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Commuters Rail Sations and Pedestrians Flows: The “Hardbrücke” Station in Zurich, Switzerland

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Abstract

In the dense European cities it is almost impossible to find new spaces for the private traffic. On the other hand the centripetal force of the most metropolitan areas is still raising, increasing more and more the pressure on the mobility infrastructures. Metropolitan trains allow high capacities with moderate space consumption. The success of these systems and the huge generated pedestrians flows can lead to new and sometime unexpected capacity problems. A micro simulation approach has been used to check and improve the functionality of the booming station Hardbrücke in the former industrial district of Zurich.

SIIV; Rome; conference; metropolitan railway; train station; commuters; passengers; pedestrians; micro simulation

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1. Introduction

The regional railway lines network of Zurich (S-Bahn) was in 1990 the first suburban train network that has been realized in Switzerland. It uses a railways network of about 230 km and 1'202 carriages (2005), to offer a suburban and regional transport service organized on 13 radial lines departing at the Zurich Main station at regular pace.

The service, granted by SBB (the Swiss national Railways) is based on a 30-minute frequency offer all days (about 5:30 – 24:00), on all the lines (minor exceptions for some of the longest lines that may have a frequency of 60' on the most peripheral parts). On the working days "extra trains" travel during the peak hours to offer 4 trains/hour (approximately 15' frequency). The S-Bahn Zurich transported in year 2011 an average (work day) of 400'972 passengers/day (passengers that travelled over the city borders, all corridors, all directions), which is about 2.5 times more than the initial amount of about 160'000 passengers/day.

To accommodate the demand the system has been continuously improved with better rolling stock, denser timetable and infrastructural improvement (i.e. the second underground Zurich Cross-link is going to be opened in 2015, the Station Oerlikon has been extended with 2 new tracks having shifted an historical building).

The Hardbrücke station in the former industrial part of the city of Zurich has been realized for bunch of workmen arriving there with few trains per day. The area has been now converted in a residential and services district and has about 4'500 inhabitants and 24'000 working places (2011), in the next ten years a final capacity of about 9'000 inhabitants and 46'000 working places is planned.

The station, also because of its strategical position in the railway network, is now one of the most important nodes in the metropolitan railway network of the region of Zurich (and among the 15 most important stations in Switzerland) and is served with about 550 trains/day on four tracks. On top of the waiting platform there is a bus station served by two important bus lines distributing passengers on a pericentral ring. A new tram-line has been already planned and will be realized in the next years. During 6 years (2003 - 2009) the number of passengers increased form 23'500 to more than 40'000 (+72%); with the improved local public transport connections as well as the thousand of living and working places still in the realization phase the growing rate is not going to slow down and Harbrücke will have a growing significance as both local and interchange station. The infrastructure need to be improved for the new tasks.

In 2010 the city of Zurich decided that the situation of the commuter station need to be proofed and that short term as well as long term interventions for the improvement of the safety and comfort of the commuters need to be developed. We checked the functionality of the short term improvement (project 0+) as well as the long term one (project new Hardbrücke).

2. Definition of the Evaluation Criteria

The functional level of the station has been evaluated according to the SBB (Swiss Federal Railways) standards for waiting and connecting spaces. The level A is the best, level D is sufficient; normally the level B has to be reach in each component of the station, for long waiting the level B may also be asked. In congested urban networks, where the safety problems related to passing-through vehicle is less important (e.g. a tram line) a LoS F may be during the "peak" of the rush hour still acceptable. In the following table the required level of services in the railways station are expressed as function of the density and status.

For the evaluation of stairs and corridors a maximum delay of 7 seconds can be accepted.

Table 1 Required Level of Service (LoS) of waiting and connecting spaces

Status	Minimum Value [P/sqm]	LOS
Waiting (long)	1	B Waiting
Waiting (short, train passing through)	1.5	C Waiting
Waiting (short, getting on)	2	D Waiting
Getting off	0.7	D Walking

3. Definition of the Reference Scenario

The level of service has to be assessed defining a "worst case" scenario. This has been done considering a large-scale as well as a small-scale framework. Within the large scale framework the chosen time horizon and the related development state of the surrounding areas, transport networks and transport services are considered. Within the small scale framework the critical and still realistic combination of flows during the peak hour are considered.

