Changing Strategic Alignments in European Urban Traffic Control – Requirements for Future Developments

Mario Ilic*[1], Natalie Sautter[2], Martin Margreiter[2], Dr. Allister Loder[2], Univ.-Prof. Dr.-Ing. Klaus Bogenberger[2]

[1] Corresponding author, mario.ilic@tum.de, ORCiD: https://orcid.org/0000-0003-2457-698X,

Chair of Traffic Engineering and Control, Department of Mobility Systems Engineering,

Technical University of Munich, Germany

[2] Co-Authors, Technical University of Munich, Germany

SHORT SUMMARY

The objective of this paper is to provide an overview of the changing strategic alignment of European urban traffic control (UTC) and to subsequently derive requirements for future UTC systems. Therefore, data from expert interviews with Central European representatives of UTC authorities were used. Several topics of interest are addressed, with a special focus on multimodality and its resulting challenges for UTC as well as on spatial levels of UTC measures. The results show a changing strategic focus on promoting public transport, cycling and walking and a lack of network-wide control systems for UTC. Subsequently, general requirements for future (network) control systems were synthesized from the interview results, such as multimodal functionalities, improvement of traffic state estimation and prediction, and inclusion of general traffic management tasks. Additionally, transparency of the operating principle of complex traffic control systems is identified as prerequisite for future research and development.

Keywords: multi-modal transportation, urban traffic control strategies, requirements for future urban traffic control systems

1. INTRODUCTION

European cities and their transportation networks have evolved over the last centuries, leading to regions characterized by urban polycentrism and high population densities. While mobility is considered a basic human need, increasing transport demand and highly car-oriented urban planning in recent decades have led cities to increasingly struggle with various traffic-related problems. Congestion, accidents, air and noise pollution, the contribution to anthropogenic climate change and other factors cause external costs of transportation in Europe, accounting for more than 5 % of its Gross Domestic Product annually (Van Essen, et al., 2019). Urban areas in particular face the challenge of improving overall mobility while minimizing the aforementioned problems. In 2018, nearly 75 % of Europe's population lived in urban areas and this share is expected to increase to nearly 84 % in 2050 (European Commission, 2021).

In view of a further tightening of the traffic situation, ambitious political regulations of the European Union and its member states aim at reducing transportation externalities. At the same time, cities face individual conditions that affect not only a city's traffic situation, but also its financial resources, regulatory responsibilities, and municipal policy framework. Solutions to mitigate urban traffic challenges, taking into account the needs and traffic strategic goals of cities, require proposals for policy making, research and development that are based on requirements of urban transportation authorities as their operators.

Several benchmarking studies have been conducted in the past comparing different cities to analyze general standards for urban traffic control (UTC) (Fakler, et al., 2014; Schmöcker and Bell, 2010; Zavitas, et al., 2011). While the focus is often on current UTC systems in terms of infrastructure and strategies, the requirements for future UTC systems from the perspective of the UTC authority and considering changing strategic alignments have not yet been elaborated in detail. Therefore, this study summarizes the results of a data collection based on expert interviews with UTC authorities of different Central European cities. Changing strategic directions in UTC were identified and serve the subsequent derivation of requirements for future control systems.

2. METHODOLOGY

For this study, interviews were conducted with representatives of UTC authorities in Central Europe between April and July 2021 to identify the changing strategic goals of UTC and the resulting challenges. An interview guide was provided in advance from which only aligned content was included in the following analysis. Subsequently, requirements for future UTC systems were derived from the expert interviews. Figure 1 shows the sample of 14 Central European UTC authorities interviewed for this study.

Figure 1: Geographical location of the interviewed cities

The interviews were thematically divided into three categories:

1. Strategic Focus in UTC
2. Multimodality
3. Spatial Levels of UTC

3. RESULTS AND DISCUSSION

The following section presents the results of the expert interviews, thematically divided into the same categories as the interviews themselves. Subsequently, the results of the expert interviews are used to synthesize requirements for future UTC.

Strategic Focus in UTC

Figure 2 categorizes the answers about the strategic focus in UTC into six categories, regardless the specific execution of the mentioned strategic alignment.

