Loading flows

The same shape function f should be used to fit loading flows (i.e. a piecewise linear step-like function) with one small difference: pedestrians arrive before the train departs, and not after. Unfortunately, due to the absence of any distinctive pattern in the available data set, this methodology is inconclusive. If trains depart often from the station, the assumption can be made that a constant flow of pedestrians arrive on any platform. Hence a more simple model is used: a linear model (not piecewise-linear) is considered for these loading flows of pedestrians. The average loading rate β depends on the number of outbound pedestrians Q_m and the length of the time interval specified by $t_{max} - t_{min}$.

$$\tilde{y} = \beta \cdot t + \varepsilon = \frac{\sum_{m=1}^{M} Q_m}{t_{max} - t_{min}} \cdot t + \varepsilon \tag{5}$$

The number of disembarking passengers is extracted from the travel survey data (HOP & FRASY) and not estimated from the tracking data. Hence only one average value is obtained. The distribution of passengers using each possible stairway/ramp leading up to the platform must be estimated. The same methodology is used, except that the ratios are modelled using the overall number of pedestrians using each possible access way (not train-specific ratios).

$$v_i = \frac{\sum_m^M Q_m^{v_i}}{\sum_m^M Q_m} \tag{6}$$

The parameters are fewer in number than for unloading flows. The average loading flow rate (β) is the sum for all access ways to the platforms. The ratios v_i represent the number of passengers

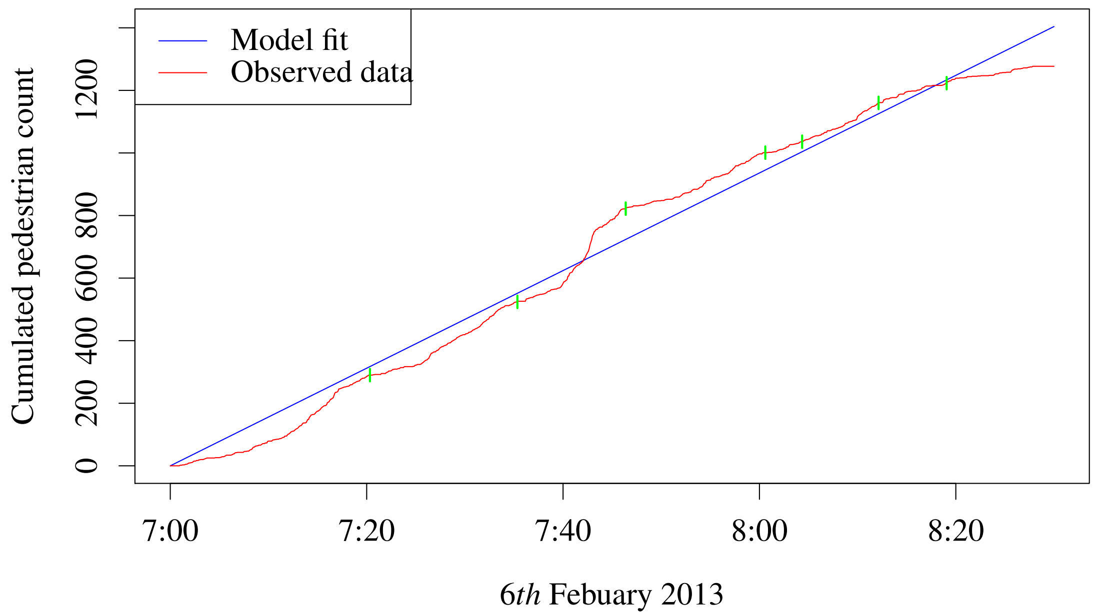


Figure 8: Fit of the loading curve for the 6^{th} February 2013. The absence of pattern imposed the use of a constant flow model. The results for the other days are similar to this one.

using each access ramp to the platforms over the total number of passengers (see figure 9, with the opposite direction).

Average flow rate

The average loading flow rate is fitted using the model specified in section 5.2. The travel survey data is used as an estimate of the number of people embarking on each train. With such methodology the flow rate is a year average, i.e. the same for all days. There is one issue though as for some trains no travel survey data is available, nevertheless the average flow rate is still calculated and yields the following:

$$\beta = \frac{\sum_{m=1}^{M} Q_m}{t_{max} - t_{min}} = \frac{2400}{4500} = 0.53 ped/s$$

The time interval is shortened (1h15 and not 1h30) since the last train has no travel survey data and extending the time interval to cover this train would lead to an underestimation of the loading flow rate.

