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# ALTERNATIVES TO AUTOMATED PEOPLE-MOVER SYSTEMS FOR SMALL BUT DENSE POPULATED AREAS

**Milena Scherer[1], Jost Wichser[2], Jūratė Venckauskaitė[3]**

*[1, 2] Institute for Transport Planning and Systems (IVT), ETH Zurich, Wolfgang-Pauli-Strasse 15, CH-8093 Zurich, Switzerland, e-mail: [1]scherer@ivt.baug.ethz.ch*

*[3] Vilnius Gediminas Technical University, Institute of Territorial Planning, Saulėtekio al. 11, LT-10223 Vilnius, Lithuania, e-mail: vjurate@ap.vgtu.lt*

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**Abstract.** This paper describes the operational and technical requirements for a high quality public transport system in the country of Liechtenstein and is based on a study conducted by the Institute for Transport Planning and Systems (IVT) at the ETH Zurich. In this case study, a new public transport system (NPT) is defined as a new guideway transport system introduced in a region where this system does not exist yet. Often there are forms of a new technology, for instance, an automated people mover or a modern tramway. Some of the surveyed NPTs are not introduced in many places. The Liechtenstein case study made it possible to analyze, why these systems have not been successful than expected and what is the most appropriate way to introduce a NPT in this country.

**Keywords:** new public transportation system, case study Liechtenstein, fast growing economy, rising transport demand, international transport demand, migration strategy.

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## 1. Introduction

The country of Liechtenstein consists of several municipalities situated mostly along the main road between Sargans (Switzerland) and Feldkirch (Austria) (Fig. 1). Due to its prospering economy, accompanied by an increase of jobs by 25% until 2025, the government expects the traffic in Liechtenstein to get worse.

The efficiency of urban transportation is getting more and more important because of an increasing rate of mobility demand. Particular attention has to be paid to the influence

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of demographic and social factors, to plan, control and organize urban transportation in the most efficient way, we also need to consider the aspects of land use (Tanczos and Torok 2007; Niewczas *et al.* 2008). Several legislative initiatives to construct new roads in this country have been defeated by the residents. Because of the resistance against new roads the government decided to analyze other possibilities to shift the mode share towards public transportation systems (Regierung Fürstentum Liechtenstein 2004a, b). Hence, the only way to handle the increased demand seems to be a massive improvement of the public transportation system, combined with measures to limit the car usage.

Although the current offer of public transport (PT) in Liechtenstein is attractive – compared to similar regions – the mode share for PT reaches only 10%, whereas the car ownership is one of the highest within Europe (700 cars/1000 inhabitants). This fact makes it more difficult to define a PT offer that causes an appropriate change in mode choice.

Considering that one half of all employees in Liechtenstein live abroad (more precise in the border region of Switzerland and Austria), reflections for a new public transport system (NPT) have to take into account three countries to meet all the needs of the affected people.

In this case study, a NPT is defined as a new guideway transport system introduced in a region where this system doesn't exist yet. Often it is a form of a new technology, for instance, an automated people mover or for the case of Liechtenstein – a tramway as well. Some of the surveyed NPTs are not introduced in many places. The Liechtenstein case study made it possible to analyze, why these systems have not been as successful as expected and what is the most appropriate way would be to introduce a NPT in Liechtenstein.

This paper starts with some basic facts about Liechtenstein and its predicted development, including the estimated demand for transportation until 2025 according to the national forecast. Next, the considered alternatives and measures to meet the future transport needs in Liechtenstein are briefly summarized. This includes also an estimation of the annual cost of the different alternatives. Finally, reflections about the migration in terms of the flexibility of the routing and the ability for a system-upgrade of the different PT systems are discussed. The paper ends with conclusions about where NPT can be introduced easily and which alternatives should also be considered.

## 2. Facts and figures about Liechtenstein

For a better understanding Liechtenstein's dilemma, it is necessary to have some background information about the country.

The small country is situated between Switzerland and Austria (Fig. 1). Its area covers about 160 km$^2$, whereof only 50% is populated due to the mountains. The River Rhine indicates the natural border between Switzerland and Liechtenstein, which divides the


**Fig. 1.** Overview of Liechtenstein and its surroundings (GoogleMaps)

valley into a Swiss, and a Liechtenstein part. A drive through Liechtenstein takes about 30 min by car.

