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Major public transport hubs in the light rail design and operation

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Abstrakt

Background and objective of the paper

Light Rail Transport systems (shortly LRT in the text) are experiencing a second youth in Europe in general and more specifically in Northern European countries in recent years.

New lines are built and existing LRT networks are extended, both in countries where they previously existed (like in Denmark) or where they see the light for the first time.

We see an important goal in the planning process of a LRT in conceiving and designing user friendly projects, which will attract the maximal number of customers. Only by obtaining this goal a LRT will be a successful alternative to road/private traffic and hence be the driving factor for an environmentally conscious urban development.

Thus a key factor in the realization of the design and the operational concept of a high performance LRT is to guarantee rapid and trustworthy connections combined with optimized and reliable interchanges with other public transport modes.

This will give the customers the feeling of a competitive transport service they will choose because of its attractiveness.

The paper will analyze the role of major public transport hubs in LRT projects during the realization of the design and the operational concept:

- which are the main issues integrating a new LRT hub in the existing public transport network?
- what operational, infrastructural or systems solutions make the hub attractive?
- what operational challenges have to be overcome?

Applied methods, analyses and approach

We will carry out an analysis utilizing a two level approach:

1. General analysis of the main elements of the hubs within the LRT line:

- layout (infrastructure, systems, customer focus)
 - operational issues (general operational functioning of the hubs, special issues concerning timetabling,
2. Analysis based on experience gained with the modelling of the LRT line/network including hubs using an operational model (e.g. OpenTrack, VISSIM)

Results

The results will be presented by comparing real life examples of different interesting/similar LRT projects followed by Rambøll and currently ongoing the design and operational concept stage like e.g. Copenhagen, Utrecht and others.

For each LRT project the main elements derived from the operational simulation of the LRT lines and specifically for the hubs will be presented, like:

- Interactions with other public transport modes such as buses, S-Trains
 - Impact on LRT operation (for the LRT line/network and the hub)
 - Impact on project and external stakeholders
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Introduction

The present article considers a peculiar aspect in LRT projects: how LRT hubs can contribute in building the success of a LRT line/network?

From LRT conception till construction and further developments we intend to analyse the key elements to needed to guarantee LRT is a successful part of the whole Public Transport system.

The question how connections with other transport means are planned and realized is fundamental to ensure the LRT system attracts the maximum number of customers and to make it a successfully alternative to road/private traffic and hence be one of the driving factors for an environmentally conscious urban development.

Using the example of three LRT projects in three cities in this article we analyze the role of major public transport hubs in LRT projects during the realization of the design and the operational concept.

The three cases considered are briefly presented and are located in the following cities:

- Utrecht, the Netherlands
- Greater Copenhagen, Denmark
- Heidelberg, Germany

These three cases are similar and different at the same time which allows an interesting comparison of issues emerged and solutions proposed. Or a deeper analysis of one of the cases as good practice if an issue has been considered especially for this one.

- Similarities:
 - all projects concern key LRT hubs with several PT modes involved
- differences - projects types and stages:
 - planning/design of a completely new LRT line for the Ring 3 LRT (or Hovedstadens Letbane) project, including several hubs with existing PT modes, Glostrup being the major and most challenging one expected
 - evolving one existing line into an LRT network by planning/design an additional LRT line in Utrecht, with parallel planning/design of a new layout of the central station hub
 - reorganization and strengthening of a major LRT hub layout in Heidelberg as part of an overall strategy to increase the overall attractiveness of the light rail network in the city.
- Differences in the scales of these hubs:
 - million passenger hubs with also medium/long distance travel connections for Utrecht and Heidelberg
 - predominantly a more local/regional scale for Glostrup in the Greater Copenhagen

Glostrup in the Ring 3 LRT project, Greater Copenhagen (Denmark)

Type of project: new LRT line with creation of several new PT hubs at S-train stations



