



## D5.1: Case study set-up descriptions

Project acronym:	TRANS-FORM
Project title:	Smart transfers through unravelling urban form and travel flow dynamics
Funding Scheme:	ERA-NET call on Smart Cities and Communities (ENSCC)

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State:

Final

Distribution:

Confidential

**Deliverable History**

Date	Author	Changes
22-07-2016	Clas Rydergren	Draft for table of contents
23-08-2016	Clas Rydergren	Revised ToC and added time plan
24-10-2016	Clas Rydergren	Revised deadlines
6-1-2017	Oded Cats	Dutch case study objectives, applications and demarcation, Section 4.3
16-02-2017	Riccardo Scarinci	Hub case study description
16-02-2017	Johanna Törnquist Krasemann	Draft of Section 5, the Swedish case study specification including challenges and objectives.
22-02-2017	Menno Yap, Flurin Hänseler and Oded Cats	Dutch case study, Section 4
19-03-2017	Clas Rydergren	Review of Section 5, Added intro
28-03-2017	Patricia Bellver	Internal review, all sections

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## Summary

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This document reports on Work Package 5.1 of the TRANS-FORM project, and is entitled "Case study set-up description."

The three main chapters of the document covers the three case studies covered by the TRANS-FORM project. First, the hub level case is presented. For this case, the application are pedestrian movement analysis within the train station in the city of Lausanne, Switzerland. Second, the urban level case is presented. In the urban level case, The Hague is used as the case study area. The focus is on modelling the public transport flows operated by HTM at the urban-metropolitan level in this area. Third, the regional level case is presented. This case use the Blekinge region, Sweden as the case area. The focus is on regional trains and busses, organized by the regional public transport authority, Blekingetrafiken.

## 1. Introduction

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### 1.1. Purpose and approach

The TRANS-FORM project focus on three case studies on three different levels. For the first case, the indoor public transport station movements are in focus. In the second case, the public transport urban network is in focus. For the third case, the focus is on the public transport regional trips by regional train and regional busses. For the first case, input data from video camera analysis is used, and for the second and third case, smart card data is used for analysing the movements within the systems, respectively.

The purpose of this deliverable is to describe each of the three case studies. For each case study, a description of the case area is given, and the set up for the analyses are presented.

The material for the case study specifications has been gathered from country-specific workshops with the project stakeholder. The stakeholders and implementation partners have contributed with knowledge from their current strategies and operations. Further, data consistency, security, privacy and ownership issues for the smart card data has been tackled for each of the cases.

### 1.2. Report outline

The remaining of the document is structured as follows. Section 2 presents the hub level case. For this case, the application is the train station in the city of Lausanne, Switzerland. The focus for this case is pedestrain movements, described by origin-destiantion matrices and passenger trajectories when moving within the train station. In Section 3 the urban level case is presented. In the urban level case, The Hague is used as the case study area. The Hague is the urban agglomeration area in the west of the Netherlands. The focus is on modelling public transport flows at the urban-metropolitan level in this area. The case study covers the public transport network consisting of 12 tram lines, 8 bus lines and related train corridors. These tram and bus lines are operated by HTM, the urban public transport operator of The Hague. In Section 5, the regional level case is presented. This case use the Blekinge region, Sweden as the case area. The focus is on regional trains and busses, organized by the regional public transport authority, Blekingetrafiken.

## 2. Hub level case

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The train station of the city of Lausanne, Switzerland, is used as a case study for the hub level (Figure 1). Lausanne station is the largest node in the railway network of Western Switzerland, serving 650 arriving and departing trains and close to 120,000 passengers on weekdays (Amacker, 2012). The pedestrian facilities of the station have reached capacity in the year 2010, and a doubling of passenger demand is expected by 2030. For this reason, Swiss Federal Railways (SBB) planned an expansion of the pedestrian facilities by 2020. The station is equipped with a tracking system to collect pedestrian movements in the two underpasses linking the entrances to the platforms.



*Figure 1: Aerial view of Lausanne railway station*

In addition to the national train network, the station is a multimodal hub connecting the metro and bus systems at the urban level. It is located in an area with high public and private mobility (Figure 2). Moreover, the station is used as a pedestrian connection path between the north and south part of the city.

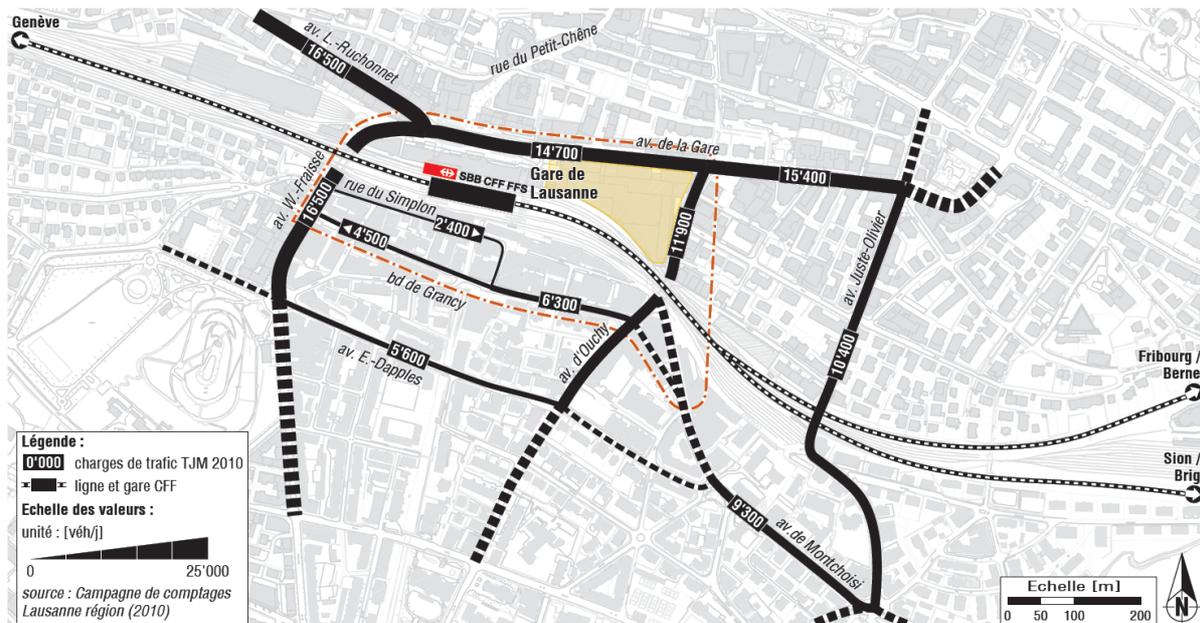


Figure 2: Average vehicular and pedestrian flows surround Lausanne train station

Lausanne train station presents appropriate characteristics to be used as a case study. The high passenger demand on the pedestrian facilities of the station results in congestion and low level of service. Accurate data are available, and new developments of pedestrian infrastructure allow a meaningful evaluation of control strategies.