In 2007, a total of 35 322 people were registered in Liechtenstein that makes an average population density of 220 inhabitants/km$^2$ (that is about the same density as Germany has). The high amount of 30 000 employees can only be explained with 14 000 commuters from abroad (Table 1).

Liechtenstein's national forecast predicts a growth of population and employment by 20–25% within the next 20 years due to its prospering economy.

**Table 1.** Development of the population and employment in Liechtenstein 2000–2040 (Strittmatter Partner AG 2000)

| | **2000** | **2005** | **2025** | **2040** |
|---|---|---|---|---|
| Inhabitants | 33 500 | 34 900 | 41 900 | 47 500 |
| Employees | 27 000 | 30 170 | 37 500 | 44 700 |
| International commuters | 6 885 | 14 503 | 18 000 | 23 000 |

The increase of jobs has to be covered mainly by commuters from abroad, what comes along with an increase of traffic. Table 2 shows the expected increase of the transport performance in Lichtenstein by 2025. The transport performance in 2025 will become 160% of the existing performance in 2001; however, only if there are enough capacities on the streets for this huge demand.

**Table 2.** Development of the transport performance in Liechtenstein 2001– 2025 (Ingenieurgemeinschaft EGB-Guha-Konrad 2003)

| | **Car: person-km per day** | **PT passenger-km per day** | **Total transport performance per day** | **PT-share** |
|---|---|---|---|---|
| 2001 | 915 000 | 131 000 | 1 046 000 | 10% |
| 2025 | 1 456 750 | 214 000 | 1 670 750 | 10% |

## 3. Fundamentals and goals of the study

Liechtenstein's transport policy is based on the following 5 principles (Regierung Fürstentum Liechtenstein 2005) that have to be considered by planners:

- Economy: Liechtenstein needs an efficient transport network to guarantee a certain level of traffic flow not to prevent the growing economy.
- Quality of life: Improvements of the situation in congested areas increase the quality of life and attracts new residents and enterprises.
- Safety: High safety standards on roads and for the public transport are common.
- Environment: All possibilities concerning a reduction of air and noise pollution as well as energy consumption have to be exploited.

- Basic services: An attractive public transport service is available for every citizen.

Identifying accessibility is a standard issue of transport analysis, which can be of interest to many socioeconomic applications (Jakimavičius and Burinskienė 2007). Moreover, D. Halden in his article maintains that evaluation of accessibility has to be pursued according to national requirements (Halden 2002).

Every action is oriented by these principles. But it is obvious, that there occur certain conflicts especially between economically-based growth and environmental goals. Furthermore, the following points led to the here presented study:

- Most of the roads in Liechtenstein have no capacity for additional traffic; especially the sensitive locations are already suffering from congestion.
- The existing bus system is highly affected by these conditions on the roads and the service lacks reliability and speed.
- Residents do not appreciate the construction of new roads. The limited space due to topological reasons makes it even more difficult to find a routing for new roads.
- The expected traffic cannot be managed with the current bus system due to its interdependence with the car traffic.

These facts emphasize the need for a very attractive PT-service, including high capacities, optimized connections to other PT-networks, and high frequencies as well. Otherwise the expected economic development cannot take place.

A previous survey that considered the feasibility of the introduction of NPT (Ingenieurgemeinschaft EGB-Guha-Konrad 2002) concluded, that the public transport in Liechtenstein needs a dedicated right of way at least in the centre parts of the municipalities and along highly frequented traffic routes. Otherwise the required acceptance is not approachable. Furthermore, the study showed that there are several NPT-systems that fulfil the requested terms but they generally come along with very high capital costs. The study had the aim to elaborate the framework for a decision for a PT-system that can achieve the desired modal share. Essential was the evaluation of potential NPT for spatial patterns like Liechtenstein.

## 4. Current transportation facilities

Liechtenstein's road network consists of 120 km main roads and about 260 km rural roads. This serves the 31 200 registered vehicles and the traffic from abroad including suppliers and throughway from Switzerland to Austria and vice versa.

The total length of the road network has not changed much in the last 40 years. Especially the will of the people not to extend the roads was the determining factor.

The buses operate in mixed traffic and the bus network has a length of 105 km (more or less the full length of the main road is covered with public transport services). The buses in Liechtenstein carry 12 000–17 000 passengers per day and 15 000 persons own an annual ticket for Liechtenstein's bus company (LBA).