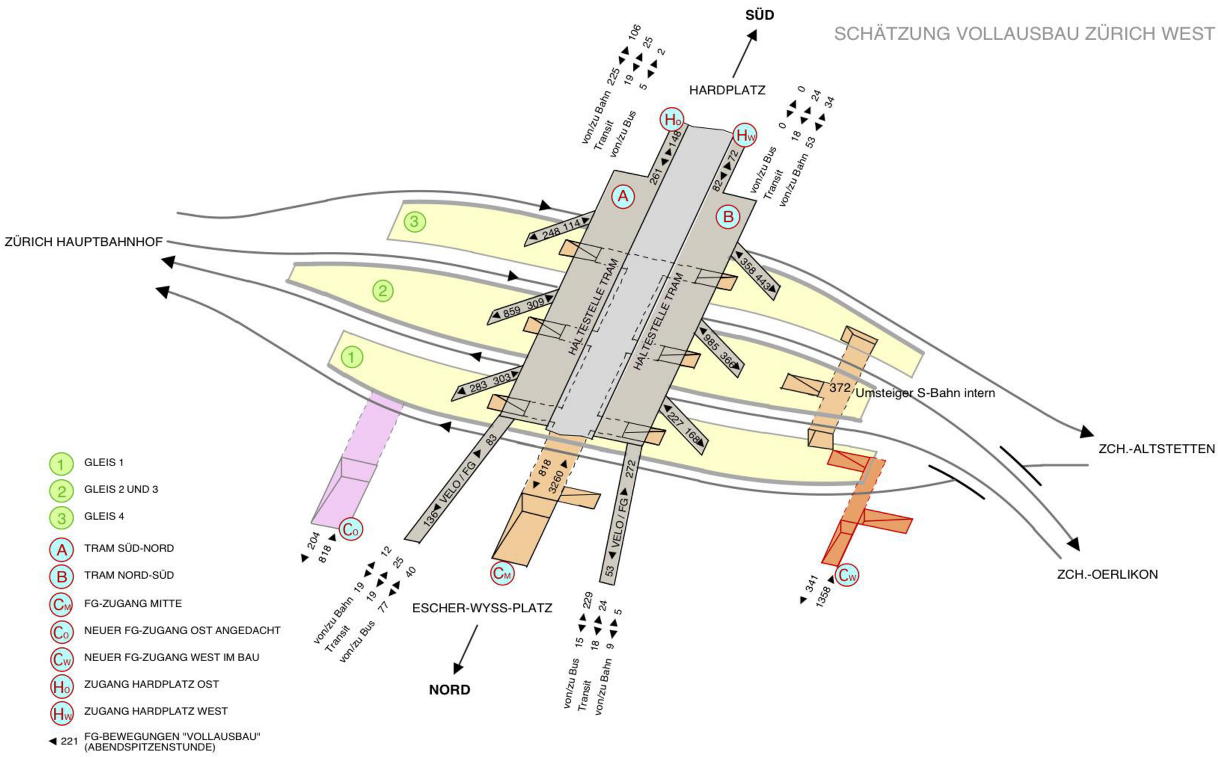


Figure 1 Pedestrians flows during the evening peak hour (2010)

3.1. Large Scale Framework

All the estimations are based on manual and automatic counting of passenger at the station and on the vehicles. In 2010 we carried a detailed counting of the pedestrians flows on each internal (train and bus platforms) and external access of the station during the morning and evening peak hours.

A theoretical long term “reference” estimations has been made considering the full development of all the known development projects and plans. In the following figure the functional layout of the station (4 tracks, 3 waiting platform, 2 bus station) as well as the estimated frequencies during the evening peak hour in the long term are reported.

Two different scenarios have been defined for the short-term project “Project 0+” and for the long-term evolution “New Hardbrücke”.

3.1.1. Project 0+

For the estimation of the demand in the short term scenario the following factors has been considered:

- Realization of 75% of the development program in the Zurich West Area (surroundings).
- Realization of a new tram-line over the station (situation with 2 bus and 1 tram line).
- Realization of the 4th development step of the S-Bahn).

As a consequence for this scenario 80% of the pedestrian flows of the reference scenario has been considered.