In the following, we introduce the stakeholders, input data, application and methodological aims, and the case study set-up of Lausanne train station.

## 2.1. Stakeholder and implementation partner description

Swiss stakeholders are represented by the Geneva Direction Générale des Transports (DGT), Transports Publics Genevois (TPG) and Swiss Federal Railways (SBB).

SBB is the owner and operator of the train station. It has interest in understanding behavioral patterns using the hub information and video data of Lausanne train station. SBB is the provider of the tracking data deployed in the station. DGT and TPG represent the operator of bus and tram services connected to train stations. SBB is the beneficiary of the improved models at the hub and regional level, while DGT and TPG at the urban level.

We expect a contribution in different aspects from the stakeholders. SBB can share their expertise on the current practice for pedestrian management in transportation hubs, recovery strategies in case of disruptions and interface with other public transport operators. DGT and TPG can share their expertise on the current practice of bus and tram coordination with train schedules, and recovery strategies for urban busses. All stakeholders are expected to share the current needs and future challenges in operating the system.

EPFL and IBM are directly involved in the Swiss case study. We expect both methodological innovation and implementation aspects. EPFL, as the academic partner, is mostly focused on the methodological innovation, meanwhile IBM, as the industrial partner, is more involved in the implementation, scaling and commercialization of the developed methods and tools.

EPFL and IBM have previous work experience with the stakeholders and other public transportation operators, and they have completed several research and development projects in this domain successfully. Moreover, the support of the EPFL transportation center TRACE facilitates the dissemination of the project results beyond the academic community to further public and private

stakeholders and interest groups. Furthermore, the SBB Key Account Hub (collaboration platform between EPFL and SBB established in 2015) offers the possibility for the dissemination of the practical outcomes of the project to the public transport operators.

The Swiss stakeholders and dissemination partners, besides providing knowledge and idea transfer, are actively supporting a demonstration of the developed tools, and are seeking further possibilities in developing research-industry joint project collaborations.

## 2.2. Input data overview

The following data sources are available for the hub case study:

- OD flow data: flows are available for the two pedestrian underpasses, in which a tracking system is installed. This sensor system allows to simultaneously track the trajectories of pedestrians across space and time. Origin and destination zones are identified in each underpass, and OD flows can be calculated.
- Link flow data: Ten links of the pedestrian walking network are equipped with sensors that provide directed link counts with a resolution of one minute. To account for sensor saturation, observations are post-processed using a quadratic correction function.
- Traffic condition data: Pedestrian trajectories obtained from the aforementioned tracking system allow to compute the prevailing speed, density and accumulation in pedestrian underpasses. Accumulation is defined as the number of pedestrians present in an area at a given point in time.
- Train timetable and ridership data: The actual arrival and departure times and the assigned track are known for each train. An average estimate of boarding and alighting volumes is available from ticket sales data, within-train surveys, and infrared-based counts at train doors. These estimates date back to the year 2010 and are increased by 15% to reach the estimated level of the year 2013. The boarding and alighting volumes are modeled as random normal variables with a standard deviation equal to 19.2% of their mean.
- Other demand data: For the sales points located in PU West, an estimate of the number of customer visits is available.
- Infrastructure data: Detailed building plans containing the dimensions of all relevant pedestrian facilities, and the exact location of all parts of the monitoring system are available.

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

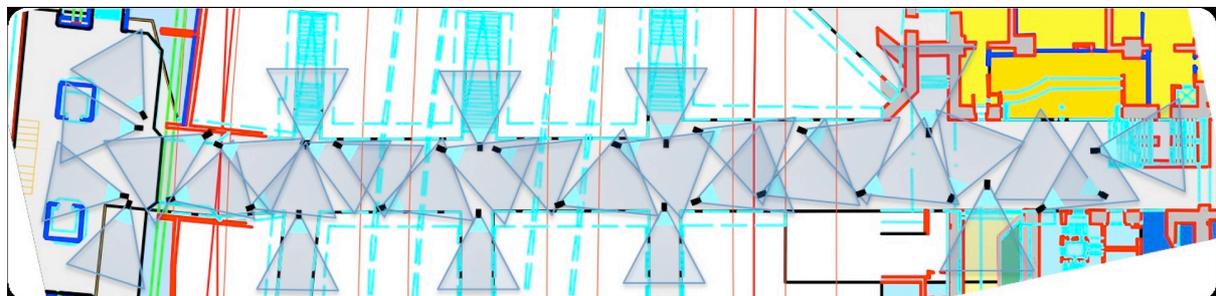


Figure 3: Location of the tracking sensors in the west underpass of Lausanne train station

From the available input data, we plan to compute indexes useful for representing the pedestrian dynamics in the hub.

- Count. It represents the number of people occupying the defined scene at a given time. It is a good indicator of the amount of traffic across time.
- Velocity. In train stations, people walk at various speeds across time. They could accelerate/decelerate to reach their destination, depending on local conditions (attractors, obstacles, presence of other pedestrians, etc.).
- Density. Density of people represents the number of people observed per unit area (in people/m<sup>2</sup>) at a given time.
- Throughput. In Lausanne corridors, people are constantly moving. A valuable measurement is the throughput. The latter represents the number of people observed per second over a given area.
- Travel time. It represents the duration of people's trajectories in seconds from their origin to their destination, both being located within the measured scene.
- Travel distance. It represents the spatial distance walked by people from their origin to their destination in meters.
- Destination flow. It represents the number of people entering a predefined area, i.e. a Destination or a predefined "door" to a given sector.
- Origin flow. It represents the number of people exiting a predefined area, i.e. an Origin or a predefined "door" to a given sector.

### 2.3. Case study aim

The aims of the case study can be classified in two different categories, namely, methodological and application. Methodological aims concern the scientific advances that are needed to perform the modelling of the hub case study. Application aims, instead, are aspects that could be applied by the stakeholders and implementation partners to the case study.

#### 2.3.1. Methodological aims

Existing models and methods can be used to develop the modeling framework that represents the hub level. However, some aspects require methodological advances to ensure an integration with the other modeling levels. These are listed in the following subsections.