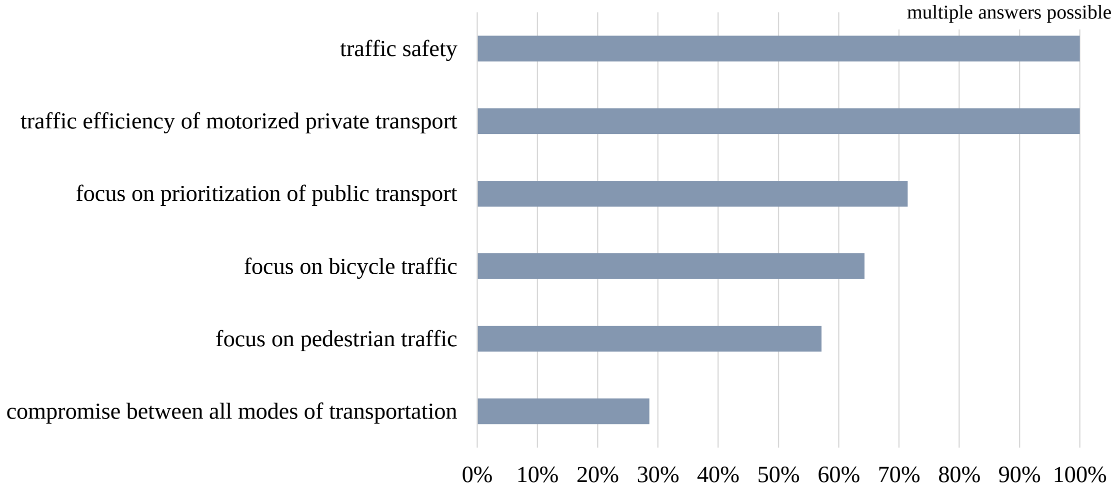

Figure 2: Strategic focus in UTC

European guidelines explicitly mention traffic safety and traffic efficiency as main objectives of UTC, which is why all interviewed cities indicated them as important strategic alignment. An interesting finding is the high strategic focus towards environmentally friendly modes of transportation (public transport, cycling and walking) that most of the cities mentioned. The compromise between all modes of transportation has been named by less than 30 % of cities. The reason given for this is the political reorientation from a strongly car-oriented urban and transport planning in the past to a more integrative and sustainability-oriented multimodal planning.

In addition to the overall strategic focus in UTC, evaluation criteria for UTC planning have been made subject of discussion. Time-related criteria were named significantly more often than, for example, queuing lengths or the number of stops. A frequently mentioned reason for the strong focus on time-related criteria, especially waiting times, is the applicability of the same evaluation criterion to all different modes of transportation to assess impacts of UTC measures simultaneously.

Multimodality

A key finding regarding the prioritization of public transport (PuT) is that in all cities nearly all intersections, that are part of PuT routes, are technically equipped with a prioritization system. Nevertheless, differences in the extent of prioritization between cities were found. While Austrian and Swiss cities aim for unconditional PuT prioritization, German cities tend to limit its extent to certain lines, intersections or a certain scope. It was highlighted, that PuT prioritization schemes often have a negative impact on crossing signal coordinations for motorized private transport (PrT).

Notwithstanding the high strategic focus on promoting cycling observed for the interviewed cities, the specific measures to achieve this goal show a wide range of responses, that can be assigned to two general categories:

1. Constructional measures:
   a. Construction of new infrastructure (segregated bike lanes, bicycle highways, etc.),
   b. Designation of bicycle priority roads (mixed space with other transportation modes),
   c. Spatial separation of bicycle traffic and other modes of transportation.

2. Traffic engineering measures:
    a. Increased detection of bicycle traffic,
    b. Coordination of traffic signals (TS) for bicycle traffic,
    c. Information of cyclists about the state of upcoming TS.

A lot of cities highlighted challenges in the implementation of signal coordinations for cyclists. Inhomogeneous velocities of cyclists and the lack of compatibility with coordinations for PrT were named. Today, the majority of cities opt for signal coordination for PrT in order to cope with the high traffic demand. However, some cities indicated in the interviews that in the next few years, 30 km/h speed limits will be expanded in city centers, which would allow coordinations for both PrT and fast cyclists. As an example for the practicability and feasibility of this measure, Paris was often cited.

Pedestrian traffic was also named as a clear strategic focus for UTC. Given the high share of interviewed cities naming waiting times as the predominant evaluation criterion for UTC, it is worth mentioning that some cities emphasized planning short cycle times. This measure was reported to minimize waiting times and the number of jaywalkers. The strategic focus on the needs of mobility-impaired people (MIP) in UTC was also highlighted. Increasing intergreen times for pedestrian traffic streams at intersections was cited as a measure to achieve this goal. This, on the other hand, results in less green time for other transportation modes. Therefore, cities plan to improve and expand contactless detection of pedestrians in future, which would even make it possible to identify MIP. It makes sense to assign higher green times when MIP are actually present at the intersection, and otherwise exploiting maximum green times for PuT and PrT streams to maximize overall intersection capacities.