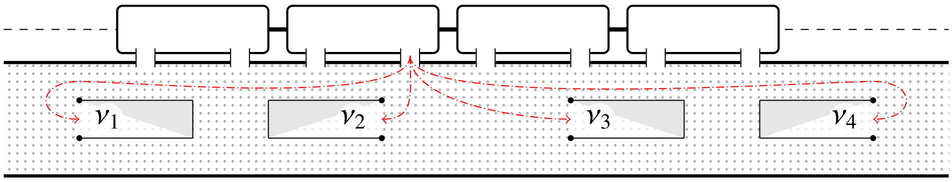


Figure 9: The flow of disembarking passengers using the different access ways to leave the platform. Stochastic estimations of the ratios of pedestrians using each possible stairway/ramp is obtained by fitting normal distributions to the number of passengers from each train using different access ways.

5.3 Access ramp distribution

The model fitting the disembarking flows estimates a flow capacity rate (α) for all access ways simultaneously. An important aspect which must not be neglected concerns the distribution of pedestrians between each access ramp/stairs to the platform. Since the flow capacity is estimated for the whole platform, a distribution between all access ways is modelled. The fraction of pedestrians using access way i is ν_i. Figure 9 illustrates the modelled phenomena.

$$Q_m^{\nu_i} = \nu_i \cdot Q_m, \text{ with } \sum \nu_i = 1 \tag{7}$$

The ratios are presented using the total number of disembarking passengers. To estimate the values of ν_i, a normal distribution is fitted to the ratios of pedestrians from each train using different access ways. This ratio definition is valid for both unloading (disembarking) and loading (embarking) flows.

Stochastic fit for unloading flows

The number of carriages of trains differs (i.e. length of trains) implying that the distance that disembarking passengers need to walk to get off the platform will change. The variation in walking distance will affect the distribution across each access way since some will be significantly further away than others depending on the place where the train stops. By analysing the ratios of people using each stairway/ramp, trains can be categorized in two groups based on their number of carriages.
Trains with five or less carriages ($N_c \leq 5$) concentrate unloading flows in the two middle access ways (sectors B & C) whilst trains with $N_c \geq 7$ tend to use all four possibilities (sectors A, B, C and D). No classification is done for trains with five or six carriages since these cases do not occur in the analysed time interval. In order to model the distribution across each access way,

Train Length	Sector	Mean (μ) [%]	SD (σ) [%]
Short trains	A	6.6	5.7
	B	49.8	11.0
	C	39.2	5.9
	D	4.3	3.2
Long trains	A	18.8	11.7
	B	31.1	8.3
	C	29.0	9.2
	D	21.0	6.7

Table 2: Summary of the normal distributions fitted to the ratios of passengers using each access ramp from platform 3/4. For short trains the two centre sectors (B & C) are used much more than the outer sectors. This behaviour can also be observed with long train, but is not as significant.