##### Multi-level integration

Traditional destination choice models at hub-level consider the decision performed at urban or regional levels as static input. Passengers are generated at a specific entrance point in the train station with a pre-calculated destination by the higher-level models. This means that the dynamics at the hub-level cannot influence the pre-made decision of the destination. A challenge of the multi-level approach is to allow this "reverse" decision-making process. For example, a passenger encountering congestion in an underpass may decide to change the destination or to embark voluntarily on a later train.

In order to allow this process, we need to define what type of information should be associated to the passengers generated from the urban/regional level to the hub-level. For example, we consider currently changing train in a hub, and with the final destination in another city. In order to evaluate how the hub dynamics influence the remaining of his/her trip (at the urban level), we need to associate to a passenger the available choices (at the urban level) that she/he has to reach the destination.

##### Destination and activity choice models

A particularly challenging aspect of the hub-level model is how to represent the behavior of individuals within the pedestrian facilities. A review of destination and activity choice models should be performed, and these should be expanded including how internal hub dynamics influence the passengers' choices at the higher levels.

##### Providing information and reaction to information

The way in which passengers react to information is still largely unexplored. To evaluate the effect of flow management strategies based on "soft" control measurement, we need to model the behavioral changes accurately.

We clarify this with an example. A few minutes before reaching Lausanne train station, a passenger receives the information on her/ his mobile phone that there will be (forecasted) congestion in Lausanne underpass, and she/ he may miss her/ his connection.

A methodological challenge is to understand how the passenger reacts to this information. In case, the project gives suggestions of alternative routes, we are interested in knowing to what extent passengers comply with the suggestions, and what effects we can expect on the congestion level in the underpasses. In addition, other fundamental questions on the control strategy should be addressed, such as when to give the information, what information to give (expected average travel time, travel time distribution, worst-case travel time to reach the platform), suggestions of alternative routes and activities.

### 2.3.2. Application aims

The application aims are related to a better understanding of the pedestrian dynamics and the deployment of flow management strategies.

#### Pedestrian flow dynamics

It is expected that the hub-model will provide a more accurate modeling of pedestrian dynamics within the train station. This result can be directly used by the stakeholders to have a better understanding of activities and movement. A direct application of the hub-model is the visualization of the flows and a forecasting of the congestion level in the short future. This short forecasting capability can be used by the operators to anticipate possible unsafe situations and adopt actions proactively.

#### Pedestrian flow management

The ultimate goal of the hub-level model is to evaluate and deploy flow management strategies in the case study. It is planned to simulate the effects of two types of control on congestion level and transfer time: physical barriers and information strategies.

Physical barriers range from gates at access ramps that are open at specific times to light indications similar to traffic signals (see Figure 4-a). The modeling difference between these types of barriers is the compliance of the passengers.

Information strategies aim to suggest alternative paths or activities to passengers. They can be deployed with variables message signs inside the hub or through mobile devices (see Figure 4-b). The second type of control can reach passengers before they enter the hub, and advise them on unexpected congestion or level of services.

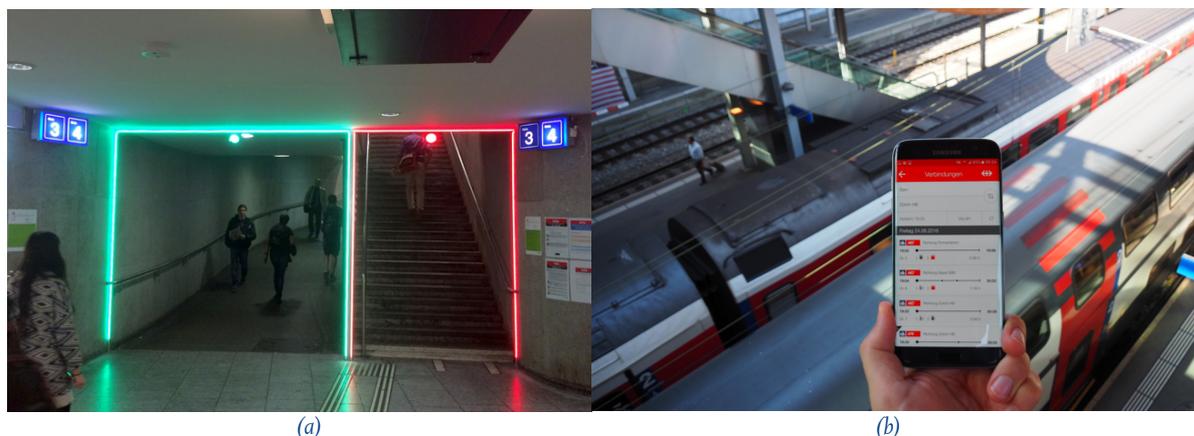


Figure 4 (a): Example of physical barriers, and (b) Information strategies to control the pedestrian flow in the hub

The objectives of the control strategies should be defined. These can be minimizing the passenger discomfort, the travel time or the density. Other approaches could try to maximize the service

reliability and ensure transfers. In all cases, simulation and forecasting of the passenger demand is needed to evaluate the most effective control actions.

#### 2.4. Case study set-up

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

##### 2.4.1. Current Lausanne train station

Lausanne railway station is the largest train station in the French-speaking part of Switzerland. Figure 5 shows a schematic map of the station, encompassing nine rail tracks for passenger traffic (thin dashed lines). At its heart are two pedestrian underpasses (PUs), referred to as PU West and PU East (vertical corridors, indicated in the figure). Platforms are shown as dotted areas. Solid lines represent the walking network of the pedestrian facilities, and dashed curves represent corresponding network links that cannot be shown in the 2D scheme. OD areas are represented by labeled rectangles. Dark rectangles symbolize entrance/exit areas as well as service points within the train station. Rounded rectangles represent platform OD areas, i.e., platform sectors or entire platforms. Pedestrian count sensors are represented by diamonds. The shaded parts in the two pedestrian underpasses represent areas that are covered by a pedestrian tracking system.