3.1.2. New Hardbrücke

For the estimation of the demand in the long term scenario the following additional factor has been considered:

- Realization of 90% of the development program in the Zurich West Area (sourronding).

As a consequence for this scenario 95% of the pedestrian flows of the reference scenario has been considered.

3.2. Small Scale Framework

Peedstrians flows in a railway station are characterized by strong “waves”. As a consequence the definition of the LoS cannot be made according to an hourly average, real combinations of arrivals at the different platforms need to be considered. Moreover the increase of the frequency from today on the different trains cannot be determined with a single factor: the “weaker” trains have “more space” and will grow up more than the already almost saturated ones.

The critical scenario has been defined taking into consideration the train and bus/tram timetables. For each single vehicle has been estimated the number of passengers getting on/off as well as their origin/destination. The worst-case scenario has been defined between the timetable minutes 19 and 24, when four trains arrive within 3 minutes. For the dimensioning has also been considered the possible delay of one train and therefore the presence of the passengers of about three trains waiting at the same time on the central platform.

4. Methodology

Given the complexity of the situation the functionality of the infrastructure has been proofed with the usual empirical methodology and carrying on a micro simulation. The micro simulation allows the modeling of the pedestrian movements in the station considering individual origin/destination in time and space. Each “agent” enters in the system through a simple “gate” or with a specific bus/tram/train (e.g. gate south, Tram 8 - 17:11) and heads to its destination (e.g. exit north, S-16, etc.). Agents do not jump on the first bus/tram/train that arrives on their platform; on the contrary they wait for the right one. The superposition of passengers waiting for different bus/tram/train on the same platform has a determining effect on the LoS of the infrastructure.

The complete simulation models modeled the behavior of about 5’000 passengers coming/going from the station through six entrances and getting on/off to/from 16 trams (1 line, 2 directions), 32 buses (2 lines, 2 directions), 34 trains (9 lines, 2 directions) over three layers during 30 minutes.

The simulations has been carried on using the commercial software “Simwalk” part of the Swiss Savannah Simulation AG. The complexity and scale of the problem as well as the high level of detail required resulted to be “new” for the software. An intensive and creative cooperative work with the developers was needed and carried on. Several modules of the simulation software have been radically improved to push the program well beyond its limits of the moment.

The models have been calibrated according to direct observations and literature values [1] [2]

5. Simulation

5.1. Actual Infrastructure

The actual infrastructure has been simulated using the estimated passengers flows for the reference scenarios (0+ and New Hardbrücke). The result of the simulation clearly showed that the infrastructure needs to be improved. In particular the weak links were the stair connections between the middle train platforms (tracks 2 and 3) and the bus/tram station. The central platform, which serves two tracks, shows very high frequencies (about 60% of all the train passengers), as a consequence the connecting stairs can be easily saturated by two strong flows coming from opposite directions (bus>train vs train>bus). Moreover passengers coming form the bus station tend to remain near to the end points of the stairs; this lead to congestions in the central part of the platforms where all the accesses are concentrated.

5.2. Scenario 0+

5.2.1. The Project

In the Scenario 0+ short-term improvements of the infrastructure have been planned. Basically the connection between the local transport bridge (bus/tram) and the central platform (track 2 and 3) has been doubled with two new stairs and a connection platform. The expected results are a better distribution of the passengers on the waiting platform (thanks to the new, more distributed, access points) and most of all a higher efficiency of the stairs that can be in case arranged in a one-way system to minimize the conflicts. For the simulation has been considered the one-way layout.

Near a qualitative observation of the resulting animation a quantitative check of the functional level of the infrastructure has been made according to the SBB standards. For each critical instant has been taken a “picture” of the position of the agent and the resulting densities have been calculated.

5.2.2. The Bridge

The new layout of the stairs improves the performance of the infrastructure. Relative high densities are reached near the bus station but only for very short time.

5.2.3. The Central Platform

The central platform has a surface of about 1400 sqm (without considering the 51 cm safety band on the edges), which is sufficient for the estimated 1500 to 1700 (considering the transition time after the arrival of the trains). The problem is the distribution of the passengers along the 300 m long platform and the access to the stairs and exits. The simulation shows the evolution of the density after the arrival of the trains. After 45’’ critical densities are reached at the base of the stair, thanks to the one-way layout of the stair the congestion lasts only a few seconds and after 2 minutes the “wave” is completely gone.