Glostrup station along the LRT Ring 3 line

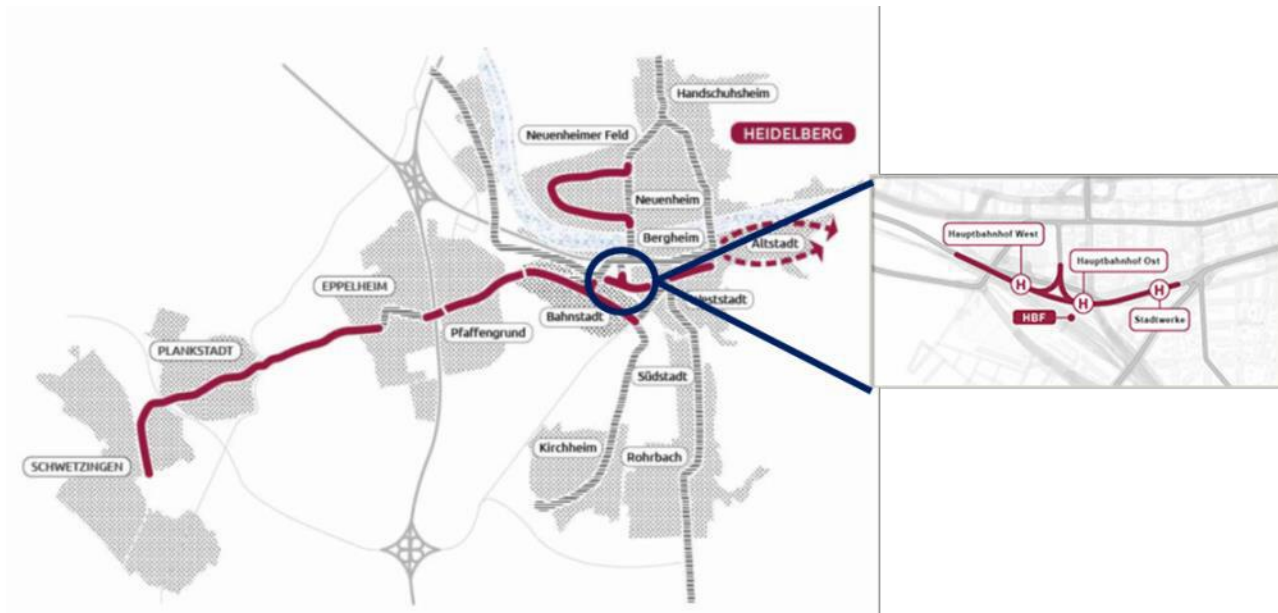
The Ring 3 LRT project is a new LRT line running along the Ring 3 road axe in the Greater Copenhagen Area expected to be in operation in 2021. It will have 27 stations on a 27-kilometre line and frequent services at five-minute intervals on weekdays make the light rail an attractive public transport solution. The light rail is expected to carry 13-14 million passengers a year. The passenger total may increase to 17-18 million, as the area gradually develops.

The Ring 3 LRT will be a high performance public transport system in the Greater Copenhagen area connecting the Ringby municipalities along the north-south axis and all commuter and regional train lines to and from the centre of Copenhagen conceived in the Finger Plan, which has been the backbone of the public transport system in the area since the 1940s. The Ring 3 light line will cut across all the commuter train lines and therefore it will create a transport network with new, major traffic hubs at the stations at Glostrup, Lyngby, Buddinge, Herlev, Vallensbæk and Ishøj. Glostrup is expected to be the most important one in terms of passengers' exchange. The new hubs will underpin other public transport plans in the Greater Copenhagen area including the metro line Cityringen which opens in 2018 and the national strategy which aims to develop new public transport hubs.

This will change the transport infrastructure in the metropolitan area providing an easy means of transport between the new well-served hubs and access to workplaces, educational institutions, cultural and sports activities and shopping facilities in all 11 municipalities along the line. It will be a feasible alternative to cars for commuters dogged by road congestion. Consequently, public transport will become more attractive for the local population and it is expected that almost half of the passengers will use the light rail in combination with other public transport modes. For this reason, the light rail and the new traffic hubs must be designed to create optimal conditions for transit between light rail, commuter, region and national train and bus services. This will be done in cooperation with DSB, Banedanmark and Movia (bus operator).

LRT station Hauptbahnhof Nord (central station North), Heidelberg (Germany)

Type of project: reconstruction of the main LRT hub Hauptbahnhof Nord at Heidelberg central station



Hauptbahnhof Nord LRT hub in the LRT network

The Hauptbahnhof Nord is currently the second busiest LRT station in the network of Rhein-Neckar-Verkehr (rnv) GmbH, the light rail operator serving Mannheim, Heidelberg and Ludwigshafen and a crucial interchange point, not only for the local mobility within the city but also for the regional and national railway network.

The current location and layout of this hub where LRT, bus and railways services connect has become inappropriate to satisfy the new challenges imposed by a growing demand. The LRT station currently positioned between the road lanes of one of the major road axes in Heidelberg forces the passengers coming from the train station to cross two-lanes of highly utilised and sometimes congested road arterial road, no matter from which direction they want to reach the LRT station. This is highly limiting the efficiency of the hub (longer time to reach the connection mode in both directions and/or pedestrians occupying the LRT tracks for longer periods while trying to cross). In addition the consequences of this forced behaviour in terms of safety are not to forget as well as the negative impact on the general perception by passengers.

The current project, which is part of a larger LRT improvement project called “Mobinetz HD”, consists in relocating the LRT station closer to the station building: this will significantly improve accessibility and consequently the global efficiency of the hub, the overall safety conditions of the hub area and the customer-friendliness. At the same time the conversion is intended to accelerate public transport (PT) and improve traffic flow. As today, both light rail and bus services will utilize the new PT station.

The reconstruction of the Hauptbahnhof Nord is scheduled to begin end of 2016. It is not a completely new LRT hub, but the new design and conception of the existing LRT hub. Therefore is particularly interesting as an example how to find the optimal solution for new needs under existing constraints.

Which are the main issues integrating a new LRT hub in the existing public transport network?

We see an important goal in the planning process of a LRT and in particular of a LRT hub, to conceive and design a user-friendly project, which will attract the maximal number of customers. Only by obtaining this goal the LRT will be a successful alternative to road/private traffic and hence provide the basis for a more sustainable mobility.

