A METHOD TO DEVELOP DYNAMIC TRAFFIC MANAGEMENT STRATEGIES FOR CASES OF INCIDENTS

Prof. Dr.-Ing. Manfred Boltze, Technische Universitaet Darmstadt (Germany), Section Transport Planning and Traffic Engineering; boltze@verkehr.tu-darmstadt.de

Dipl.-Wirtsch.-Ing. Leif Fornauf, Technische Universitaet Darmstadt (Germany), Section Transport Planning and Traffic Engineering; fornauf@verkehr.tu-darmstadt.de

ABSTRACT

Transport systems are affected by various kinds of incidents such as accidents, severe weather conditions, and other events which can lead to disturbances and operational irregularities. To avoid unnecessary disadvantages for road users and railway passengers as well as transport operators, such incidents require situation-dependent, dynamic interventions which need to be chosen and organized within short time. Especially for more complex situations, it is usually not sufficient to rely on improvisation, only. Instead, this operational task should be supported by pre-defined strategies, in which all actions of relevant stakeholders for specific situations are described. This paper presents a planning method to develop such dynamic traffic management strategies for transport operators.

Based on several research projects and current German guidelines, this paper presents a basic method to develop dynamic traffic management strategies for incidents. The method is based on the general transport planning process, but it reflects the specific requirements of real-time operation. The paper provides definitions for relevant terms such as strategy, measure, situation and the interconnections of these terms. Furthermore, different types of incidents as well as generally suitable measures to be taken to cope with different types of problems will be defined. The course from identifying problems to the selection and activation of appropriate measures will be described including the necessary technical systems and communication processes.

Preparedness for cases of incidents seems to be very important and needs additional attention. The proposed method presents a general methodological framework on how to develop dynamic traffic management strategies to be activated in such cases. Although a broad application of this method is on the way already, many further research needs could be identified. For example, the specific consideration of environmental problems, improvements for dealing with intermodal strategies, modifications to apply the method in developing countries or in other modes of transport

Keywords: Traffic Management, Strategies, Transport Planning

1 INTRODUCTION

Traffic management influences the supply of traffic and transport systems as well as the demand for travel and transport through a bundle of measures with the aim to optimise the positive and negative impacts of traffic and transport. This implies that traffic management needs to consider and to weight different aspects (traffic safety, traffic quality, economical and environmental aspects) and consequently the requirements and goals of different stakeholders (motorists and cyclists, cities and communities, traffic operators).

Unexpected but also expected deviations from a defined basic traffic condition need pre-defined measures to handle the problems effectively and efficiently. Hence, **dynamic traffic management** consists of influencing the current transport demand and influencing the current transport supply by coordinated situation-adaptive measures. In this context, a **strategy** can be defined as an action plan which includes a bundle of pre-defined measures to improve a defined initial situation. A **situation** is defined as a combination of certain events, problems, and conditions. Both, the situation and the developed strategy for it, describe a specific **scenario** (Figure 1).

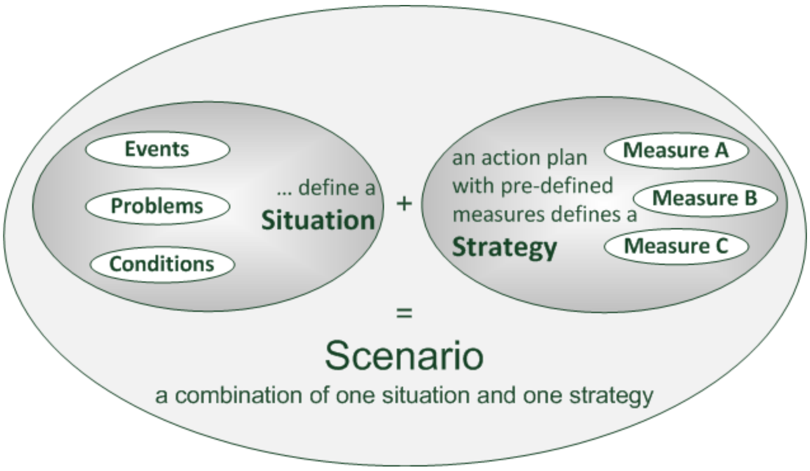

Figure 1: SITUATION, STRATEGY, SCENARIO
(SOURCE: ZIV et al. (2000))

Measures are taken to avoid traffic, to shift traffic (in mode, in destination, or in time), and to control traffic. Moreover, strategies have to meet some requirements: They

- have to be geared to a superior goal concept of a specific region,
- are developed for specific situations,
- have to contribute to the problem solving and reduction, and
- have to be designed in an integrated way, considering their impacts across transport modes, administrative boundaries, and disciplines.