## 5. National and international demand

Based on national data about the commuter relations from Switzerland (Bundesamt für Statistik 2008) and a survey of the transport demand structure in Liechtenstein (Hasenmaile and Golay 2004), the following statements about the transport demand can be made:

- The corridor between Balzers-Triesen-Vaduz –Schaan (in the southern part of Liechtenstein) has the highest demand (2/3 of the jobs in Liechtenstein are located in this part).
- The city of Schaan is the most important hub of the country. 50% of the Austrians employees and 30% of the Swiss employees pass by.
- The Swiss part of the Rhine Valley creates the highest international demand.

These facts and the forecast of housing facilities on the Swiss side of the valley underline the supposition, that this transport relation has to be watched carefully.

According to the Swiss Transport Census (Bundesamt für Raumentwicklung, Bundesamt für Statistik 2001), the mode share concerning car usage is mainly influenced by:

- A free parking lot at the workplace,
- The availability of a car,
- Self- employment and
- Income.

All these statements match very well with Liechtenstein's conditions. Especially the motorization ratio and the availability of a parking space at the workplace are often taken for granted.

## 6. Considered transportation systems and requirements

For an approach to get an appropriate public transport system we can distinguish between 2 levels of services:

- Bus systems without dedicated bus lanes, operating in mixed traffic with cars.
- Rail based systems based on an independent network, spatially separated from other transport facilities.

Of course, there are systems in between, such as dedicated bus lines and tram systems that operate partly on the road.

Based on a system evaluation in 2003 (Ingenieurgemeinschaft EGB-Guha-Konrad 2003), the following public transport systems and routings were taken into account:

- A new transport system such as a VAL (vehicule automatique legere) or a guided bus system (tram sur pneu) on the whole distance between Sargans and Feldkirch, whereas in the northern part of Liechtenstein the route connects the municipalities of Bendern-Eschen-Mauren instead of a direct connection between Nendeln and Feldkirch (see map in Fig. 1).
- A combination of the S-Bahn between Feldkirch, Buchs and Sargans with a new transport system Sargans-Vaduz-Schaan. Schaan would become the main hub und interchange station in Liechtenstein.

- A bus system on the whole axis with dedicated bus lines at locations where congestion occurs and where an acceleration of the overall travel speed can be realized.

A new public transport system – new in the sense of not operating in Liechtenstein yet – is to fulfil certain requirements:

- Small spatial consumption.
- The PT-system has to be as conform as possible with the landscape.
- Ability to realized it step by step.
- Compatibility with existing systems.
- Small capital costs and small operating costs.
- Automatically operation (in the future).

Based on the framework presented above, several alternatives were elaborated, and their impacts on the required aspects evaluated.

## 7. Evaluation method – alternatives

For evaluating an appropriate alternative 3 perspectives – customer, public transport company, and general public – were surveyed. All relevant criteria and measurement methods for each group were defined. Finally, the following criteria were estimated for each alternative:

- Number and geographical location of stops. The sensitivity of the total travel time, access, speed and the effect of the parameters on the optimum stop location are analyzed and discussed (Ziari *et al.* 2002; Daunoras *et al.* 2008).
- Frequency and operation hours.
- Average travel speed (especially along the high demand axis).
- Reliability in term of conflicts with other transport modes.
- Direct connections.
- Capital costs.
- Annual capital costs and operating costs.

The developed alternatives combine possible PT systems (e.g. S-Bahn, bus, tram, VAL) in a way that an attractive PT network results, with adequate services, amenities, and different routings. Some alternatives consisted of a dedicated lane on a second level (tunnel or elevated). The impact on the traffic was always taken into account and therefore the PT offer had to be defined for each alternative.

A possible solution was the transformation of the main road into a dedicated bus lane and to close this axis completely for the car traffic. However, this requires a new road beside the settlements with connections to the different municipalities (Fig. 2).

This seems to be the best possibility for an appropriate PT axis on a dedicated lane serving the main points of interests. Other systems, not operating on street level, have the disadvantage that the passengers have to climb stairs or use escalators what makes PT more expensive and reduces the attractiveness of using PT. Following a short overview of the considered alternatives:

**Fig. 2.** Dedicated PT lane on the existing main road (right) and new bypass road (left)

- A: Existing Bus Network Optimization.
- B: Upgrade of the Regional Rail Service and Optimization of the Bus Network.
- C: New Liechtenstein Rail Link and Optimization of the Bus Network.
- D: Upgrade Regional Rail Service and Construction of an NPT between Sargans and Schaan.
- E: Construction of a NPT between Sargans – Schaan-Feldkirch.