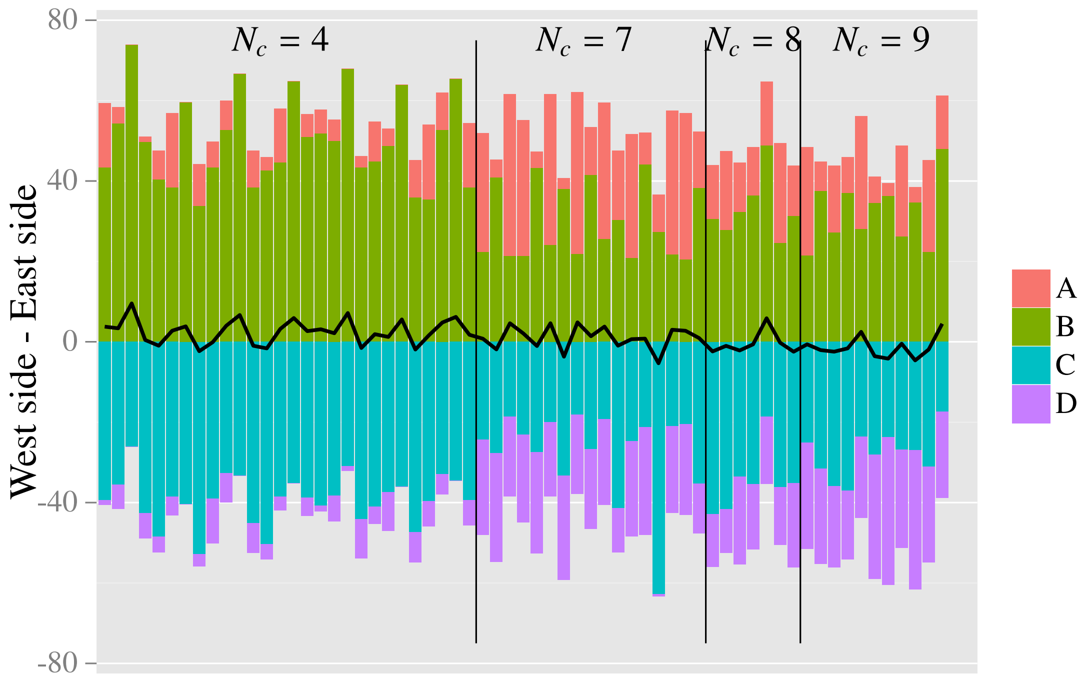


Figure 10: Flow distribution across each access way to the platform for each train in the data set. The two sections closest to the zero axis are the two middle ramp and stairway (sectors B & C) whilst the other two blocks are the outer stairways. The black line indicates the balance between East and West underground pathways (PUs). For trains with 4 carriages ($N_c = 4$) the two outer ramps are used much less than for trains with more carriages ($N_c \geq 7$). This leads to two categories based on N_c.

normal distributions are fitted to the ratios of pedestrians using each access stairway/ramp, this separately for both N_c groups.

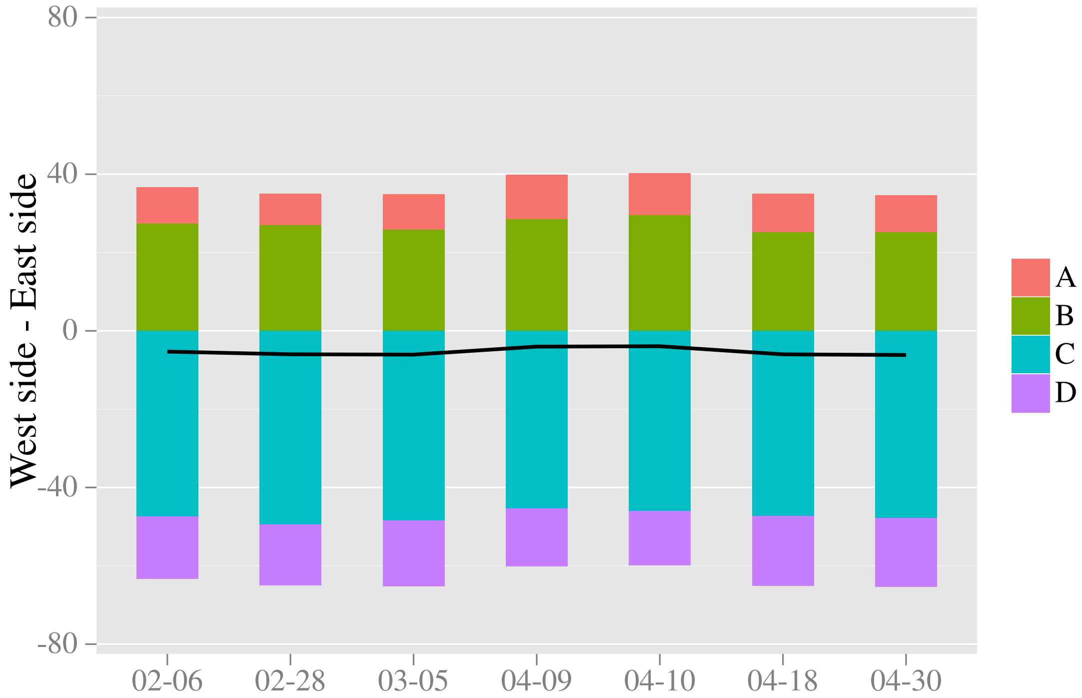


Figure 11: Distribution of the pedestrians between each access way to the platform for loading flows. PU West attracts much more people than the other. This asymmetric use comes from outside the station: buses, the metro and pedestrians are generally closer to PU West.