This paper is based on German guidelines (FGSV 2003; FGSV 2011) and publications (BMVBS, 2006) which have been elaborated with strong involvement of the authors. In addition, we report on our recent research projects in this field. International literature dealing with this topic could hardly be found even though an extensive literature review has been conducted. Due to this reason, this paper also aims to introduce the German method to develop dynamic traffic management strategies to an international audience.

2 GENERAL PLANNING APPROACH

The development of dynamic traffic management strategies presented in this paper is conceptually based on the general transport planning process, as applied in Germany, which is illustrated in Figure 2. The entire process of the strategy development and implementation can be separated into several stages.

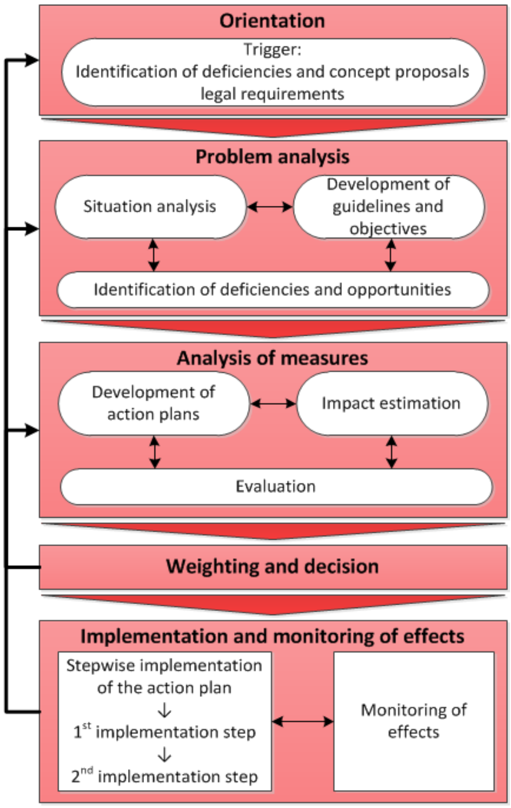

Figure 2: GENERAL TRANSPORT PLANNING PROCESS
(SOURCE: TRANSLATED FROM FGSV (2001))

On the first stage of **orientation**, the initiation to develop strategies takes place. Reasons for the initiation can be observed or expected problems regarding safety, capacity, environment or other problems. Problems may occur rarely, frequently or even as recurring events, and their consequences may be more or less severe. The motivation to plan a strategy depends on the product of the frequency of the problem and the severeness of its consequences (compare with risk assessment). The reason for the problem may be unforeseeable (as in the case of accidents), predictable (as in the case of major events) or any state in between (as e. g. severe weather conditions which are predictable only to a certain extent).

The **problem analysis** needs to compile comprehensive basic information. This includes the situation analysis, the development or clarification of guidelines and objectives (setting up a goal concept), and the identification of deficiencies and opportunities.

The **analysis of measures** starts with the development of action plans for specific situations. In the case of dynamic traffic management it is the formation of strategies. The measures for the strategies are developed and compiled to bundles of measures to form a strategy. Detailed instructions on the processes of activation and deactivation complete the formulation of a strategy. Then, the potential impact of the formulated strategies should be estimated, and alternative strategies should be evaluated.

The **weighting and decision** for the most appropriate strategy leads towards the **implementation and monitoring of effects**.

For the case of planning dynamic traffic management strategies, we have to consider not only the process of the offline strategy development, but also the **online strategy implementation** which reacts on practically detected problems and activates one of the pre-defined strategies. Figure 3 provides an overview on the planning and implementation process of traffic management strategies. This paper will focus on the offline strategy development (Chapter 3), but it will also give a brief overview on the processes of online strategy implementation (Chapter 4).

Basically, the development of a strategy is done by one authority or transport operator, and its activation is performed by one traffic control centre. But very often, several actors and close cooperation are needed to solve a problem. Therefore, integration with regard to all aspects (technical-physical, organisational-institutional, and conceptual-functional) is a major factor of success for dynamic traffic management. With Chapter 5 we address these **concepts of integration** and how they should be elaborated.