For PrT, an increased implementation of restrictive measures is expected by the interviewed cities. For example, limiting traffic volumes through (dynamic) congestion charging for inner-city areas was mentioned as a way to cope with the increasing oversaturation of traffic networks, especially during rush hours. Another frequently mentioned measure is the use of variable message signs to direct traffic away from congested areas of the transportation network. However, the interviewed cities emphasized the need for interfaces between UTC centers and commercial navigation services to increase traffic routing rates, as most road users are more likely to follow instructions from their own navigation devices.

Figure 3 summarizes the discussed challenges in multimodal UTC.

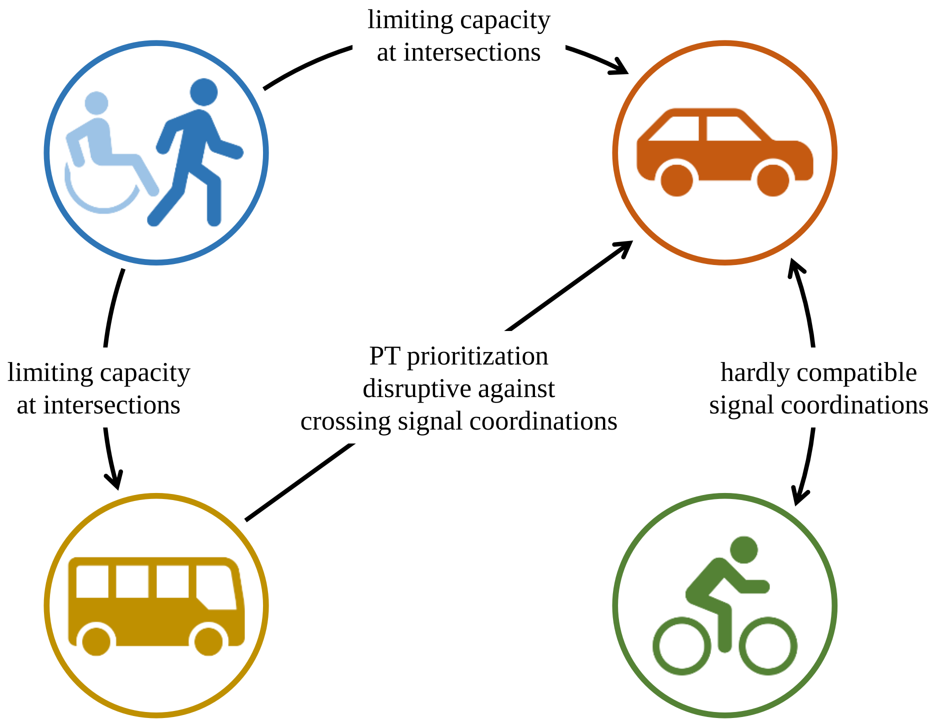

Figure 3: Challenges in multimodal UTC

Spatial Levels of UTC

While traffic-actuated control of individual intersections is referred to as point control, the coordination of successive TS along a road section is defined as line control. Network control, on the other hand, is defined as the coordination and optimization of traffic flows in a (sub)network, beyond the boundaries of a single road section. In Central European cities, two commercially available network control systems (NCS), BALANCE and MOTION, are typically offered on the market. Both are model-based and traffic-adaptive UTC systems that aim to harmonize PrT traffic flows of the strategic network in urban areas by coordinating signal control. Both systems include the following components: traffic detection system, mathematical model to predict traffic impacts, optimization method to minimize unfavorable impacts of UTC. (Hohmann, Guiliani and Wietholt, 2013) These spatial levels of UTC are illustrated in figure 4.