A three steps approach

With passengers in focus of the process, we are of the firm believe that while approaching a LRT hubs' project the following issues need to be considered (in order of priority):

- First: passengers are the primary focus, the LRT hub should secure high global quality service for passengers
- Second: the hub is a service provider, a crucial point where many different PT and non PT networks converge and their optimal operational functioning should be assured
- Third and last: passengers and service should all fit into an infrastructure, hence the optimal infrastructure to assure all this needs to be identified and should be realized

These three elements exercise a great mutual influence on each other: with the approach mentioned we recommend to bear in mind always these connections while setting clear the priority to follow.

E.g. starting planning the hub infrastructure without having clarified which is the service we aim to provide could lead to the need of not planned and therefore costly modifications, if such modifications are possible at all. Or again not considering if there are particular passenger needs in a specific case could lead to inadequate planning of the service not satisfying the customers.

Of course all this should go without forgetting the balance with other elements such as cost effectiveness since an LRT hub project should be realized, under the given economic framework, to be effective.

Planning a LRT hub

How can this approach influence the real activity of (re-)planning a LRT hub? Following are the elements to consider in the process:

- Location and space – position in relation to dimensioning: often the location is predetermined by crossing of pre-existing transport systems hence the challenge is to integrate optimally a new strong PT mode like LRT in a location often constraint. This is the situation for all our three cases although their impact on the surroundings is different due to their scale. Glostrup is local-regional scale hub with high impact on the local environment (e.g. optimization of road layout and LRT hub layout in connection with the bus and existing S-train). Bigger hubs like Utrecht OVT and Heidelberg Hauptbahnhof Nord are undergoing a global redefinition and therefore including heavy restructuration of space sharing with the other system with an overall integrate conception approach at high scale.



Glostrup LRT: visualization of new LRT hub in an area limited by existing constraints (existing buildings, tracks,...)

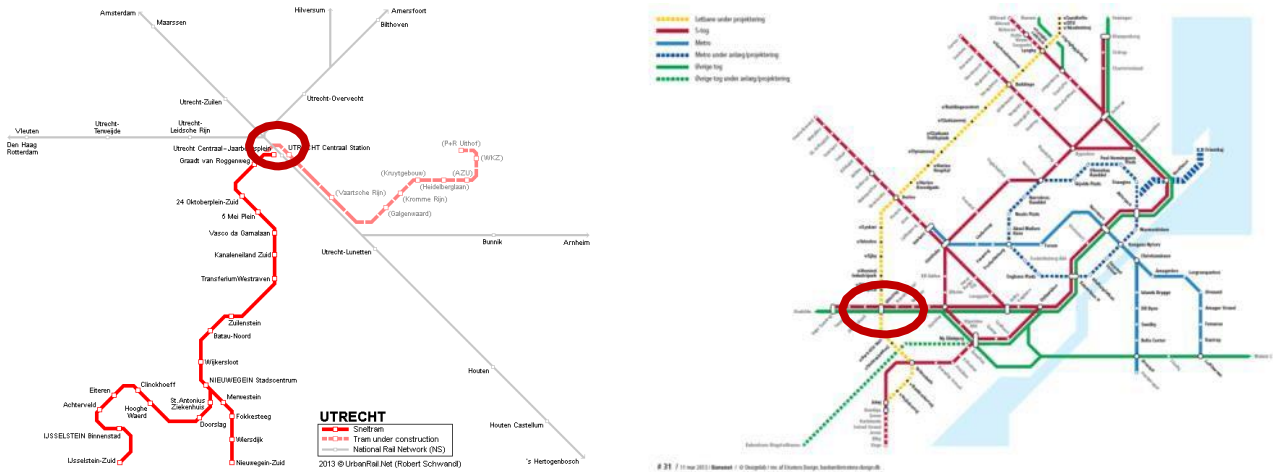


Hauptbahnhof Nord Heidelberg rebuilding the global layout of an existing multimodal hub (left) and Utrecht OVT visualization of the planned hub in the existing environment (right)