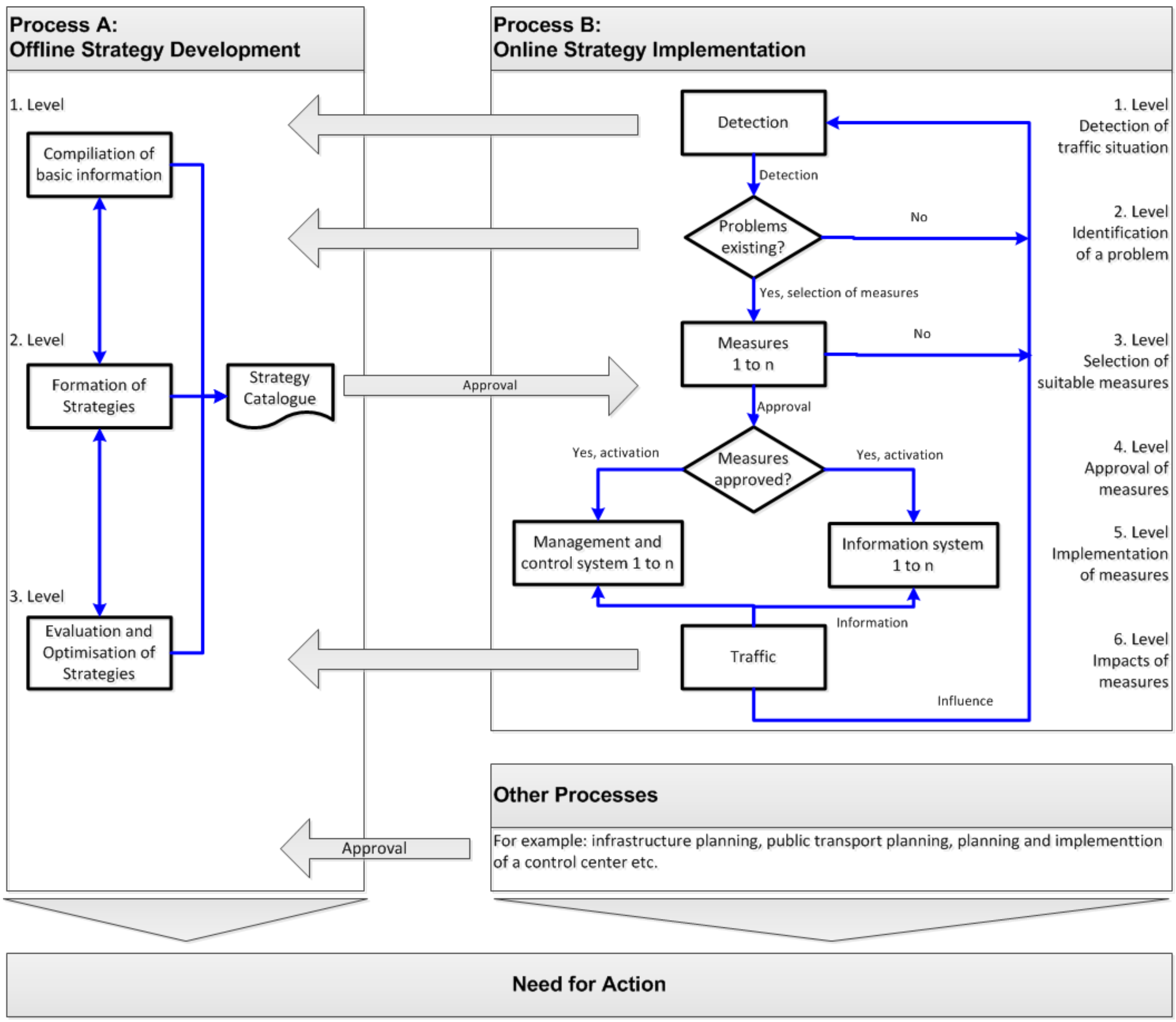

Figure 3: PLANNING AND IMPLEMENTATION PROCESS OF TRAFFIC MANAGEMENT STRATEGIES (SOURCE: TRANSLATED FROM FGSV (2003))

3 OFFLINE STRATEGY DEVELOPMENT

The offline strategy development process is basically divided into three steps: the compilation of basic information, the formation of strategies for specific situations, and finally the assessment and optimisation of the developed strategies.