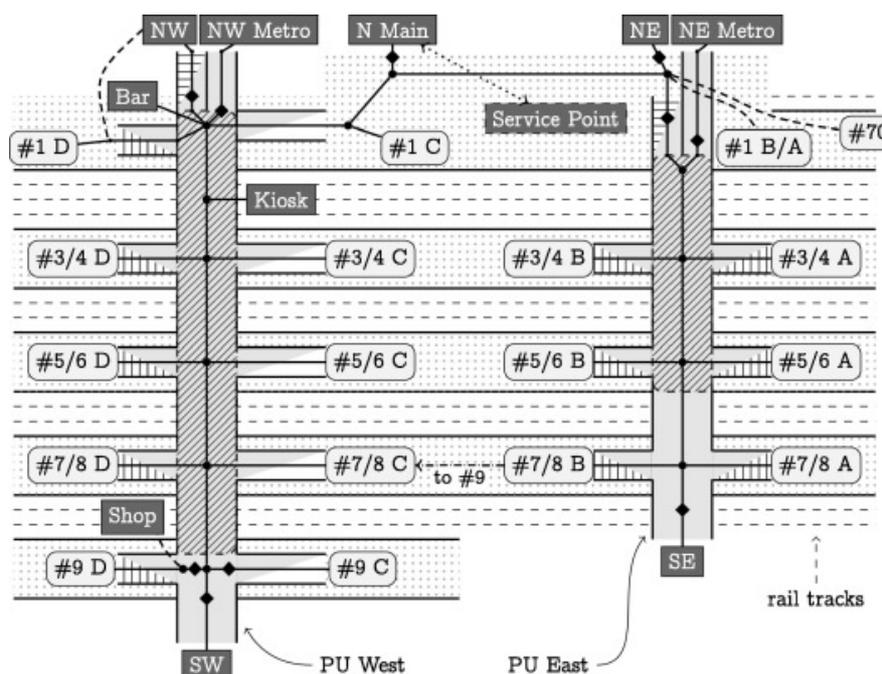


Figure 5: Schematic view of Lausanne pedestrian facilities, with underpasses, platforms and activity locations

##### 2.4.2. Future Lausanne train station

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

The station expansion involves modifications to the pedestrian facilities, installing extra tracks and extending the existing platforms. In total, EUR 1.1 billion is spent between 2010 and 2020 to enlarge the station. Three new underpasses connecting the platforms and city are planned below the tracks (Figure 6). The width varies between 17 and 19 meters, and shopping facilities are planned. The train station is connected with the urban metro line, which will be expanded too. In addition, a new exhibition area is planned, and the integration with the city is improved by a new square in front of the

south entrance. The expanded Lausanne train station is an appropriate case study for testing traffic flow management strategies. The simulated results can be useful to the facility operator to plan specific control actions and evaluate the level of service and risk in the new station layout.

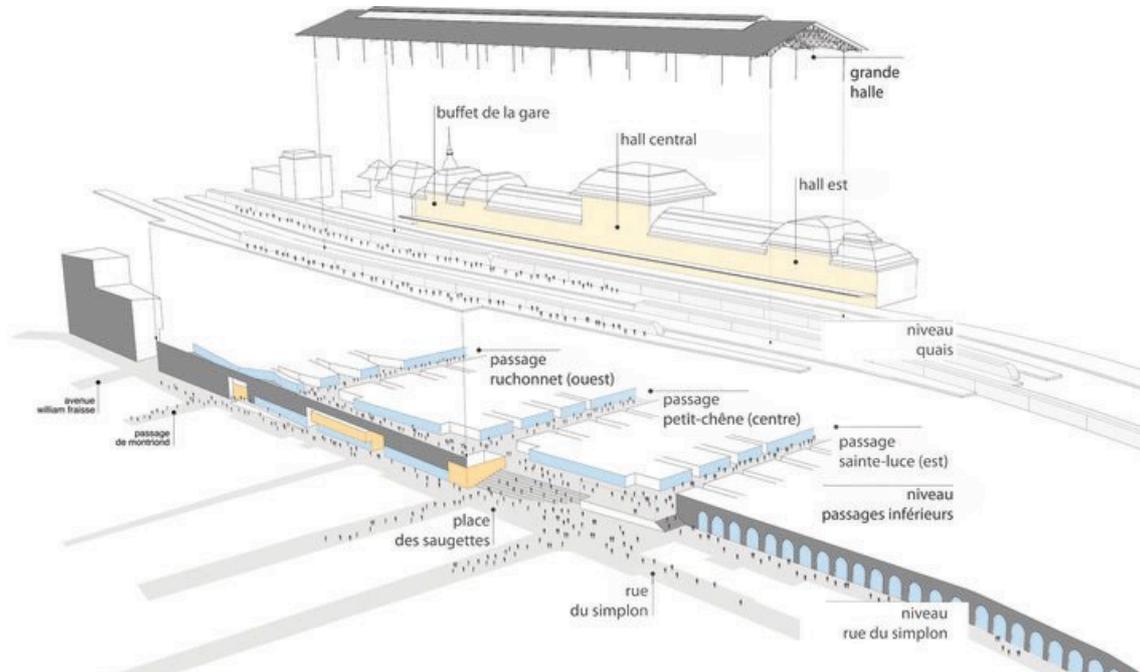


Figure 6: Expansion plan of Lausanne train station by 2020, with three underpasses and shopping facilities below ground

## 3. Urban level case

### 3.1. Geographical demarcation

The Hague, the urban agglomeration area in the west of the Netherlands is used as the case study area for modelling public transport flows at the urban-metropolitan level. The agglomeration area around The Hague belongs to the southern part of the Randstad, the most important economic area of the Netherlands, see Figure 7. The network is characterized by a grid-like structure in The Hague and two relatively long corridors extending eastwards and southwards to the cities of Zoetermeer and Delft, respectively. The case study area, also known as Hagalanden, is home to 1.05 million inhabitants.



*Figure 7: The city of The Hague (red dot) positioned in the western part of the Netherlands.*

The case study public transport network consists of 12 tram lines, 8 bus lines and related train corridors through the area. These tram and bus lines are operated by HTM, the urban public transport operator of The Hague. Two tram lines can be considered as light rail lines on the agglomeration level, connecting the main city of The Hague with the satellite city of Zoetermeer. The other 10 tram lines function on the urban network level providing connections between different areas within The Hague. The eight considered bus lines all belong to the urban concession area of HTM in The Hague. The urban bus lines of the cities of Delft and Zoetermeer, as well as the regional bus lines between Delft and Zoetermeer, belong to another concession area operated by a different public transport operator, and are not part of the case study network. The case study network consists of 498 bus, tram and light rail stops. In addition, regional and intercity train services intersect with the urban public transport services in a number of stations in the case study area. On an average working day, about 250.000 public transport journeys are made with the 12 tram lines and 8 bus lines operated by HTM. More than 80% of the journeys is made by tram; the remaining share by bus, see Figure 8.