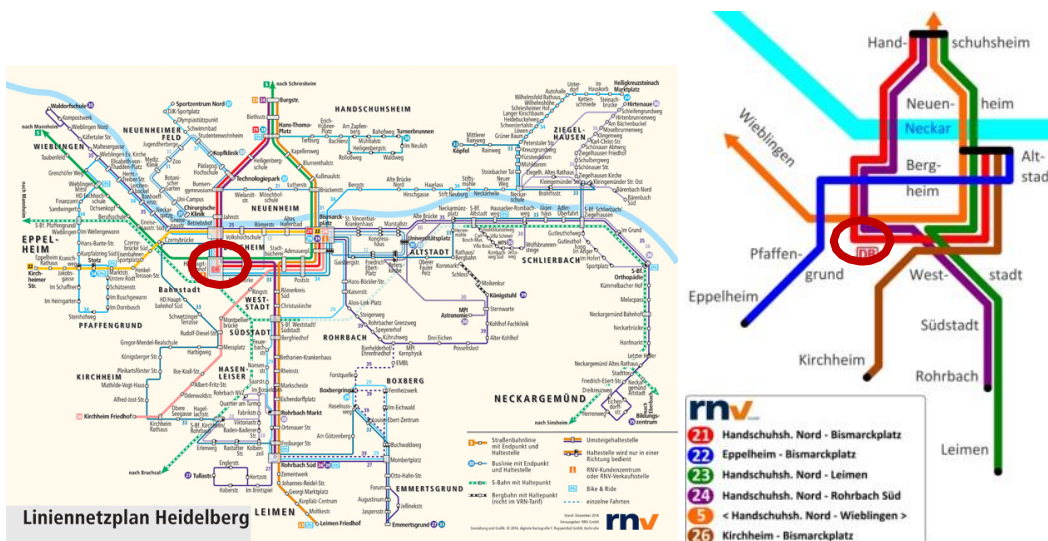
- Dimensioning of the hub– how big are the interchanges requirements (how many people will use the interchange hub): to answer this specific question passengers calculation/flow modelling can be used as support. Both in Utrecht and Heidelberg macro as well as micro simulation tools have been used: the macro models provide a valuable indication of the major flows and directions, especially of road traffic and public transport demand. Micro simulation models on the other hand are effective to determine how these traffic flows can be handled by the proposed infrastructure. For the Ring 3 LRT project the dimensioning of Glostrup has considered also the findings of an overall traffic model for the Greater Copenhagen Area for the closest surroundings of the Ring 3 LRT corridor.
- Cost effective planning - Especially in densely build up urban areas such models help to “invest wisely” into the infrastructure at those locations where it is needed, for example providing pedestrian walkways of adequate (but not excessive) width, adequate track numbers and platform widths and – especially important for the operation of public transport – how resilient the system is for any perturbed or fall back situations.
- Hub accessibility from the surroundings - How is accessibility guaranteed from the surroundings, how are the connecting traffic paths and traffic flows– with PT and non PT (car - PR)? Who wants to go where from where and how? The closest surroundings are the most impacted directly by the hub presence and all the traffic flows it generates. Therefore an accurate conception and planning of the accessibility for all transport modes is essential not to congest the area from the moment the hub is in operation.

- Transport modes connections: how many and which modes are concerned and can be connected? PT, private (car, bikes, pedestrians)? Is there standard/specific equipment for soft modes foreseen? For all the hubs we consider all transport modes are concerned and special attention is paid

The following figures show that all LRT hubs we consider are placed in the heart of a complex PT Network and supplied by different PT modes (long distance/regional railway lines, metro and bus lines).



Utrecht OVT (left) and Glostrup (right) in their respective LRT and general PT Network



Hauptbahnhof Nord Heidelberg in the LRT and general PT Network

What operational, infrastructural or systems solutions make the hub attractive?

In the practice there are two main elements contributing to the attractiveness of a LRT hub to which high attention should be paid in the hub conception and realization:

1. Layout, both in terms of infrastructure and systems' equipment to ensure accessibility of single modes and high performance interchanges (rapid, effective and comfortable) for passengers under safe conditions

Utrecht OVT is a very good example of investing in the hub layout since a total new infrastructure will be built, and the challenge is to make sure all this infrastructure can be combined in an efficient and attractive way. The different stakeholders have different stakes; functionality vs appearance and city developing vs investments.

Therefore a significant effort has been invested also to strengthen the general perception of a comfortable overall environment at OVT: liveliness and safety should be improved and there will be space for culture, leisure, the area will be better accessible and last but not least: water will flow once again in the canal that was filled in during the 70's. They are building a future that's sustainable: low emission buildings, plenty of pleasant space for bikes, public transport and pedestrians, and solar cells on top of the platforms.

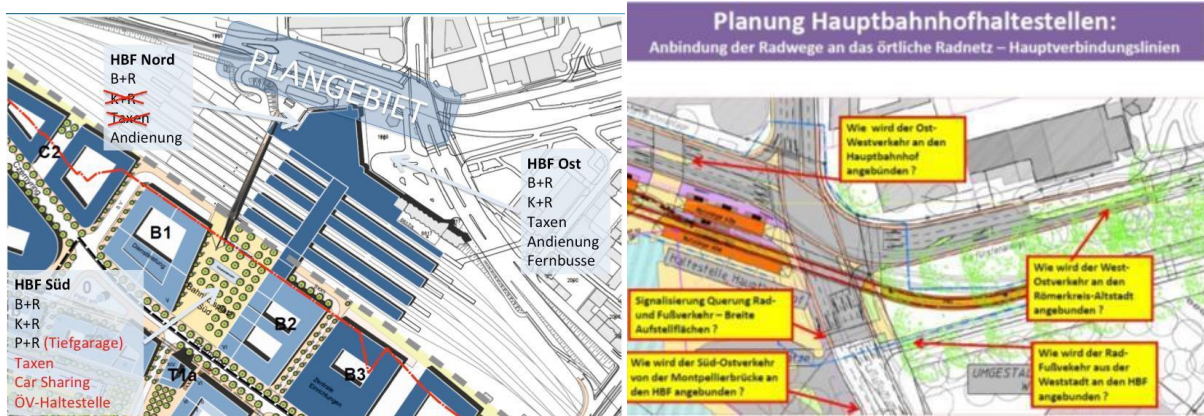
To support travel to and from the train station about 22.500 indoor bicycle parks are developed and new tram and bus terminals are planned on both the east and west side of the OVT.