The authors have compiled, modified and commented the following contents mainly on basis of FGSV 2003 and FGSV 2011.

3.1 Compilation of Basic Information

The basic information serves as a basis for the following strategy formation and includes

- the definition of the study area,
- the identification of the strategic network,
- the analysis of responsibility areas,
- the technical inventory,
- the calculation of traffic demand, and
- the identification of incidents and problems.

It is obvious, that the compilation of such an amount of information needs significant efforts. But if we assume a transport operator or authority that owns careful planning processes and a proper documentation of its systems, this task of collecting the information will be reasonable. We also have to clarify that this task is not related to the development of one strategy only but instead to the overall task of dynamic traffic management, covering all types of incidents and problems.

Definition of the Study Area

Dynamic traffic management strategies are useful where we can influence traffic volume and traffic flow in a positive way. This is not limited to the usage of one specific transport mode, but this can also be achieved by switching the transport mode or the transport system before and during the trip (FGSV 2003). Therefore, the area in which the strategies should be applied has to be defined, analysed and structured in the first step. The definition of the study area has to be done based on the traffic streams (origin-destination relations). Furthermore, organisational-institutional aspects (e. g. administrative boundaries, catchment area of public transport associations) and technical-physical aspects (e. g. connections of equipments to control centres) have to be considered. Superordinated planning areas or master development plans can also have an influence on the definition and structure of the study area.

To limit the complexity for larger areas, it can be useful to define sub-areas or sectors within the study area. These sectors can be derived from the following criteria:

- the kind, extend and allocation of the traffic problems,
- the size and structure of the whole network (strategic network),
- the identifiability of different sectors,

- the existing physical integration (e. g. responsibility areas of traffic control centres),
- the existing equipment (traffic detection, traffic control), and
- the distribution of population and economic centres (e. g. settlement structure).

The abovementioned criteria interact with each other. The definition of a sector is strongly dependent on the spatial distribution of the population and on the main origin-destination relations. Sectors may be completely separated, but they may also overlap each other.

Identification of the Strategic Network

For an effective traffic control by measures of the dynamic traffic management, it is useful to identify a strategic network for the present and planned infrastructure. This allows to concentrate with all actions on this major part of the network. The design of the strategic network depends on the objectives of the traffic management.

The strategic network arises from sections within the study area that are affected by relevant problems and from sections that can be incorporated in the strategic control (e. g. sections influenced by variable direction signs). A permanent evaluation and adjustment of the strategic network is necessary due to possible changes of the infrastructure.

Furthermore, there must be a continuous feedback loop between the identified strategic network and the working steps described in the following. A frequent consultation between persons responsible for the operation and persons from the planning department is necessary.

The strategic network comprises roads with high capacity (motorways, federal roads, state roads as well as urban main streets), intersections with appropriate control facilities, public transport lines with high capacity (railway, subway, tramways and possibly bus lines) and their stations/stops as well as other traffic-related and traffic-relevant points of interest, such as

- event locations (e. g. stadiums, sport halls, fairs),
- airports,
- shipping piers (e. g. ferries),
- touristic points of interest / leisure facilities,
- shopping malls,
- city centres, market places,
- Park and Ride (P+R) facilities, parking places with strategic significance.

The P+R facilities are of high importance for intermodal strategies since they are the switch between public transport and individual motorised transport.

The detection, control, information, and guidance systems compose the technical infrastructure within the strategy implementation and, consequently, they are part of the strategic network. The detection systems are needed for the problem recognition. It is the most important informational basis for the detection of the current traffic condition and can also be utilized as a basis for the formation and optimisation of strategies. The guidance and control systems (e. g. section control systems, variable direction signs, parking guidance systems) as well as the information systems (e. g. radio, television, internet, mobile phone based systems, display panels) are necessary for the implementation of the strategies und have to be integrated in the strategic network, as well.

Analysis of Responsibility Areas

Organisational-institutional factors are having an high impact on the effectiveness of traffic management. Therefore, a clear identification of existing responsibilities is necessary for the strategy formation and strategy implementation. Not only the relevant actors within the study area but also the actors of neighbouring regions should be considered. Since changes within the responsibilities may occur, a permanent verification and adjustment of the communication channels and agreements have to take place. Detailed analyses of the responsibility areas give information

- about the tasks which are done without an explicit order,
- about the influences of the working method of the partners on the strategy development process,
- to what extent the present communication channels meet the real requirements of the traffic management (time, availability, decisions), and
- to what extent the existing traffic management systems comply with the present tasks and to what extent they can be enlarged, respectively.