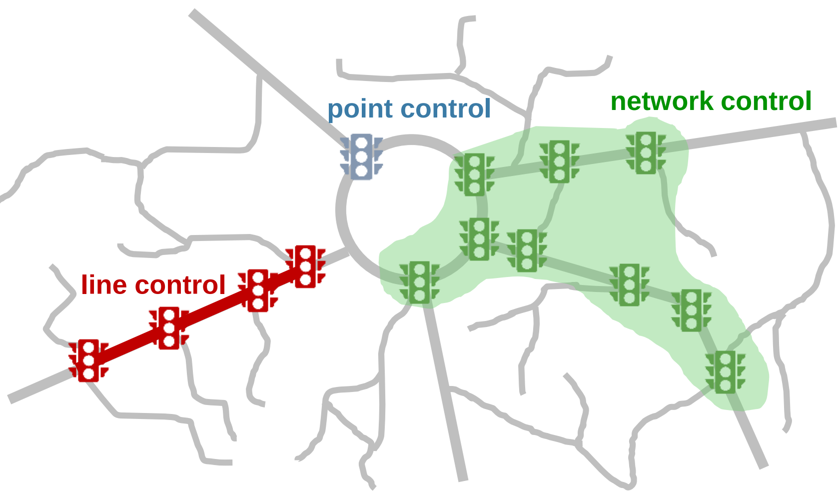

Figure 4: Spatial Levels of UTC

Figure 5 shows the share of the interviewed cities' TS in each discussed spatial level.

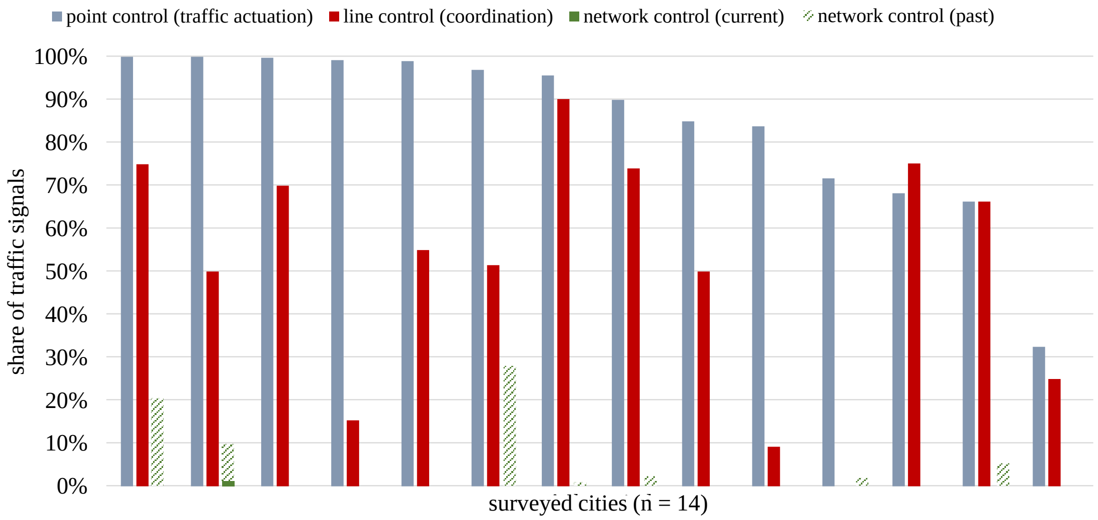

Figure 5: Share of TS in different spatial levels of UTC

Traffic-actuated signal control at intersection level (point control) generally shows high proportions in the interviewed cities compared to the total number of TS. Besides one city, all have a share of more than 60 % of traffic-actuated signals. In eight of the cities interviewed, at least 90 % of TS are equipped with traffic-actuation. Also, the number of TS embedded in a coordination along a road section (line control) is generally on a high level with eleven of the cities showing values of at least 50 %. A share of 70 % or more is observed for five cities, while three of the interviewed cities show values of 30 % or less. With respect to NCS, the interviewed cities indicated that no system is currently in operation, except for one city currently having a small number of TS embedded for research purposes. Nevertheless, some cities indicated that they have used NCS in the past as part of trial operations. The scale never exceeded about 28 % of TS in the city and the majority of cities decided to completely shut down those systems.

Frequent and too drastic switching operations of NCS, leading to temporarily significant drops in traffic efficiency, have been named as most common reason for their shutdown. Some cities criticized situations in which the systems lead to frequent back and forth switching of signal plans, decreasing traffic efficiencies of affected road stretches.

Furthermore, the lack of transparency has been named as reason for the shutdown of the systems. Since NCS available today operate more or less as a black box, UTC authorities face the problem of not being able to justify certain control commands to citizens who complain about the signalization at certain intersections or road stretches. This lack of transparency, combined with the high complexity of the systems, was named as reason for difficulties in operation and maintenance of the NCS by a UTC authority itself.