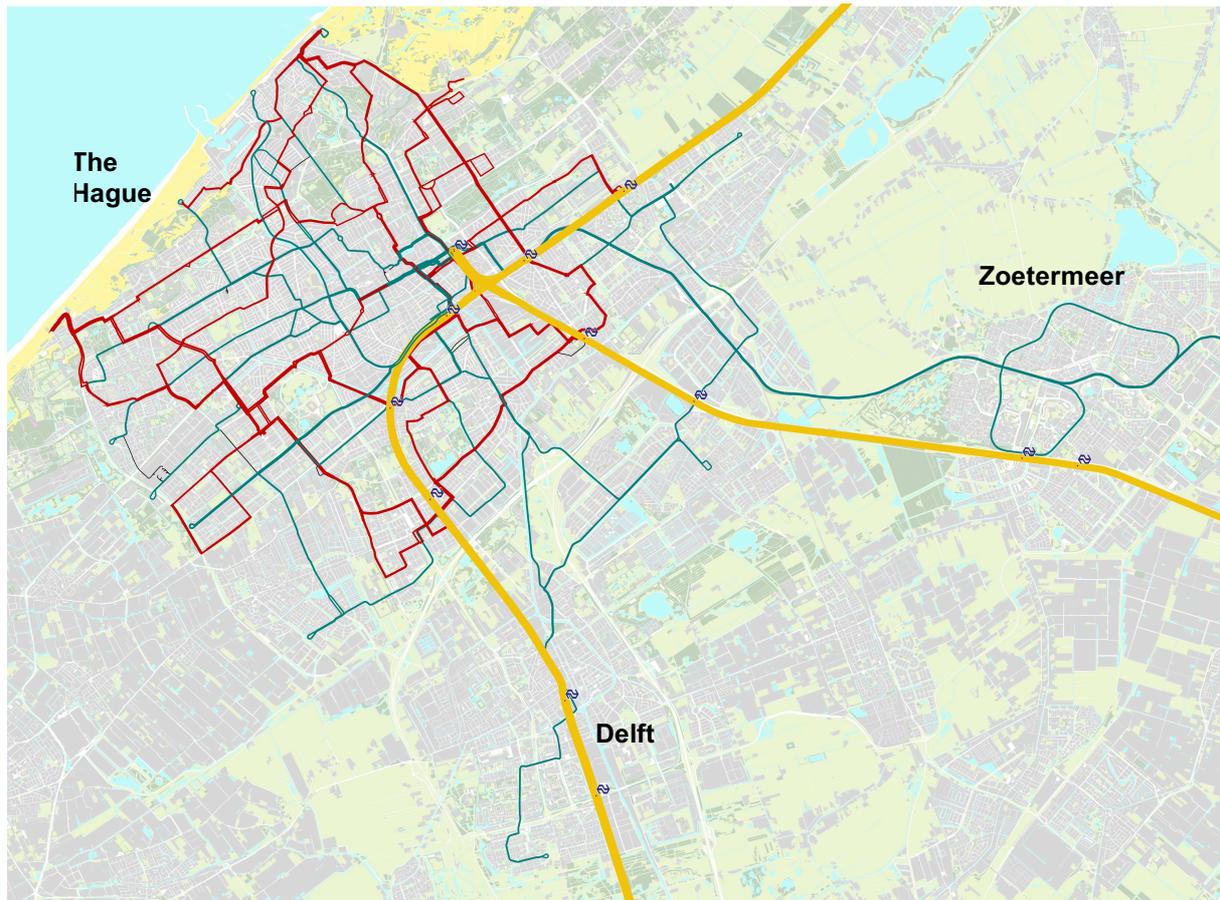


Figure 8: The public transport network of The Hague urban agglomeration area (yellow: train lines; green: tram lines; red: bus lines)

The following train stations and corresponding service lines/corridors are represented:

- Den Haag Centraal
- Den Haag HS
- Den Haag Laan van NOI
- Den Haag Moerwijk
- Rijswijk
- Delft
- Delft Zuid
- Den Haag Mariahoeve
- Voorburg
- Den Haag Ypenburg
- Zoetermeer
- Zoetermeer Oost

And all train lines that traverse these stations with gate nodes for the parts extending beyond this network.

The following hubs are identified for detailed analysis:

- Den Haag Centraal (train-tram-light rail-bus)
- Den Haag HS (train-tram-bus)
- Den Haag Laan van NOI (train-tram-light rail-bus)
- Spui (tram-light rail-bus)

In addition, the InterCity corridor between Utrecht and Amsterdam Airport (Schiphol) is investigated to study pedestrian flows in congested conditions across multiple stations. Specifically, the relevant

platforms of Utrecht Centraal, Amsterdam Bijlmer and Amsterdam Zuid are modelled. Figure 9 shows a map of the corridor.



Figure 9 Network of NS, the Dutch national railway operator, with the Utrecht – Bijlmer – Amsterdam Zuid corridor highlighted.

The platform at Utrecht is of special concern due to its small width, where understanding the distribution of passengers e.g. in presence of train disruptions is of major concern. Additionally, in Amsterdam Zuid the platform access ways represent a bottleneck that can delay passenger movements. Figure 10 shows a picture of the corresponding platform, where it can be seen that even during off-peak periods prospective passengers get critically close to the railway tracks.



Figure 10 Picture of platform in Amsterdam Zuid, which is used as part of a case study to analyse the distribution of passengers on platforms.

In collaboration with the Dutch National Railways (NS), and subject to data availability, the passenger distribution on trains and on platforms can be analysed. Arguably, such knowledge is useful to forecast passenger flows and their influence on transit safety and efficiency in situations of high demand, for instance due to train disruptions. This includes also transfer flows, or flows in stations that are not yet critical, but may become so in the near future as in the case of several stations in the Den Haag-Rotterdam area.

### 3.2. Stakeholder and implementation partner description

The key partners in the project are HTM and the Rotterdam The Hague Metropolitan Area (in Dutch called the MRDH: ‘Metropoolregio Rotterdam Den Haag’). Other stakeholders are the municipality of The Hague and possibly NS, ProRail and RET. The role of all stakeholders is shortly described below.

- HTM is the urban public transport operator of The Hague. It operates the light rail and tram lines in The Hague and surrounding cities, as well as the urban bus lines within The Hague. As indicated above, HTM does not operate regional bus lines, nor urban bus lines in Zoetermeer and Delft. HTM is a privatized organization, of which the shares are for 100% owned by the municipality of The Hague. Aside from some regional bus lines starting and ending in The Hague. HTM is also responsible for maintaining the rail infrastructure. In case of disruptions, HTM has its own control centre where rescheduling measures are taken.
- The MRDH is the transport authority of the Randstad Zuidvleugel: the southern part of the Randstad. The Zuidvleugel is a larger area than only the agglomeration around The Hague: also the Rotterdam agglomeration is part of it. All 23 municipalities, The Hague and Rotterdam being the largest, are represented in the MRDH. Currently, the MRDH is responsible for six different public transport concessions: the rail concession of The Hague, the urban bus concession of The Hague, the regional bus concession around The Hague, the rail concession of Rotterdam, the bus concession of Rotterdam, and the bus concession of Voorne-Putten (located in southwestern direction from Rotterdam). Train lines passing through the area are not part of the concessions coordinated by the MRDH. As transport authority, MRDH sets

performance standards for HTM, for instance related to punctuality, infrastructure availability and customer satisfaction.