Technical Inventory

The technical inventory is related to the available or planned technical infrastructure. As a first part, this includes the systems for traffic detection, traffic guidance, traffic control, as well as traffic information and payment systems. It has to be evaluated if the present systems comply with the state of the best available technology and if they might be adjusted with reasonable efforts. Each system is an important component for the data collection since specific situations such as congestion or occupied parking garages can be detected and processed. The data can finally be forwarded for the further processing to a superordinated traffic management centre. For example, the technical inventory may include:

- intersection and section traffic control systems,
- variable direction signs,
- parking guidance systems,
- traffic signals and controllers,
- computer-aided operation control systems in public transport,
- payment systems,
- individual navigation systems, information systems, mobility service centres,
- radio/TV broadcasts (RDS-TMC, DAB etc.),
- collective information systems, display panels (in public areas),
- internet as well as telephone-based systems (call centres, WAP, SMS etc.) and
- printed products.

Another part of the technical inventory is the analysis of the road and railway infrastructure which is available for dynamic traffic management measures. The capacity and the trafficability of the road and railway (sub-)network must be guaranteed (e. g. for heavy vehicles). For that reason, future construction projects (e. g. additional lanes) must be taken into account in the medium and long term, as well. To calculate the capacity of each network element, we can rely on available standards. The capacity of the public transport network is also very important for the strategy formation and has to be determined.

Calculation of Traffic Demand

The design of the strategic network does not only need to consider the geographical and political aspects and the technical inventory, but also the estimated traffic demand including the identification of the mobility patterns. Transport planning data will be utilised for the traffic management.

The road user's trip purpose (e. g. work, shopping, and commercial traffic) including the spatial and temporal distribution of trips have to be identified in order to estimate the traffic demand. That can be described for example by origin-destination relations, the time of the trip, the modal split, the share of heavy vehicles, the mode choice, and the route choice. This data can be determined with the aid of available data and/or additional surveys.

Detection of Incidents and Problems

With regard to the problem analysis, we have to distinguish two stages: the offline problem detection in order to prepare the subsequent strategy formation, and the real-time monitoring (online problem detection) in order to activate the developed strategies. Events and problems can generally be classified into the following categories:

- congestion in the road network,
- congestion in the public transport network,
- congestion or cancellation of parking facilities,
- bottlenecks in the road network (e. g. road works, accidents),
- bottlenecks in the public transport network (e. g. disruptions),
- emergency situations (e. g. fire, burst water pipe),
- electrical power outage (e. g. traffic signals, tramways, subways),
- problems related to special events, and
- weather conditions and other environmental problems.

An overlapping between the above-mentioned categories is possible. For example, major events often come along with a congestion in the road network.

For the preparative problem analysis, different methods can be applied, such as:

- expert interviews,
- analyses of traffic messages (e. g. RDS/TMC data stream),
- analyses of traffic accident data,

- continuous analyses of the operation of the technical systems,
- computational analyses of the volume/capacity ratio, and
- exploratory patrols and observations (to find out about traffic problems).

Only some of the above-mentioned methods are applicable for specific problem categories. As a start, the expert interviews can be a very efficient method. Analyses of traffic messages (e. g. frequency of warnings for heavy rain), analyses of traffic accident data, and analyses of data from traffic system operations (e. g. frequency of the activation of section control systems) are also powerful methods. The analysis of volume/capacity ratio leads to good estimations where frequent congestion problems might come up. Exploratory patrols and observations usually need too much effort to be applied efficiently.

To allow a proper strategy formation, the information on the problems must include the situation in which they occur. The accident which happens in the peak-hour will probably need a very different strategy compared with the accident which happens during nighttime. As mentioned earlier, the problems should be assessed regarding their frequency and regarding the severeness of their consequences.

The catalogue of problems derived from this step is also a good basis to decide on a stepwise formation and implementation of strategies.