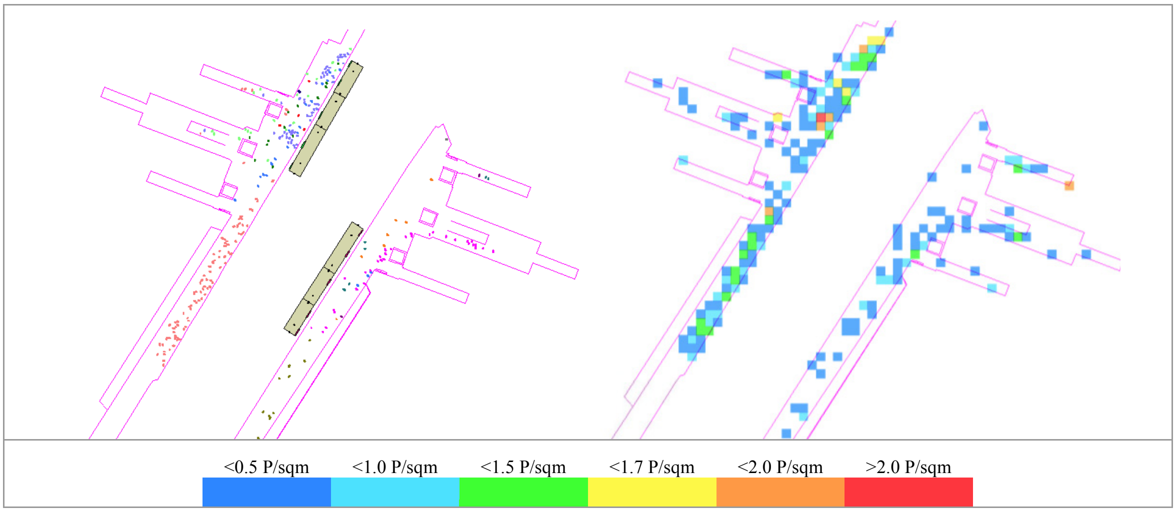


Figure 2 The Bus/tram Station: Agents and related densities on instant 17:28:09

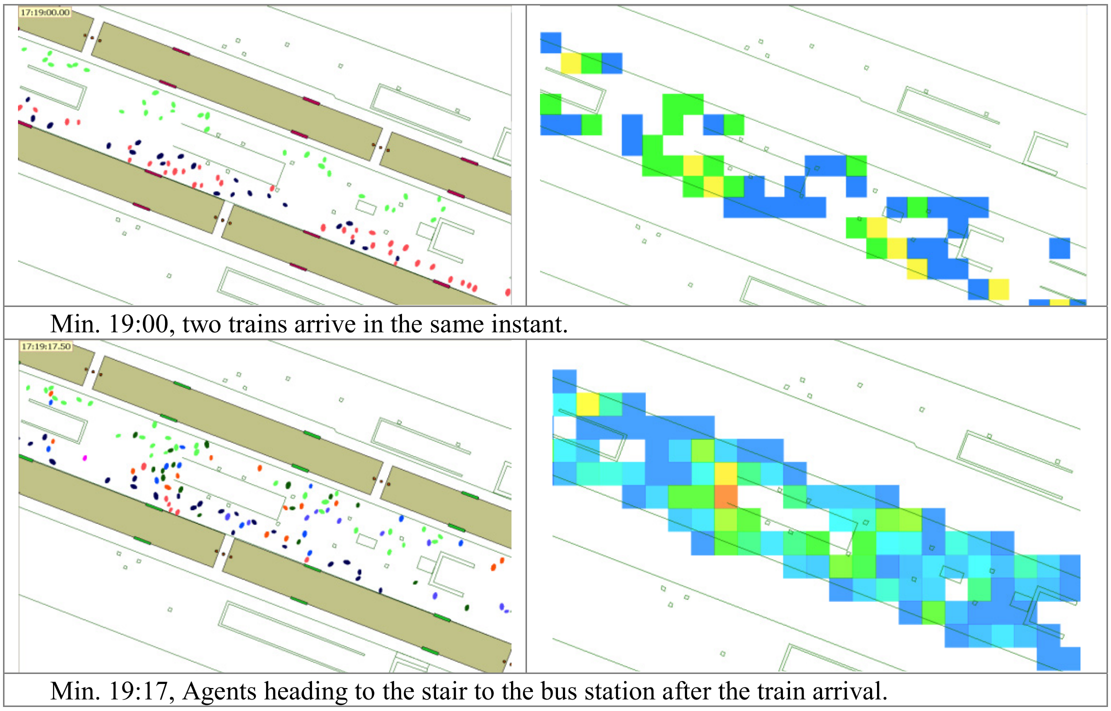
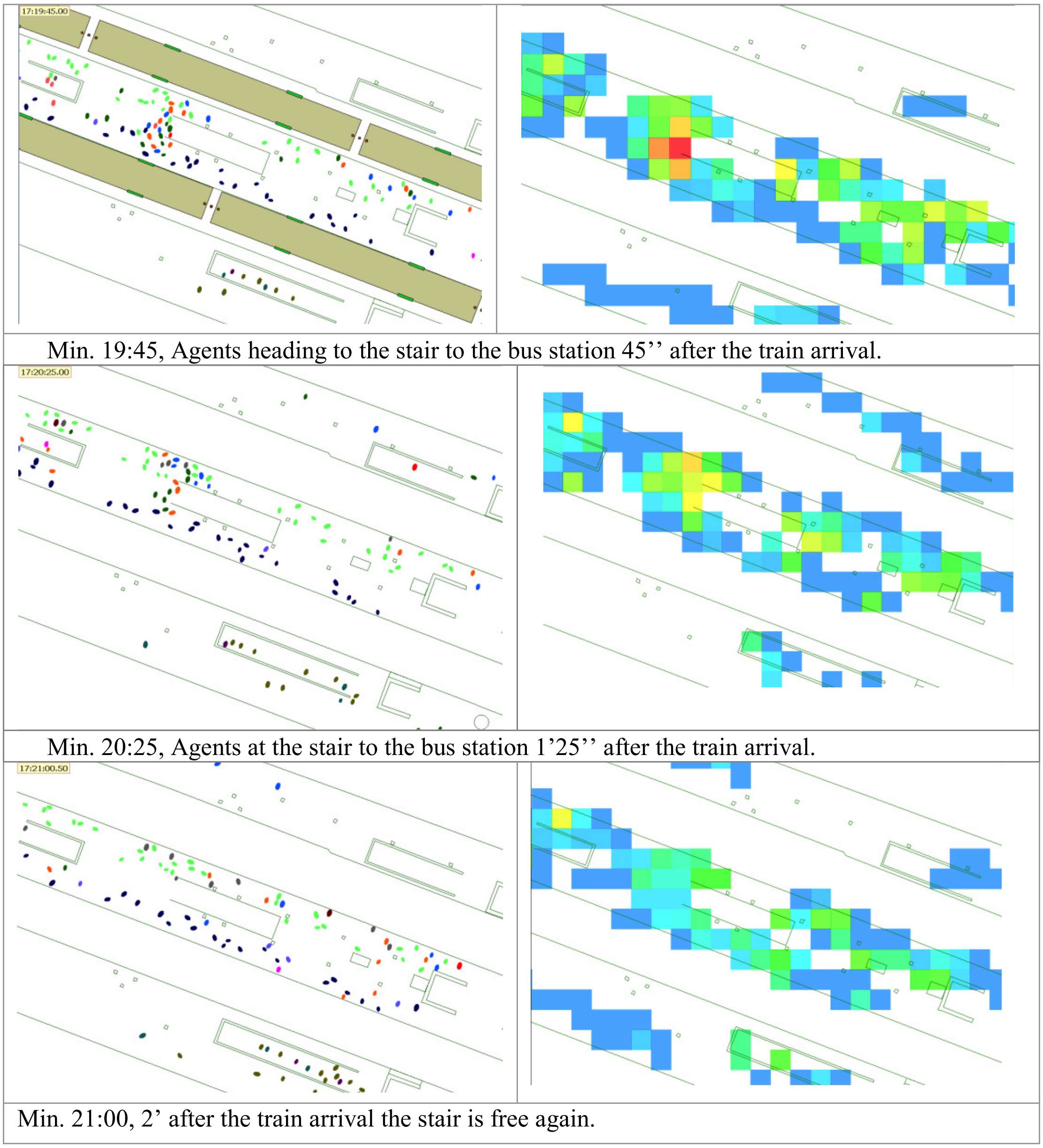


Figure 3 The central train platform: two trains arrive at the same time - evolution of the density during the first 2 minutes after the arrival (part 1)



Min. 19:45, Agents heading to the stair to the bus station 45’’ after the train arrival.