The estimated annual costs of each alternative (A-E) are shown in Fig. 3. Alternative A is a bus-based system on the main road including restricted access for cars on this lane and the cost of the construction of a new bypass road beside the settlements (as shown in Fig. 2). Alternative E is a fully NPT on a dedicated lane, partly underground. The tunnels guarantee a conflict-free routing and the main road remain as it is. Other alternatives are combinations in between.

Apparently, the annual costs of the bus-based system, including the construction costs of the new bypass road, is the cheapest. The heavier systems become more expensive due to the construction costs of a separate way. Fig. 3 shows the expected increase of passengers and put it into relation with the annual costs. The range of the average costs per passenger-km is 0.3 Euro to 0.45 Euro. The cheapest PT system costs 23 mio. Euro, whereas the most expensive system, a fully NPT, costs annually up to 60 mio Euro. It has to be underlined that the annual costs are estimated over the whole lifetime of the system.

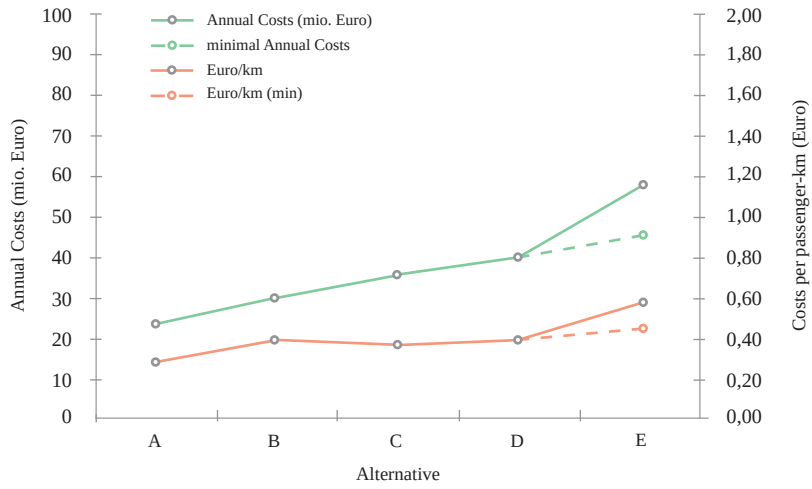


**Fig. 3.** Estimated annual costs and cost per passenger-km

## 8. Liechtenstein's transport model

The planning of urban transport systems needs a great amount of accumulated and classified data. With a purposeful and constant gathering of these data in a number of years, it is possible to foresee the trends, changes and to make suggestions about improving the urban transport system. Modern computer technologies allow for a more accelerated and precise estimation of those processes, performance of variant simulation, technical and economical grounding of solutions (Grigonis and Paliulis 2007).

To estimate the demand due to the changes in the PT we used a transport model for Liechtenstein. The model is based on the census data from 1999, on the one hand and on the other hand, on transport surveys and counted traffic.

It is important to choose correct transport models, to provide exact and right information and only then to forecast prognosis, because wrong prognosis can make very expensive sequences (Trujillo *et al.* 2002).

The daily inland traffic is created with the software VISEM (a demand software from PTV), using the structural data of Liechtenstein and the existing transport networks as input. In a next step the division into different transport modes is made. Based on an OD-Matrix, the route choice depends on an measure of attractiveness considering:

- the travel time, the distance and the category of the roads for car traffic;
- the travel time, dwelling time, different attractiveness of certain systems and the number of interchanges for public transport.

## 9. Migration path

One of the most important criteria for the decision for a PT-system was the ability to implement the system stepwise. This has the advantage that also the financial costs can be considered stepwise; hence, any big investment in a short period is not desired. With this background the ability of an implementation of a system in stages was one aspect that was analyzed, whereas the transportation system has to operate satisfactory in every stage and be capable to meet a corresponding demand. Further the flexibility of the system, flexibility in terms to handle future adjustments such as changes in the route, length and additional stops were considered as well. The third aspect of the migration study was the possibility to replace one system by another one.