3.2 Formation of Strategies

The objective of the strategy formation is to develop and to define a fixed action plan in which the different measures are compiled and the most appropriate ones can be chosen and implemented for specific situations. Depending on the situation, they can be applied for single means of transport (monomodal strategies) or multiple means of transport (intermodal or multimodal strategies). Furthermore, the strategies have to be locally allocated what means that problems, measures and systems have to be temporally and spatially described.

Measures are developed for pre-defined situations to lower or to eliminate deficiencies in the traffic system. Very roughly, the measures can be dedicated to the following categories:

- measures in public transport,
- measures in motorised individual transport,
- intermodal measures (several modes of transport related to each other),
- multimodal measures (several modes of transport independent from each other), and
- further measures (e. g. pedestrian, bicycle).

Examples of measures in the first four categories are given in Figure 4.

public transport	motorised individual traffic
▪ shifting passengers to public transport (PT) ▪ re-routing public transport vehicles ▪ strategic PT-prioritisation ▪ capacity adaptation in PT ▪ additional/special vehicles and stops ▪ assurance of connections in PT ▪ deployment of substitute traffic	▪ re-routing motorised traffic streams ▪ increase of capacity (e .g. by green time extension, lane signalisation or section traffic control) ▪ regulation of speed and/or driver behaviour ▪ access control of motorised traffic ▪ adaptation of parking space ▪ enabling special lanes
intermodal	**multimodal**
▪ influencing the mode choice (e. g. through pre-trip or on-trip recommendations) ▪ supply of temporary Park-and-Ride facilities ▪ financial measures	▪ change of usage of traffic space (e. g. dynamic bus lane) ▪ shifting the departure time of the trip (e. g. through recommendations by various media) ▪ status information, distracting measures

Figure 4: CATEGORIES OF MEASURES
(SOURCE: OWN FIGURE BASED ON FGSV (2003)).

Figure 5 introduces a systematic approach for the strategy formation. Generalised in categories, potentially useful measures can be allocated to problems (Matrix A in Figure 5). And we can also allocate the necessary systems for control, information, or guidance to the measures (Matrix B in Figure 5). Before the implementation takes place, it has to be analysed, if besides the required systems a further need for action exists (e. g. flexible traffic signal control, provision of staff, installation of Park-and-Ride facilities, installation of flag stops etc.). This process is indicated by Matrix C in Figure 5. The purpose of such matrices is to support the strategy planner. They can be provided with very general contents (as e. g. in German guidelines), or they can be adapted and detailed to cover more specific local conditions.

Several additional information may be necessary to define a strategy. This includes thresholds of various parameters for activating and deactivating the strategy, communication processes between involved institutions etc. Finally, all information on the strategy (addressed situations and problems, included measures, involved systems, further need for action etc.) can be summarised in a standard format. Such template we can call a strategy mask.

Finally, the formed strategies can be listed in a strategy catalogue which gives an overview about possible problems and events (situations) as well as a systematic description and compilation of all formed strategies. For a more sophisticated strategy management, of course, these tasks could be supported by information technology and a structured data base.