- The municipality of The Hague holds 100% of the shares of HTM. Although The Hague is represented in the MRDH, the city itself does not function as transport authority.
- RET is the public transport operator of Rotterdam. Its role is comparable with the role HTM has in The Hague. RET is privatized, but all shares are owned by the municipality of Rotterdam. RET operates the metro, tram and bus lines in Rotterdam. In The Hague, there is a distinction between urban bus lines (operated by HTM) and regional bus lines (which are tendered to private public transport operators), whereas RET operates both the urban and regional bus lines around Rotterdam. Like HTM, rescheduling during disruptions occurs from the RET control room.
- NS, the Dutch Railways, operate the main train lines in the Netherlands. The NS is also privatized, although 100% of its shares belong to the Ministry of Finance of the Netherlands. NS has the unique right to operate trains on the main lines in the Netherlands. The Ministry of Infrastructure and Environment functions as transport authority for NS. Regional train lines in the Netherlands are tendered and operated by private operators.
- ProRail is the train infrastructure manager of the Netherlands. This means that ProRail is responsible for infrastructure maintenance for the whole train network. Besides, ProRail allocates capacity to different train operators, such as NS, private operators and several freight train operators. In case of disruptions on the train network, ProRail has the main responsibility to decide how the train services are adjusted. This is done from one central control room ('operational control centre rail') and 13 decentral control rooms. ProRail takes responsibility during disruptions how train services are adjusted: the train operators are responsible for the rescheduling and recovery of their own train and personnel schedules during disruptions.

### 3.3. Input data overview

- Network and timetables (GTFS): GTFS (General Transit Feed Specification) data contains all information about the route of all public transport lines, as well as the scheduled timetable for each run of each line. This means that for each run, for each stop the scheduled departure and arrival time can be found in the GTFS data. In the Netherlands, GTFS is open data.
- Smart card data (AFC: automated fare collection data): AFC data contains all transactions made by public transport passengers. In urban public transport travelling in the Netherlands, passengers are required to tap in and tap out at devices within the vehicles. This means that for each individual transaction the boarding time and location, and the alighting time and location of each journey stage are known. Also, it is known in which public transport line, vehicle number and trip number each passenger boarded with their unique smart card number. AFC data in the Netherlands is private data, owned by the public transport operator.
- Vehicle position data (AVL: automated vehicle location data): AVL data provides the scheduled departure and arrival times, and the realized departure and arrival times for each public transport run at each stop. Each public transport run is indicated by the same trip number as appears in the AFC data. This means that by integrating AFC and AVL data based on the corresponding trip number, vehicle occupancy on the urban public transport network can be inferred for each run between each stop.
- Rail infrastructure: this data contains the track layout of the considered case study network. It contains the locations of switches, junctions, turning possibilities, depots and (only relevant for the train and light rail network) signalling and safety blocks.
- Station layouts: this consists of detailed data of rail infrastructure and platforms of all modes serving a specific station or hub. It also contains the position of escalators, elevators, stairs, facilities (like shops or the ticket office) and walking area.

### 3.4. Case study aim

The case study analysis has the following objectives:

- Assessing passenger service reliability when considering the whole urban journey as well as specific elements, in particular transfer related
- Identifying the impacts of rail service disruptions and rescheduling on passenger flows
- Evaluating link vulnerability when accounting for delay and congestion propagation
- Development of, and comparison between different indicators of link criticality
- Evaluating strategies such as transfer synchronization in the event of a disruption while considering the impacts of train and pedestrian traffic
- Investigating the impact of hub dynamics and transfer reliability on transfer location choice
- Test the implications – in terms of results, sensitivity and usability – of representing (1) passengers movements from and to train arrivals and departures; (2) train rescheduling; (3) transferring time at hubs.

Ultimately, the interface between modelling components will allow making more informed decisions when controlling the progress of urban public transport vehicles with the objective of improving passenger travel reliability as a function of: (i) updated train schedules; (ii) expected transfer walking time; (iii) observed and predicted urban public transport vehicles; (iv) observed and predicted passenger flows.

Urban PT vehicle control decision = f (train schedules (train traffic), hub walking time (pedestrian flows), urban PT vehicle movement, passenger movements)

Examples for possible applications include:

- Represent in greater detail urban-hub-rail interactions for the case study area
- Network-wide calculation of probability of missed connections
- Quantify passenger journey reliability including transfer times
- Impacts of transfer hub/line capacity management on passenger flows (hub-urban delay and congestion interactions)
- Analyze passenger redistribution effects in case of train disruptions
- Evaluate the impacts of alternative transfer sync. control designs with different levels of demand data (e.g. holding based on anticipated passenger flows)
- Evaluate the impacts of real-time information on urban connections on rail to urban transfer station choice
- Modelling of pedestrian paths across stations (e.g. to understand choice of platform waiting position)
- Safety/performance evaluation of rail access facilities (platforms, platform access ways)

### 3.5. Case study set-up

The case study analysis consists of three modelling components to be performed in the following order:

1. Modelling train traffic on the selected corridors and generating new timetables in response to disruptions
  - a. Input: Rail infrastructure, timetables, disruptions
  - b. Model: Train traffic model
  - c. Output: New train timetables
  - d. Performed by: BTH
2. Modelling pedestrian movements in hubs
  - a. Input: Station layout, OD pedestrians
  - b. Model: Hub pedestrian model
  - c. Output: Pedestrian flows, (distributions of) transfer times between platforms
  - d. Performed by: EPFL
3. Modelling vehicle and passenger movements in metropolitan networks

- Input: Infrastructure, timetables, AVL, OD passengers, train reschedules, hub transfer times
- Model: Public transport operations and assignment model
- Output: Vehicle and passenger flows, passenger and vehicle costs
- Performed by: TUD

## 4. Regional level case

### 4.1. Introduction

The case study on the regional level and the interface between regional, inter-regional and national public transport services in the TRANSFORM project focuses on the public rail transport service network of Blekinge and its connection to surrounding regions. The region of Blekinge is located in the South-East of Sweden along the Baltic Sea and has an area of 2946 km<sup>2</sup>. The region consists of five municipalities and has in total approximately 154 000 inhabitants. The largest city is Karlskrona with approximately 65 000 inhabitants. Since this particular region is not as densely populated as in the other two case studies, and the frequency of regional services and alternative services is not as high, the reliability and predictability of services is very important in order to enable citizens to select public transportation over their car. Hence, this case study focuses on efficient mobility management for urban and rural areas. The backbone of the public transport system in Blekinge are the single-tracked railway lines “Blekinge Kustbana” and the “Kust till kustbanan”, see Figure 11.