Some cities reported frequently recurring traffic states that caused NCS to generate repeating signal plans instead of responding to dynamically changing traffic states. The costly operation of NCS appeared impractical in such static traffic situations, often resulting in a system shutdown.

Cities that never operated a NCS indicated that the products available on the market do not align with their traffic strategic focus of promoting PuT, cycling and walking. Current NCS have a unimodal focus, concentrating solely on PrT.

Derivation of Requirements for Future UTC

Figure 6 summarizes four requirements for future UTC systems that were derived from the interview results. Additionally, possible implementations in future UTC systems are mentioned, which were discussed with the interviewed cities.

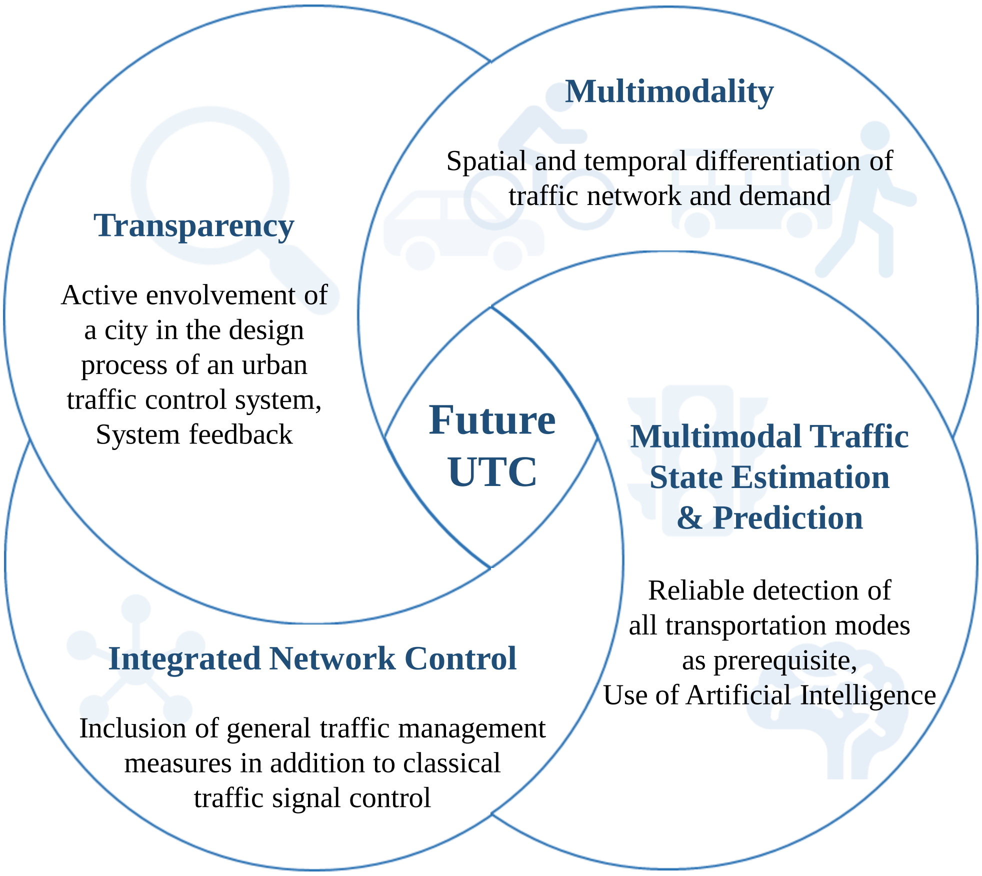

Figure 6: Requirements for future UTC

The unimodal focus of currently available UTC systems was cited as the most important factor for the non-implementation of such systems. From this, the call for an expansion towards a multimodal focus is derived to address the strategic focus in UTC of European cities. A possible solution for a multimodal focus could lie in the temporal and spatial differentiation of the transport network and its demand. Temporal differentiation can be linked to weather conditions, allowing e.g. TS to be coordinated for specific transportation modes when appropriate weather conditions result in increased demand for those modes. Spatial differentiation of UTC can be useful for different points of interest in the network, such as schools with high expected pedestrian volumes or industrial areas with low expected pedestrian volumes.

Another requirement that can be derived from the expert interviews is the need for improved TSE and prediction for all modes of transportation, while a reliable data collection was highlighted as a prerequisite for this. Early detection of unfavorable traffic states and identification of appropriate countermeasures are essential for an advanced UTC system, where the interviewed cities often see a high potential for improvement through the use of AI for data fusion and processing.