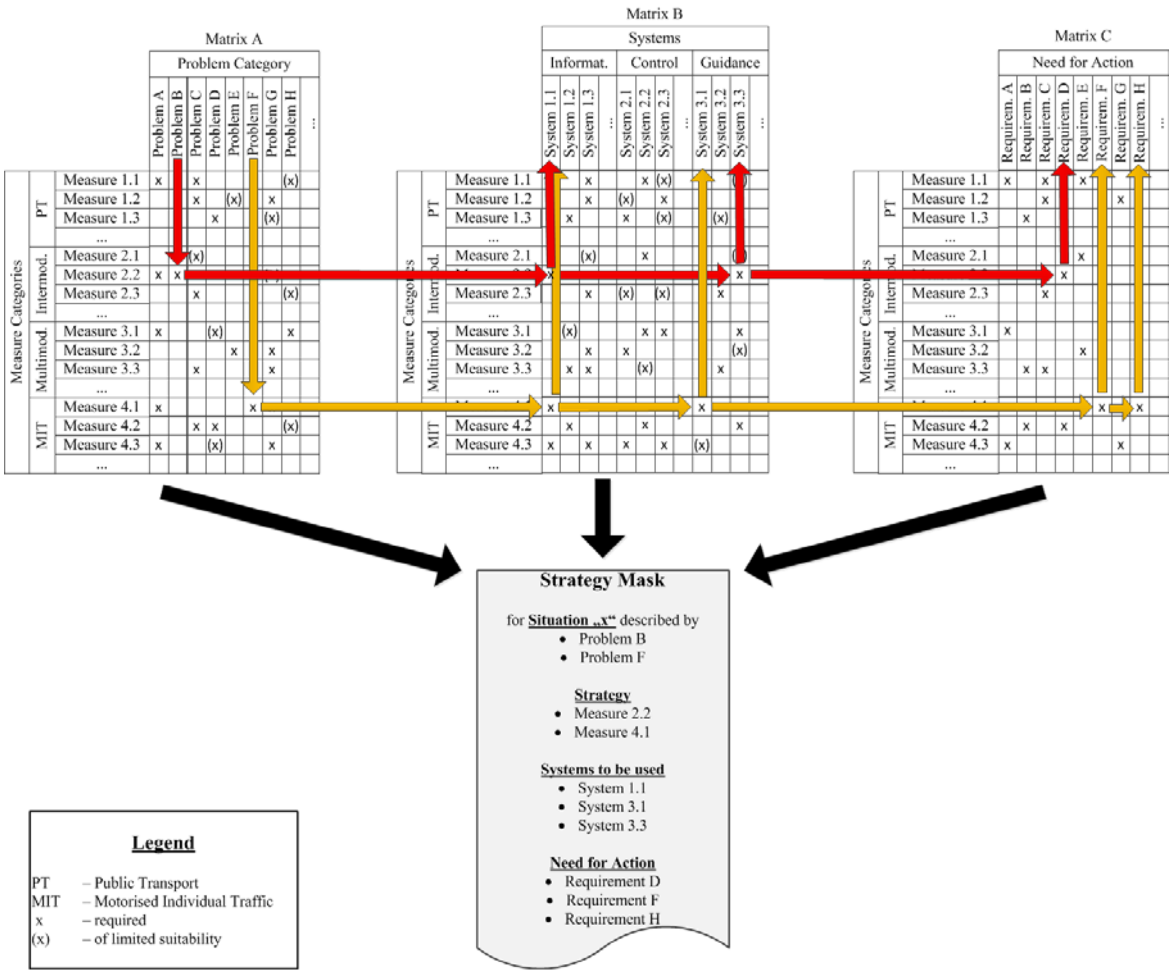

Figure 5: SYSTEMATIC APPROACH FOR THE STRATEGY FORMATION
(SOURCE: BASED ON FGSV (2003))

3.3 Assessment and Optimisation of Strategies

The process of the assessment and optimisation of strategies is illustrated in Figure 6. In the first step, the goals and weightings of the assessment and optimisation process have to be defined. It has to be secured that the developed strategies comply with the superordinated traffic management goals (usually: increase traffic quality, increase traffic safety, reduce environmental impacts, and increase cost efficiency). They have to be specified according to the local conditions and to be assessed according to their traffic-related and other impacts based on different criteria, such as traffic volume, travel time, operation costs, level of emissions, and number of accidents. The positive and negative impacts have to be quantified in order to assess the effectiveness of a strategy. Thereby, the estimated and real duration of an event is an important information from which the number of concerned road users can be derived.
In the next step, the assessment method has to be determined. This can be for instance

- qualitative considerations,
- the usage of available results for comparable strategies,
- trials and observations in the real traffic network, and
- modelling and simulation.

The approach of the assessment depends on the complexity of the situation which has to be evaluated. Extensive assessment methods, for example by a microscopic simulation of the traffic flow, are suitable for complex situations with multiple interactions. In other situations, for example in cases where traffic streams have to be bypassed over existing alternative routes, simple assessment approaches are often sufficient.

Due to the application of specific assessment methods, considerations of complex interdependencies between different traffic management measures are possible. Moreover, the illustration of the results, e. g. by using traffic flow simulation software, supports the approval and decision-making process. Using such tools, the comparison of different strategies is more effective since the impacts of the strategies can be quantified.