Utrecht OVT: planning of a new hub layout considering need of different stakeholders (left) and visualization the planned environment (right)

2. Accurate dimensioning to provide overall adequate capacity for transport means (tracks, lanes should be enough for the modes) and for the passengers (platforms, connecting paths)

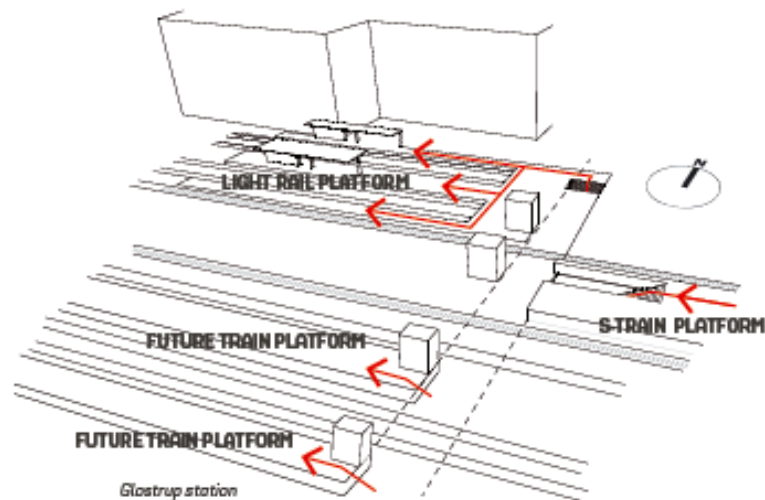
The case of Heidelberg Hauptbahnhof Nord is exemplary as re-planning of an existing hub to adapt his dimensions to increased needs for all users: the redefinition of the whole hub to be beneficial not only for the hub area and the PT modes, but it will have an indirect positive impact on the whole traffic system (road traffic included, but also pedestrian and bike flows) and not only at the Hauptbahnhof Nord itself, but on the closest surrounding areas and potentially on the farther areas as well. Pedestrian will e.g. benefit from an additional island for crossing more comfortably and safely, additional cycle lanes will be created and additional improvements for LRT network will be implemented.



Hauptbahnhof Nord Heidelberg: re-planning of the spaces for the different users (left) and joint planning of bike paths in the closest surroundings (right)

Today, Glostrup Station is a major junction where a large number of passengers change from the Vestbanen rail line to buses. The role of Glostrup will be strengthened by the integration of the LRT Ring 3 and furthermore by the Rail Net Denmark plans to upgrade the station to a long-distance train station. Glostrup will then rise from a local-regional hub to a more long-distance connections hub as well.

Therefore, as shown by the sketch below, the current planning of Glostrup within the LRT project is strongly focused on optimizing the layout of the light rail platforms, the bus terminal and the S-train platforms, to boost passengers' accessibility conditions also considering the future integration of long-distance trains.



Glostrup concept considering pedestrian access within the hub, example, courtesy of Hovedstadens Letbane

Operation

While planning and building a LRT line/network and LRT hubs, one of the most interesting challenges is the operational functioning of the hub, which should be identified as the primary driving factor. Our experience from other European LRT systems shows that often, after some feasibility and socioeconomic studies the focus goes quickly on infrastructure. In the final planning phases many LRT projects are much cost

(investment) driven, therefore the infrastructure comes first. But once a sub-optimal infrastructure is built it is very difficult to change and LRT-systems can suffer from this even long after opening. Aware of these tensions from experience in planning different LRT system we firmly advocate a strong focus, right after passengers need, on operational priorities.

Some aspects to be considered are more strictly operations related and function-focused such as:

- How is the hub operationally functioning in general for LRT and all the PT modes?
- How is the spatial coordination of different modes?
- How are time-related operational aspects like stop times/turnaround times/connections times for different services considered?

Some others are operations-related aspects with focus on customer service including:

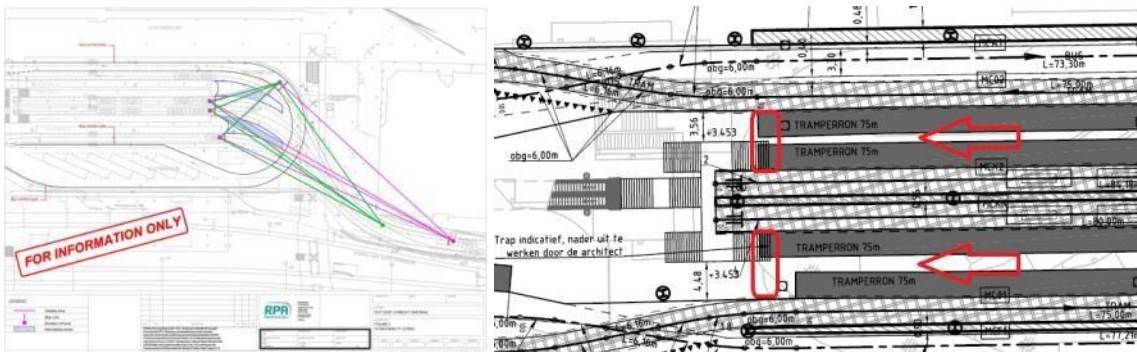
- user friendly platforms– how are platforms organized ,which services are localized where, is this easily understandable for passengers?
- high passenger usable design – are paths clear to reach a transport mean? Is the use of space creating legible ways for passengers?
- communication, customer attention: is there clear, understandable, efficient information with high legibility?