Min. 20:25, Agents at the stair to the bus station 1’25’’ after the train arrival.

Min. 21:00, 2’ after the train arrival the stair is free again.

Figure 4 The central train platform: two trains arrive at the same time - evolution of the density during the first 2 minutes after the arrival (part 2)

To check the comfort level of the infrastructure the delay at the stairs has been also considered. During the first two minutes an average of ten passengers are waiting around the base of the stair “west”, the average delay has been measured in 6 seconds, 1 second under the 7 seconds limit defined form the SBB.

The simulations show that the infrastructure respects all the safety and comfort criteria, nevertheless it works near its limit and more radical measures would be in the long term needed.

5.3. Scenario New Hardbrücke

5.3.1. The Projects

In 2011 an international architectural competition has been organized by the town council for the development of long term plans for the realisation of a new station with higher comfort and capacity standards. Five interdisciplinary teams have been invited to develop new ideas for the station. Given the complexity of the problem we were asked to make a technical verification of the functionality of the projects according the same standards and using the same methodology used for the project 0+.

All the teams developed more or less original functional scheme to achieve an optimal distribution of the pedestrians on the infrastructure. On the other hand the teams wasn't given the possibility to make any change to the geometry of the platforms. The result of the functional analysis showed that at least 3 projects achieved acceptable functional levels, but due to the lack of space on the waiting platforms, none of them could offer optimal conditions. The town councils is now using the result of the simulation to push the SBB towards the possibility of a radical redesign (and very expensive) of the station including a new layout of the rails.

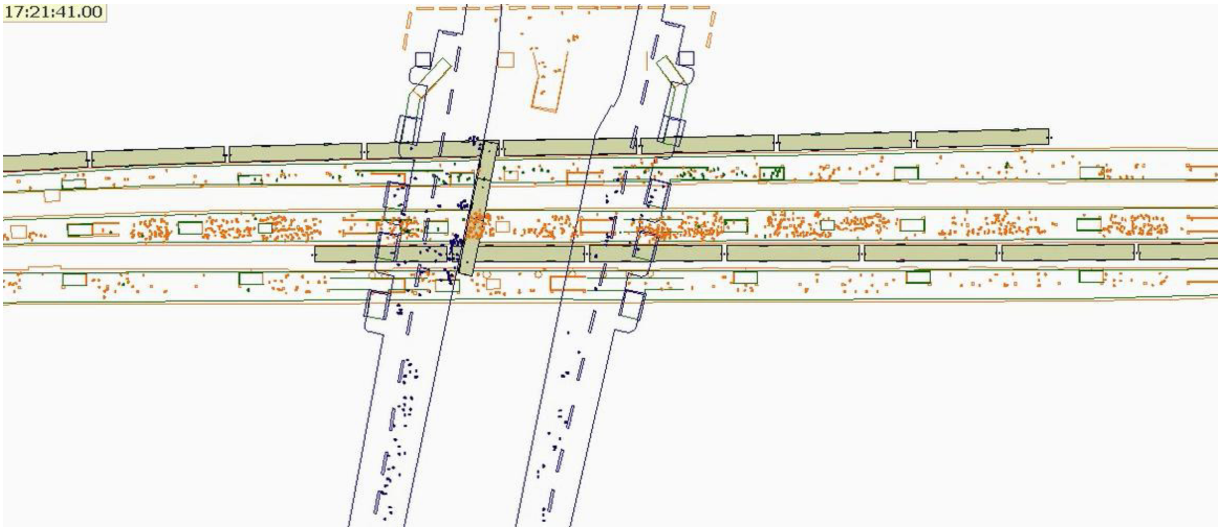


Figure 5 The train station (on four levels) simulated according to the project of Valerio Olgati.