Stochastic fit for loading flows

Train specific values aren't available since distinction between outbound flows heading towards specific trains is not possible. Nevertheless, global ratios can be estimated for each access ramp. An estimation of the ratios of each access ramp has been done by [Benmoussa *et al.* (2011)]: in PU West, 80% use the inside ramp (C), 20% use the outside (D) stairway and for PU East, 65% use the inside stairway (B) and 35% the outside one (A). The observed ratios of load between the inside and outside access ways are of 75%-25% for both PUs. The values are similar to, with some difference in PU East. The differences certainly come from the data over which these values are calculated, our data consists of 7h-8h30 periods whereas VisioSafe used many days (or even weeks) to calculate such flow distributions.

Train type	Flow capacity rate [ped/s]
Short trains	10
Long trains	10

sector	ratio
AB	40%
C	40%
D	20%

Table 3: Table summarizing the assumptions concerning platform 1

6 Prediction

To give a complete estimation of the flow capacity rates in Lausanne's train station, extrapolation of the previously estimated values is required. Lausanne's station has ten tracks from which passengers can embark and disembark from trains. The previous analysis was performed on tracking data from the access ways to platforms 3/4. Extrapolating the results to other platforms with similar configurations is necessary to have estimations of the flow capacity rates and distributions in the whole station. Platforms 3 through 8 have the same configuration, whereas platforms 1, 9 and 70 have special configurations.

Platform 1 With direct access to the mail hall, platform 1 isn't structured like most of the platforms in the station. Many different possibilities exist to leave the platform and there isn't a bottleneck situation (access ways for platforms 3/4). Hence the limiting factor of this platform is assumed to be the train door capacity. An estimation of $10 ped/s$ for the flow capacity for all trains is reasonable given the individual capacity of each train door (Hänseler *et al.* (2014)). Table 3 summarizes the assumptions about the flow distribution between different sectors and the flow capacity rate.

Platform 3/4 The previous analysis was done on this platform, a summary of the results for the unloading flow capacity rate is presented in table 1. Table 2 presents the distribution of pedestrians between access ways (or sectors).

Platform 5/6 Identical configuration as platform 3/4, tables referenced in the previous paragraph are valid.

Platform 7/8 Nearly identical configuration to platform 3/4. The only difference is the width of the access ways, which are slightly smaller for platform 7/8. This change is taken into account by proportionally reducing the flow capacity. The reduction is about 25%. Table 4 summarizes

Parameter	Value
Stand. dev.	0.74
Q_c [ped]	250
a	1.135
b	0.0075
Max rate [ped/s]	3.0

Table 4: Summary of the numerical values of the $alpha$-model fit adapted to the width of the access ways for platform 7/8. Compared to platforms 3/4, the turning point Q_c is lower as well as the a parameter (slope) hence the maximum unloading rate is $3.0 ped/s$ (not $4.5 ped/s$ for platform 3/4)

the unloading flow capacity rate adapted to platform 78 access ways. The flow distribution is assumed to be the same as platforms 3/4.

Platform 9 This platform is again slightly different, it is only a half-platform with sectors C & D only. The access ways have a different configuration, with one ramp containing a 180° bend and the other consists of a stairway. Distribution between these two access ways is assumed to be 50% – 50%. This platform is used only for short regional trains, hence the access way isn't used to its full capacity and the train doors are the limiting factor. The flow capacity rate for this platform is $10 ped/s$ (train doors).

Platform 70 Unlike all other pedestrian platforms in Lausanne, this one is a dead-end platform. The only motivation for pedestrian to walk in direction of this platform is to take - or get off from - a train. Since the walkway leading to the platform is obstructed with a large elevator (about 60% of the width), the limiting flow capacity point is this constriction. The width available for pedestrians is $5.85m$, hence a flow capacity rate of $7.1 ped/s$ using a specific flow rate of $1.22 ped/ms$.