The interviews furthermore revealed, that European cities increasingly understand traffic management measures such as perimeter control, (dynamic) congestion charging or traffic guidance as part of a network control due to their network-wide impact on traffic states. Future UTC systems focusing on the coordination and harmonization of entire traffic networks should therefore include these measures in addition to classical TS control.

Finally, the lack of transparency combined with the high complexity of existing UTC systems was highlighted as a difficulty in operating and maintaining the control system by a city itself. Involving a city in the design of a control system allows the consideration of individual city characteristics and traffic patterns, while at the same time increasing the transparency of the control system to the UTC authority. In addition, visual or text-based feedback from the system on reasons for implementing control measures was cited by the interviewed cities as being appropriate for increasing the transparency of complex UTC systems.

4. CONCLUSIONS

This paper summarizes a study aimed at identifying strategies for UTC, using data from expert interviews with UTC authorities of 14 Central European cities. The expert interviews covered various topics of UTC, focusing on multimodality and its resulting challenges for UTC as well as the spatial level of UTC measures.

The results show changing strategic alignments towards the promotion of sustainable transportation modes and a lack of use of NCS in Central European cities. Subsequently, requirements for the development of future UTC systems were derived. These are the expansion of control systems towards a multimodal functionality, the improvement of TSE and prediction for all transportation modes, the integration of traffic management measures beyond classic TS control, and the transparency of the control system. Possible implementations discussed with the interviewed cities include spatial and temporal differentiation of the transportation network and demand, the use of AI for data fusion and processing, or the active participation of the city's UTC authority in the design process of an UTC system.

Future steps of this research include extending this study to other European, North American, and Asian cities to identify global trends and differences in strategic directions of UTC and derive requirements for future UTC systems for different global regions. In addition, future work will focus on the next tasks of the KIVI research project on which this work is built upon. This will involve the design and development of a multimodal NCS through the use of data-driven AI methods, for which this study will serve as a basis. Furthermore, the project includes the multimodal extension of an existing microscopic traffic simulation for the city of Ingolstadt, the simulative testing of the developed NCS and the use of different AI methods in the control process. This is done in cooperation with the city and UTC authority of Ingolstadt, Germany.

ACKNOWLEDGMENTS

This work has been carried out as part of the KIVI research project (“AI in the Transportation System of Ingolstadt”), which is funded by the German Federal Ministry of Transport and Digital Infrastructure (Funding ID: 45KI05A011).

The authors of this study would like to thank the representatives of the UTC authorities for the willingness to participate in the expert interviews.

Contributions to the paper are confirmed as follows:
Study conception and design: Margreiter, Ilic, Sautter, Dr. Loder; Data collection: Sautter, Ilic, Dr. Loder, Margreiter; Analysis and interpretation of results: Ilic, Sautter; Draft manuscript preparation: Ilic, Sautter; Supervision: Univ.-Prof. Dr.-Ing. Bogenberger

REFERENCES

European Commission. 2021. Developments and Forecasts on Continuing Urbanization. Available from: https://knowledge4policy.ec.europa.eu/foresight/topic/continuing-urbanisation/developments-and-forecasts-on-continuing-urbanisation_en [Accessed 20th July 2021].

Fakler O.,Geßenhardt J., Lüßmann J., Busch F. 2014. Structures of Traffic Management and Control in German Cities. In Proceedings of the 10th ITS European Congress, 16-19 June, Helsinki, pp. 1-9.

Hohmann S., Guiliani S., Wietholt T. 2013. Verkehrsadaptive Netzsteuerungen – Untersuchung ihrer Einflussmöglichkeiten auf die Emissions- und Immissionsbelastung städtischer Straßennetze. Bergisch Gladbach, pp. 8-25.

Schmöcker J.-D., Bell M. 2010. Traffic Control: Current Systems and Future Vision of Cities. International Journal of ITS Research, Vol. 8, No. 1, pp. 56-65.

Van Essen H., Van Wijngaarden L., Schroten A., Sutter D., Bieler C., Maffi S. 2019. *Handbook on the External Costs of Transport*. CE Delft.

Zavitas K., Kaparias I., Bell M., Nocera S. 2011. Urban Traffic Management and Intelligent Transport Systems: A European Perspective. In Proceedings of the Transportation Research Board 90th Annual Meeting, 23-24 January, Washington, pp. 1-13.