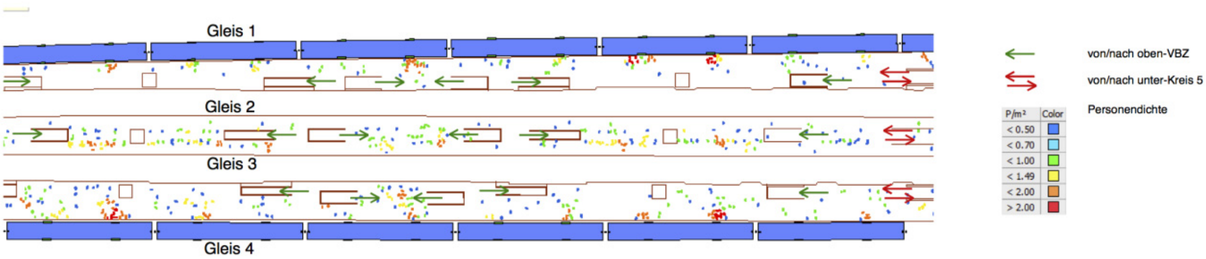


Figure 6 The train platform level simulated according to the winning project of Gigon Guyer.

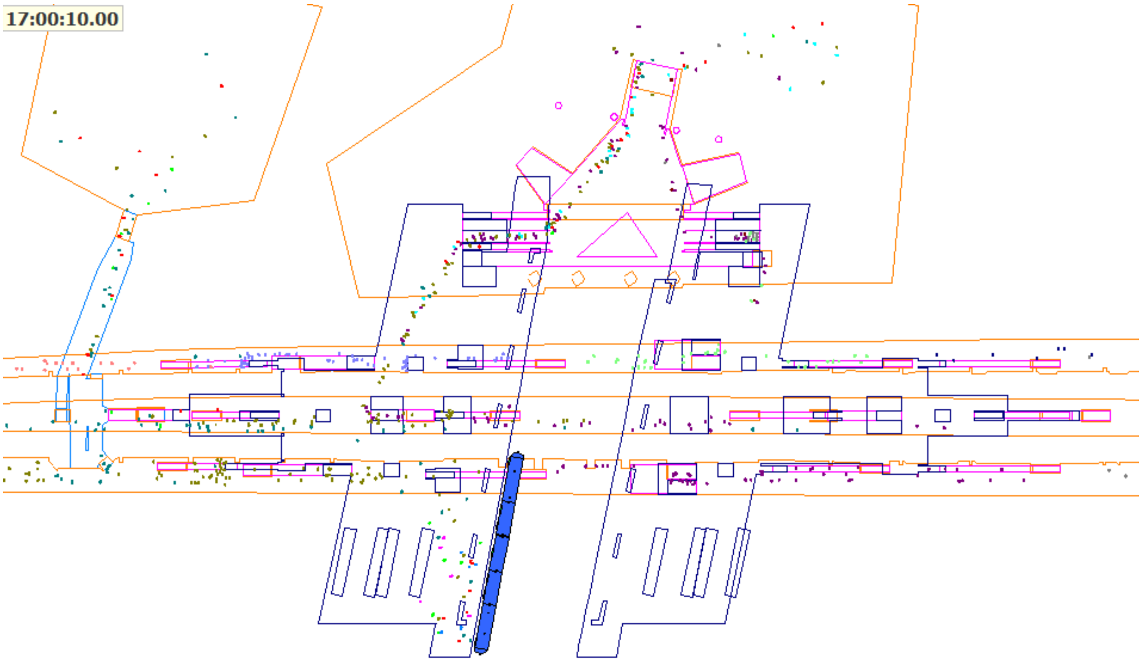


Figure 7 The train station (on 3 levels) simulated according to the project of EM2N Architects.

6. Conclusions

The transformation of the urban structures and mobility patterns make the metropolitan and suburban railways a very interesting option in the transportation panorama. The success of these concepts and the consequent increase of the passenger's frequencies put every link of the chain under pressure. Relative small stations may have to "suddenly" deal with huge waves of passengers. The underestimation of the problem can lead to severe capacity, comfort and most of all safety problems. The micro simulation approach, with the development of a detailed model in "time and space" proofed to be the right instrument to deal with complex situations such interchanges nodes. The analysis delivered interesting and valuable results that could be directly used by the decision makers.

References

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