Figure 11: A snapshot of southern Sweden, where the greener area including Olofström and Sölvesborg in the west and Karlskrona in the east, refers to the region of Blekinge. Source: Länstransportplan för Blekinge 2014-2025, Region Blekinge.

Between Karlskrona and Malmö/Köpenhamn (via Kristianstad and Hässleholm), the regional trains “Öresundståg” are running every hour and stopping at every larger station with some minor exceptions. The travel time between Karlskrona and Kristianstad is approximately 1h 30 min. There are also train services, “Pågatågen”, between Karlshamn and Kristianstad during the morning and afternoon, and where one can transfer to other south-bound trains from Kristianstad. Since public transportation in Sweden is organized and regulated according to the law “Kollektivtrafiklagen”, these regional services are organized by the connecting regional public transport authorities, including Blekingetrafiken, but operated by the private train operator that won the public tender, Transdev. Similarly, the train service

running between Emmaboda and Karlskrona, “Krösatågen” are organized by Blekingetrafiken and operated by a private operator, also in this case Transdev.

During 2016, over 2 Million train trips were made with Blekingetrafiken, which is an increase of 17 percent from 2015. The largest increase was on the stretch Emmaboda-Karlskrona. Blekinge also has a large bus service network, where some regional bus lines run in between the train departures and serve the train stations and also the municipality of Olofström, which is not connected directly to the railway line.

In order to travel from/to Blekinge to larger Swedish cities such as Växjö, Göteborg, Linköping, or Stockholm by train you have different alternatives depending on your origin, but in any case minimum one train transfer is required and in some cases additional train and bus transfers are necessary even if you depart from the main cities central stations. The most important train connection points are on the boarder to Blekinge, or just outside. Those are Kristianstad, Hässleholm and Lund as well as Emmaboda and Alvesta. The robustness and reliability of those connecting services and transfers are therefore of significant interest to measure and analyze in this study.

When transferring from one train service to another train or bus service, those are often operated by different train operating companies. There may be services organized by the same regional public transport authority (RKM) but operated by different companies, but there may also be services organized and operated by private companies, typically the commercial long-distance train services offered by SJ, Transdev, MTR, etc.

In addition, the railway traffic management is carried out by the national transport authority, Trafikverket, which is responsible for re-scheduling the different trains that are operated by various private train companies, such as Öresundståg/Transdev or SJ. So the public transport services are managed in real-time by several different organizations and if the distributed decision-making is not coordinated when delays and disruptions occur it affects the passengers negatively. Furthermore, in order to enable a passenger-oriented regional public transport management, information about the passenger flow, and the associated transfers, is also necessary.

#### 4.2. Stakeholder and implementation partner description

The Swedish stakeholders are represented by Region Blekinge/Blekingetrafiken, the Swedish Transport Administration, and Municipality of Karlshamn/Netport Science Park. It is expected a contribution in different aspects from the stakeholders.

- Region Blekinge/Blekingetrafiken is, together with Skånetrafiken/Öresundståg, responsible for the train service between Karlskrona-Kristianstad-Malmö in Sweden. This service is called Blekinge kustbana, and is operated by Transdev. The trains in this service continues to Copenhagen and Helsingør, Denmark. Blekingetrafiken is, together with Kalmar länstrafik, also responsible for the train service Karlskrona-Emmaboda-Nybro-Kalmar. This service is also operated by Transdev. Blekingetrafiken operates eight boat passenger traffic routes in the Blekinge archipelago. Blekingetrafiken is also responsible for the bus services in the Blekinge region. Part of this is the local bus traffic in Karlskrona, Ronneby, Karlshamn and Sölvesborg. Regional bus routes are operated between Karlskrona-Karlshamn-Olofström. The bus service are operated by Berkvarabuss. Blekingetrafiken have contributed with the public transport ticket data used in the case study, and will take part in defining and reviewing the case study.
- The Swedish Transport Administration (Swedish: Trafikverket) is the government agency in Sweden responsible for long-term infrastructure planning for transport: road, rail, shipping and aviation. Trafikverket owns, constructs, operates and maintains all state-owned roads and railways. Trafikverket will contribute in reviewing the case study and actively seek further

possibilities in developing research-industry joint project collaborations in the domain of covered by the case study.

- Municipality of Karlshamn/Netport Science Park has three focus areas, where one is Intelligent Transport Systems. Netport will participate in seminars and exchanges of ideas related to the project and the case study as well as dissemination activities. The municipality of Karlshamn is also funding part of the work with the case study.

#### 4.3. Input data overview

Time table data for the study area is available from Samtrafiken and includes both planned train services and other public transport services connecting the nodes/stations. This data is available in the GTFS-format<sup>1</sup>.

Dynamic data concerning trains operated within the Swedish railway network are published as public data by Trafikverket via an open API<sup>2</sup>. This data gives the actual state of the running trains and their ETA (Estimated Time of Arrival) when the trains are delayed. The system does not provide any historic data. This dynamic data does not include any information on actual connections or transfer times. Scheduled connections can be identified via the timetables instead.

In order to perform analysis on the passenger flows, several data sources need to be combined. Information from ticket data provides information about the number of travelers on trip legs, but does not contain information about the intended destination and planned connections.

The smart card data is connected to a specific card-id, and an anonymized card-id will, however, remain unique for the data instance so that connected trips can be identified and linked over the given time period. Single trips purchased in the ticket machines, but it does not currently include trips bought via the apps. Those purchases correspond, however, to less than 5% of all purchases.

#### 4.4. Case study challenges and aims

This case study has two main goals:

- 1) Enabling good estimations and analysis of the Quality of Service (QoS) for the public transport service network, using available passenger flow data.
- 2) Enabling a more passenger-oriented real-time public transport service management.

Previously the passenger flow and transfer activities for the region of Blekinge has been assessed via manual questionnaires mainly, although smart card data exists. This smart card data has not been explored yet by Blekingetrafiken, nor used for the purposes mentioned here. So by merging various data sources, including the smart card data, and developing suitable filtering and matching algorithms to apply on this data, better estimations of what trips and transfers that occur should be possible. Such analysis should be able to answer questions like:

- Which are the most frequent trips and transfers?
- Are those transport relations sufficiently robust and how are the passenger transfers affected by different disturbances?
- What are the actual transfer times and unscheduled waiting times, and what factors seem to have a significant impact on the success rate?