Fig. 4 shows an overview of the migration ability of the different examined PT systems. It is not surprising that the bus system is the most flexible one. Based on a bus network with partly dedicated bus lanes and the development of fully dedicated bus lanes step by step, it is the most appropriate basis to implement a future system-upgrade such as, for instance, a tram system or any automated people mover. But therefore the dedicated lane has to be realized first. The decision whether a system upgrade is needed or not, depends on the increased demand of the PT system running at the dedicated lane.

The stepwise development can help not to over-invest in systems that do not bring the necessary revenues at these times. This approach is highly recommended for the case of Liechtenstein and similar regions.

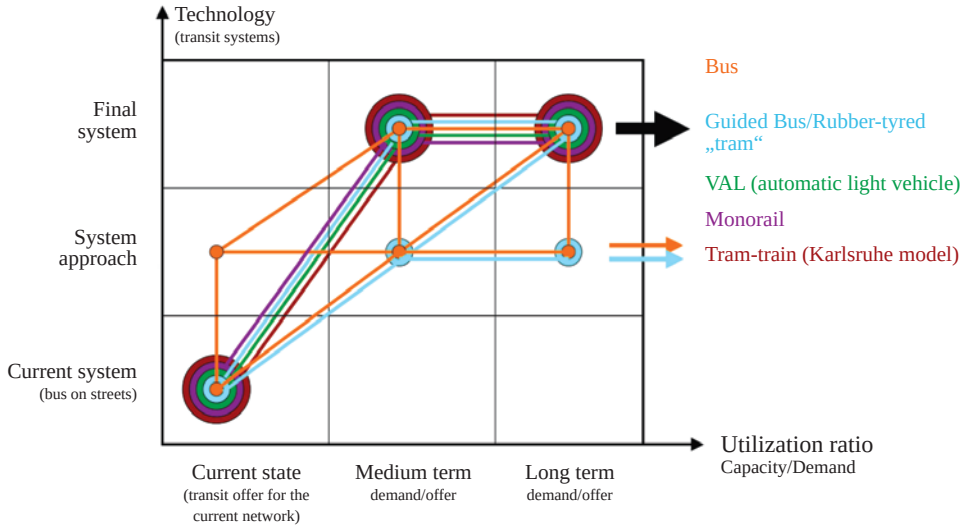


**Fig. 4.** Migration path

The first step has to be the construction of a dedicated lane along the corridor with the highest demand. That is probably the most difficult step, but the only way to generate the required demand, and a corridor where the further development of any PT system can take place. The disadvantage of the other examined PT-Systems such as a VAL, Monorail and the tram-train is, that they have to be implemented in one step, otherwise they come along with high additional costs. Another argument is that these systems are not flexible enough to be adjusted by future changes.

Considering the required remarkable improvement in the modal share, reflections about the attractiveness and quality of the systems were made. To benefit from the so-called rail bonus, a not closer defined factor for higher attractiveness to PT-users, the authors recommend an early system-upgrade to a tram or at least a rubber-tyre-tram-system, when the dedicated lane is available.

## 10. Recommendation and conclusions

NPT systems, defined as new guideway transport systems, introduced into a city/region, often contains a form of new technology (e.g. automated people movers). NPT systems can be considered in regions with an existing well-developed fixed guideway network (NPTs are often implemented in regions with existing systems, since these are the places where public transport has the greatest demand) or in regions where no similar guideway transport system exists yet.

However, many of NPT systems have not been successful in the sense that they are not extended or built in other cities. The Liechtenstein case study provided the opportunity to analyze the benefits and weaknesses of those systems.