For Utrecht OVT one of the measures to be realized to increase reliability is to invest in separated infrastructure for pedestrians, bicyclists, busses and trams. Therefore a completely new infrastructure will be built, separating the busses and LRVs from the pedestrians and the cyclists. It is a challenge to make sure all this infrastructure can be combined in an efficient and attractive way.

Especially the conception of the bus terminal together with the new expanded LRT network plays a key role in the operational functioning of the hub.

The new bus stations will be smaller than the old ones (there have always been two or three bus stations because of the high number of bus lines with more than 400 departures per hour in peak hour traffic). But the number of busses arriving and departing is growing every year. Therefore it is very important that every bus is stopping very shortly at the bus platforms in the OVT. This is only possible when the regularity of the bus lines is getting better. In that case the need for additional correcting time in the schedule of all busses will be lower. This means that more busses can be facilitated at each platform.

The operation of the new hub should not only be robust but also safe, therefore a safety analysis has been conducted to verify among others the safe operational condition for the new LRT line (e.g. visibility conditions) and the potential conflicts (and mitigations measures) between the different modes, pedestrians included.



Utrecht OVT: Safety Analysis - Intervisibility zones from point where all drivers see each other (left) and points of conflict (right), courtesy of BRU

Glostrup is a crucial point in the operation of LRT Ring 3 since all LRT services in both directions are expected to supply the new hub. Therefore LRT movements inbound/outbound the new hub for all LRT services from Northbound and Southbound are expected.

Thus the main operational challenge for the new hub is to achieve optimal conditions both in terms of:

- coordination of LRT movements inbound/outbound with the road traffic at the junction just outside Glostrup station along Ringvej (Ring 3) and
- pure optimal operational functioning of the Glostrup layout for the LRT services as intermediate terminus with turnaround of all LRT services.

The operational capacity and robustness of the planned LRT track layout at Glostrup has been assessed and the findings have been used to design the optimal LRT infrastructure solution.



Glostrup: LRT operational functioning for Southbound services (blue) and Northbound services (green)

For Hauptbahnhof Nord in Heidelberg different measures are planned to improve the operational functioning of the hub for all transport modes:

- Moving PT platforms close to the station building

- Removing the (current) issue of PT vehicles stopping at non-defined positions along a very long platform edge
- Providing fixed platforms locations for the different destinations generally favoured by passengers
- Testing layout for efficient operation in conjunction with the road intersection in close proximity (possibility for 2 PT vehicles to move across the intersection at the same time)
- Allowing flexible platform



Hauptbahnhof Nord Heidelberg: current LRT platforms (left) and LRT alignment (right) in front of the train station

What specific operational challenges have to be overcome?

As described in the previous section, every new or rebuilt LRT hub has inevitably to undergo operational challenges to optimize both the coordination with all other modes in the hub and the performance of the LRT system itself.

Different tools can be used in the planning and design stage to model the LRT line/network including hubs to gain a significant experience of operational functioning and related issues before the hub (and in some cases the LRT) is built and in operation.