We therefore intend to develop and apply tools that merge available data sources and analyze passenger flows and PT system performance. The purpose of these tools is to identify weaknesses and

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<sup>1</sup> <https://www.trafiklab.se/api/gtfs-sverige-2>

<sup>2</sup> <http://api.trafikinfo.trafikverket.se/API/Model>

possible improvements that can increase service reliability and reduce the impact of disturbances and the associated delays.

As described in the introduction, the real-time management of the regional transport services is currently not sufficiently coordinated, nor is it passenger-oriented. This is both an organizational and technical challenge. In order to address this challenge we intend to develop and evaluate concepts and tools to enable an improved real-time coordination and passenger-oriented public transport delay management. The concepts and tools will be based on mathematical models of the re-scheduling and delay management problem and use optimization methods to solve them.

In order to incorporate the passenger perspective in the re-scheduling of railway traffic and associated public transport services, the passenger demand and passenger flow needs to be assessed and quantified somehow and also explicitly represented in the decision-making model. Previous models of the railway traffic re-scheduling problem consequently needs to be extended to better capture also the passenger-perspective. Traditionally, focus of such models has been on train delays rather than on passenger delays and the use of passenger flow data in the models is rather rare so far. The extensions primarily concerns:

- Including the passenger flow explicitly and potential associated dynamics
- Including alternative services provided by e.g. the bus operators.
- Including a more detailed model of train station configurations for the track and platform allocation and better estimates of minimum transfer times for different pairs of platforms.
- Including and comparing alternative constraints representing the different potential holding strategies in the delay management problem (to wait, or not to wait).
- Including and comparing different objectives considering train delays, passenger delays, connections, rolling-stock restrictions and the potential conflicts between different objectives.

The developed tool(s), i.e. a computer-based decision-support module, has two main purposes: It can be used to study the effect of alternative decision-making models and delay management strategies, but it can also be used as a real-time decision-support. In both cases, but primarily in the latter, the computation time is important. A significant challenge is therefore also – in addition to the modelling challenge – the selection and implementation of an effective solution method.

#### 4.5. Case study set-up

The case study analysis consists of several modelling components covering integration of the multiple-levels of hub-level, urban level and the regional level. The multi-level integration ensures that even since the focus for this case is on the regional level, aspects from the hub and urban level will be either considered directly, or indirectly from results of the hub and urban level studies.

The main part is the modelling of train traffic on the selected corridors and stations covered by the study area described above. The input to the modelling is train and regional bus time tables and their associated routes/infrastructure, approximate passenger data gathered from the public transport ticket data analysis, together with disruption scenarios which are gathered from insights from historical train data.

Based on identified, feasible, smart real time strategies, the decision support tool will provide suggestions on relevant measures to implement, either for trains or regional busses.

Multi-level integration with the hub level will be developed based on, from the passenger data, identified transfers. Together with the physical layout of the analysed station pedestrian flows will be inferred and distributions of transfer times between platforms, provided by the hub level analysis, will be used. The distributions of transfer times between platforms will be provided by EPFL.

Figure 12 gives an overview of the railway network related to the case study area, where the red line and blue line show the single-track railway lines explicitly studied while the black and green lines are connecting railway lines that are important also because of the connecting train services.

For the analysis, the variability measures described in Deliverable 2.1, Section 3.3, will be utilized.

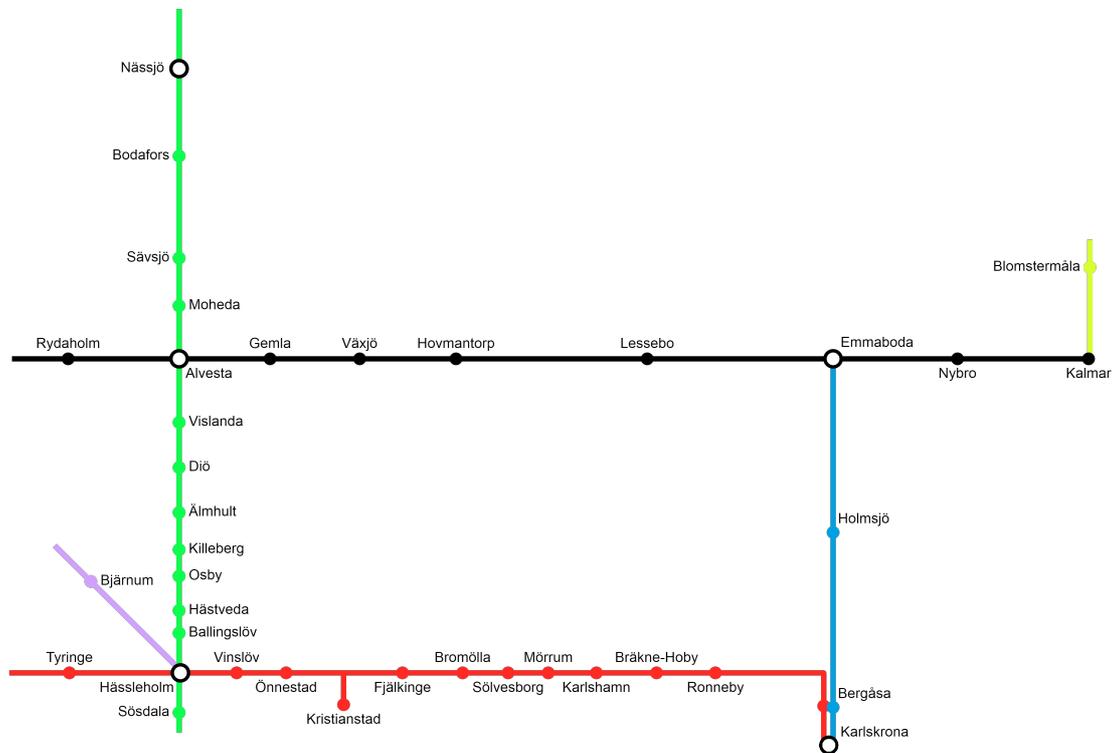


Figure 12: Overview of the railway network included in the case study.

## 5. Conclusions

In this deliverable, the set-ups for the three case studies have been outlined. Their respective geographical area has been presented and a description of the transport related infrastructure is given. Further, an overview of the input data used in the case studies are presented, together with the different stakeholder, which, for two of the cases also supply the input data. Finally, the multi-level integration is outlined for each of the cases, where it is apparent that all cases can make use of the hub level analysis or results, and the urban level case can integrate with both the hub level and the regional level.