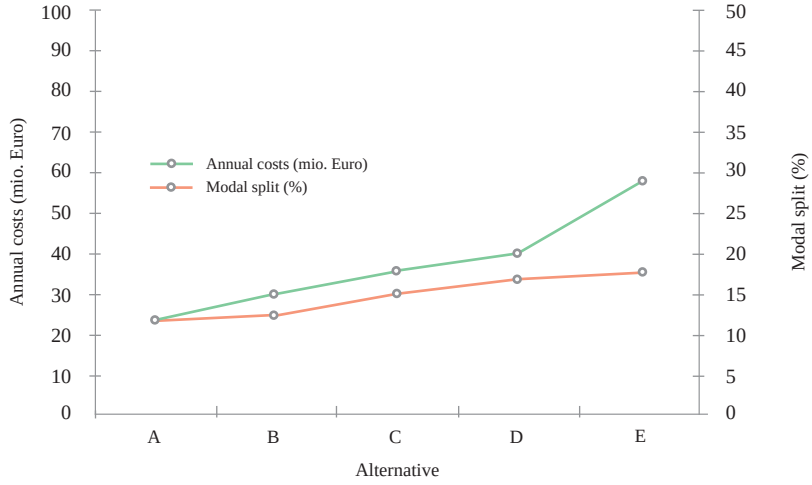


**Fig. 5.** Modal split versus annual costs

The Liechtenstein case study was unique for Europe because Liechtenstein is facing rapid economic growth on one hand and on the other hand the country has no existing guideway transit system. The region's geographic conditions, which focus development in a single corridor, is another reason what makes it an ideal market for an NPT system. The study evaluated 5 main alternatives: an improved bus network, an improved bus network combined with a regional rail system, a NPT rail system through Liechtenstein, and two NPT APM alternatives. The results showed that all alternatives would be extremely expensive and, without measures to reduce automobile use, would not significantly improve public transport mode split.

Fig. 5 shows the predicted modal split (%) of each alternative. The maximum modal split that can be reached is about 18% (today 10%). As you can see in Fig. 5, this plus of modal share is – compared to the increase of annual costs – very high. To get the 2% more modal split (step from alternative D to E) it costs almost 20 mio Euro more per year.

However, the study also showed that Liechtenstein has to improve its PT system to preserve or increase the quality of life and encourage the economic growth. Therefore the study identified a migration strategy that consists of improving the bus network stepwise with the background idea that an NPT system can be implemented in the future when the demand increases and reaches an appropriate level what makes it more cost-effective. In summary, the following general conclusions can be made:

- Any implementation of NPT systems strongly depends on the region's existing public transport system and on road conditions as well.
- In cases where there is no existing public transport system, it is much easier to implement an NPT system. In these cases, the decision whether to implement an NPT or not depends on economical criteria and on criteria of the desired service quality.

- In cases where there is an existing public transport system – NPT has the best possibility for implementation as the last stage of a migration process for a public transport line or network.
- A corridor covering the main demand axis has to be realised before a NPT system is going to be implemented.

Obviously, a NPT systems make sense in certain situations, specifically when special problems or travel demands cannot be solved with conventional public transport systems, but they are not the general solution for public transport problems.

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## AUTOMATIZUOTO TRANSPORTO MAŽOSE BEI TANKIAI APGYVENDINTOSE TERITORIJOSE ALTERNATYVOS

**M. Scherer, J. Wichser, J. Venckauskaitė**

Santrauka

Aprašomas poreikis sukurti aukštos kokybės viešojo transporto sistemą Lichtenšteino kunigaikštystėje. Remiamasi Ciuricho planavimo ir transporto sistemų instituto parengta studija. Šiame tiriamajame darbe pasiūlyta nauja viešojo transporto sistema. Dažnai naujos technologijos sistemos suprantamos kaip automatizuotas transportas, pvz., modernus tramvajus. Lichtenšteino studija parodė, kodėl ne visos naujos transporto sistemos sėkmingos, kaip tikimasi. Studijoje pasiūlytas priimtiniausias naujos Lichtenšteino viešojo transporto sistemos būdas.

**Reikšminiai žodžiai:** nauja viešojo transporto sistema, Lichtenšteino studijos tiriamasis darbas, auganti ekonomika, didėjanti transporto paklausa, tarptautinė transporto paklausa, migracija.

**Milena SCHERER.** PhD student at the Institute for Transport Planning and Systems (IVT) at the ETH Zurich. She obtained her Master degree in civil engineering at the ETH Zurich in 2005. Since then she worked as a research assistant at the IVT with main interest of public transport systems in urban areas. Her main research focusses on multi-modal and public transport quality and capacity.

**Jost WICHSER.** Lecturer and Senior Researcher at the Institute for Transport Planning and Systems (IVT) at the ETH Zurich. After obtaining his Master degree in civil engineering he worked for more than 25 years as a transport planner, technical manager and head of engineering of the Rhätische Railways infrastrure devision. His main research focus lies on the technology of track of railways, on the management and operation of freight transport, especially intermodal transport chains and on the interaction of track, vehicle and operation in public transport.

**Jūrate VENCKAUSKAITĖ.** PhD student at Vilnius Gediminas Technical University, Department of Urban Engineering, junior research assistant at Vilnius Gediminas Technical University Institute of Territorial Planning. Her main research focusses on territorial planning, sustainable development.