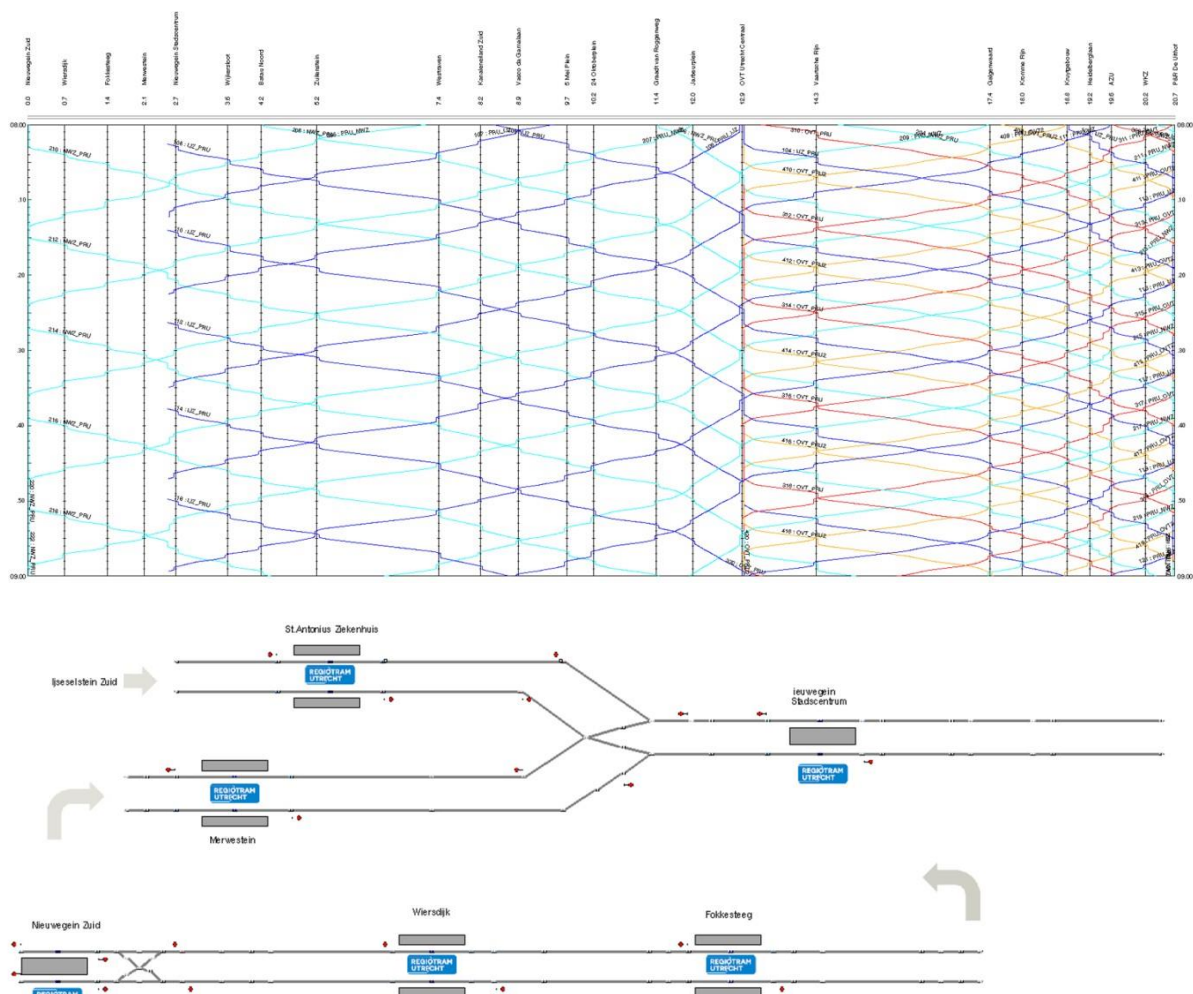
There are several tools with different purposes for this, the most commonly used are:

- operational modelling software (e.g. OpenTrack, Rail Sys) with focus on LRT and rail-based lines/network modelling including hubs/terminuses for existing/planned systems
- traffic modelling software (VISSIM) with focus on knots modelling for all modes existing/planned (LRT/rail-based, private traffic, pedestrians and bikes)

During the design stage of the new LRT network in Utrecht and the parallel re-building of Utrecht OVT the operational modelling software OpenTrack has been used to verify the new operational concept for the new Uithoflijn and therefore the new LRT network. Furthermore the operational model has been integrated with detailed road traffic modelling with VISSIM at some junctions where LRT priority is an issue.

This test enhanced as well whether the planned new infrastructure could guarantee the robustness of the operation planned for the new LRT network. As a consequence of this process some modifications has been

integrated in the infrastructure design in time to be then considered for the tender and the construction stage in order to optimize the infrastructure layout connected to the operational use foreseen for it.



Utrecht OVT: Operational model

Glostrup is a crucial operational knot in the Ring 3 LRT project, an intermediate terminus supplied by all LRT services.

In terms of operation, Ring 3 LRT having 5 minutes headway during the day, the connections with other PT modes from/to LRT do not represent a major issue for LRT timetabling in Glostrup. This means that LRT services arriving/leaving Glostrup are frequent enough to ensure passengers comfortable connections with other PT modes without any additional operational requirement for LRT timetable.

The real challenge in terms of operation for Ring 3 LRT at Glostrup is due to the in/outbound movements of all LRT services. LRT operation at Glostrup should be highly robust and reliable not to generate perturbations in normal operation conditions along the line and not to amplify perturbations already present.