6.1 Prediction on platform 5/6

Validation of the parameter estimates is done using data from platforms 5/6, which wasn't used for estimation. Only travel survey data and the estimates of the parameters are required for such prediction (no complex or expensive data is required). For a specific day, the effective time table is used combined with the travel survey data to run predictions. Stochasticity is taken into account on all parameters: the flow capacity rates, dead time parameter and travel survey data

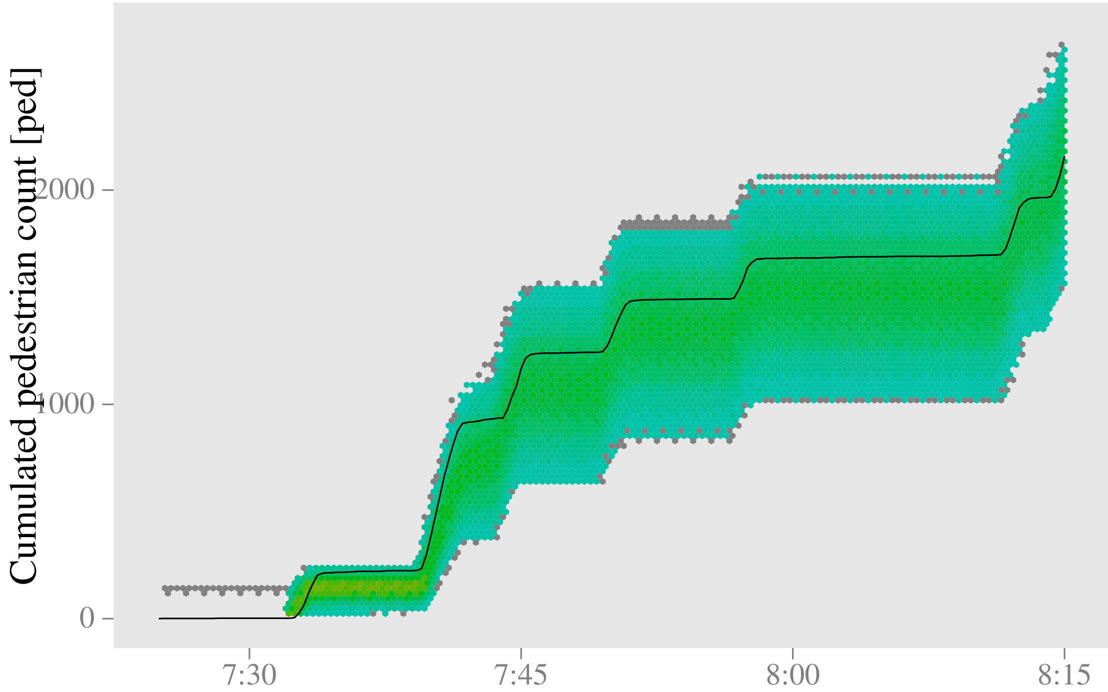


Figure 12: Prediction accomplished for platform 5/6 based on the estimates and the travel survey data. The black line is the observed cumulated pedestrian count on 30^{th} April 2013. The density based coloured band is obtained by running the prediction framework many times. The colour scale is logarithmic. This prediction is good ans both the estimated shape parameters and the travel survey data prove to be reliable.

except the effective train arrival time.

The prediction for April 30^{th} contains the observed cumulated pedestrian count, this trend is representative for the other days as well. The developed model and specifications capture the trend where each train arriving in the induces pedestrian flows in the access ways.

The limiting factor in the model is the travel survey data and the variation of the daily demand in trains. The daily variation of the demand is the main factor for the differences between the predicted cumulated count and the observed data set. Another limitation is the propagation of bad estimates in a cumulated function. If the estimated number of disembarking passengers from the first train is for from reality, then the rest of the curve is shifted. This issue can be avoided by using arrival rates instead of cumulated counts.

With estimations for the future usage of trains, predictions can also be done and integrated into station simulations in order to estimate whether the actual facilities have sufficient throughput capacity for example. Of course the numerical values presented here are valid for Lausanne's train station and the use in other stations would require analysis of the station's configuration.

7 Conclusion

The capacity to predict train induced flows using only passenger travel survey data is a significant advantage for modelling future scenarios of train stations. For different station configurations, tracks assignments or even train capacities different models can be analysed to estimate the influence of each of these parameters on the facility's pedestrian throughput capacity. The required data is cheap and SBB already have it so little investment is needed to run quick predictions for future scenarios.

Prediction accomplished on a different data set showed that the stochastic estimates of the flow capacity rates and distributions are realistic. Reliable travel surveys are critical to having good predictions since they are the base for such calculation. The flow distributions should be analysed further to investigate the motivations of passengers to choose either access ways, by using reliable tracking systems on platforms themselves for example.

8 References

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