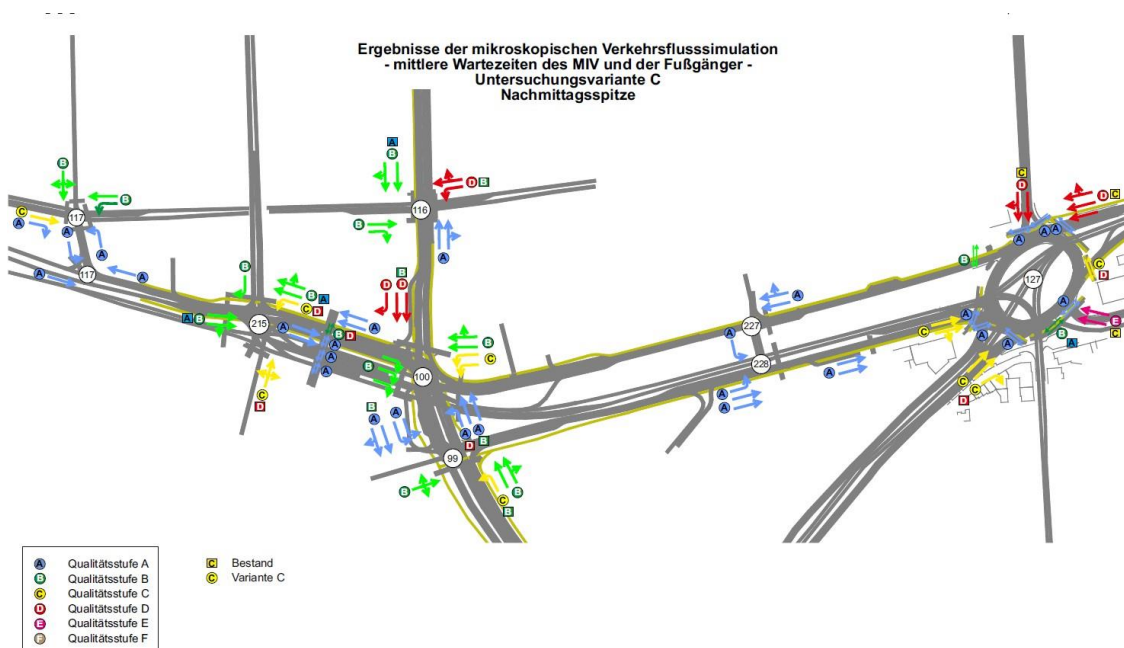
As for Utrecht OVT, also in this case a combination of two different tools has been used to test the operational robustness of the hub and the suitability of the planned infrastructure: VISSIM for detailed road

traffic modelling to feed the operational model for the simulation of the operation along the whole LRT line which has been developed in Opentrack.

This combination has been a winning one allowing building a realistic picture of Ring 3 LRT operation at a very early stage of LRT Ring 3 planning and design. Therefore issues requiring an infrastructure optimization could have been addressed in due time.

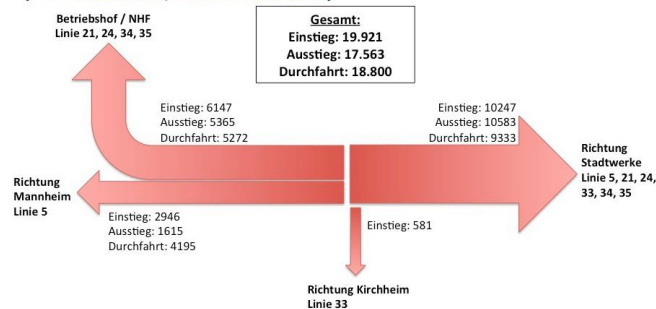
For the main station in Heidelberg a VISSIM simulation has been developed to determine whether the interaction between all the different transport modes including car traffic, public transport, bicycles and pedestrian can be adequately accommodated within the new arrangement and also to show that performance improvements for public transport can be gained as expected – without inadequate negative impacts on other transport modes.

Such a simulation was carried out for different options available and the results were also used to determine the most appropriate solution for this location.



Hauptbahnhof Nord Heidelberg: VISSIM simulation results for various transport modes

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Hauptbahnhof Nord Heidelberg: Boarders, alighters and through traffic in public transport (rnv buses and trams only)

Conclusions

Irrespective of the kind or stage of the project, whether is planning of a completely new LRT hub or renovating (substantially) an existing LRT hub, we firmly believe that passengers should always be in focus of the process.

Therefore while approaching a LRT hubs' project our strongly recommended approach is to consider the following issues(in order of priority):

- First: passengers are the primary focus, the LRT hub should secure high global quality service for passengers
- Second: the hub is a service provider, a crucial point where many different PT and non PT networks converge and their optimal operational functioning should be assured
- Third and last: passengers and service should all fit into an infrastructure, hence the optimal infrastructure to assure all this needs to be identified and should be realized

All this should go without forgetting the balance with other elements such as cost effectiveness since an LRT hub project should be realized, under the given economic framework, to be effective.

Last but not least an early and continuous stakeholder and public involvement is always a key to project success.

Definitions/Abbreviations

- PT: Public Transport
- LRT : Light Rail Transport
- PR: park and ride
- Utrecht OVT: Utrecht Openbaar Vervoer Terminal: Public Transport Terminal
- BRU: Bestuur Regio Utrecht (administrative authority for the region Utrecht)

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- <http://www.uithoflijn.nl>

Heidelberg Hauptbahnhof Nord

Public documents available on:

- <http://www.heidelberg.de>
- <http://www.mobinetz-hd.de>

courtesy of Rhein-Neckar-Verkehr GmbH (RNV)

Ring 3 LRT project

- Program Study (Danish) and Summary (English) available on www.ringtre.dk
- Other studies ongoing within the Ring 3 LRT Project, courtesy of Hovedstadens Letbane