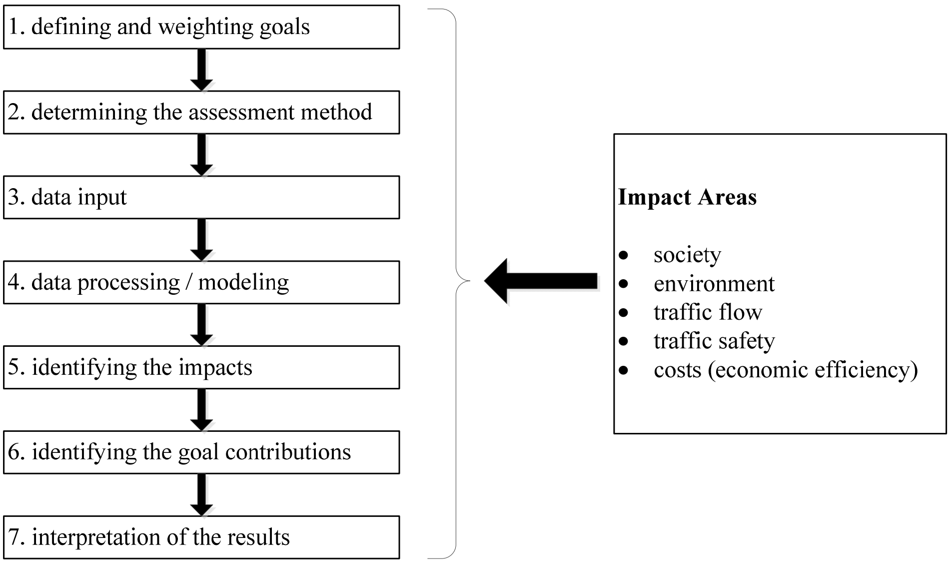

Figure 6: STRATEGY ASSESSMENT PROCESS
(SOURCE: BASED ON AS&P et al. (1999))

In the next stages, the data have to be chosen for the respective method and processed before the strategies will be analysed and optimised regarding their potential impacts and effectiveness. Sometimes it is useful, to conduct the impact analysis in several steps, with a first step of rough impact estimation for a large number of strategies, but then with a detailed assessment of the most promising strategies.

The determination of impacts has also to consider long-term developments. A change of the driver or passenger behaviour observed short time after implementation may turn to a lower level in the long run. The reason is the increasing experience with new systems and situations.

The impacts of strategies are case-specific and are influenced by several boundary conditions. Therefore, selective analyses are necessary for a precise estimation of the effects which can only be determined by comprehensive comparisons. Due to that reason, impacts should be investigated for three cases:

- zero-case (normal, without incident),
- case of incident without strategy implementation,
- case of incident with strategy implementation.

Finally, the goal contributions of the strategies and the assessment results have to be identified. Interactions with other measures and undesired side-effects have to be considered. An allocation of observed impacts to specific components of simultaneously realised measures is often difficult or even impossible. Sometimes, a comparison with similar situations and strategies can help.

With the results of the impact analysis, the strategies can be optimised. In general, it can be stated that our knowledge regarding the impacts of many systems is quite limited, so far. Guidelines for the application of differentiated assessment approaches or even strategy optimisation procedures have not been elaborated so far. Thus, a further need for research can be identified in this context.

4 ONLINE STRATEGY IMPLEMENTATION

The traffic management is responsible for the implementation of the strategies. In detail, it has to be decided in which situation the strategies have to be activated with regard to the defined threshold values, and when they have to be reversed. This tasks can either be done computer-aided in a closed loop or open loop, or completely manually.

The implementation process passes through different stages which are interrelated to each other (cf. Figure 3). A quantitative and/or qualitative real time detection and data basis of the traffic situation is necessary for a proper strategy selection and strategy activation. Based on the detection systems, relevant problems can be identified. To solve or to reduce the identified problems, an appropriate strategy must be chosen and assessed regarding its suitability and feasibility in the current situation. The selected measures will be implemented by using guidance, information, and control systems, sometimes also by using staff. The impacts of the strategies should be assessed in the course of their activation and, if necessary and applicable, the strategies should be adjusted. The implementation of strategies should be strongly related to the continuous improvement of strategies, which is only possible if the processes, problems, and experiences are documented. The documentation should be supported by a geographical information system.

Since the implementation of effective strategies very often interferes in different responsibility areas, the decision processes for activating a strategy must be clarified in advance. Detailed agreements on specific pre-defined strategies and on standardised communication processes between partners help to allow fast decisions in critical situations.

5 CONCEPT OF INTEGRATION

In a specific area, the traffic management and the developed strategies require an interaction of different functions, systems, and stakeholders for the traffic detection and traffic control. An elementary pre-condition for a successfully integrated strategy with different traffic detection and traffic control systems is the knowledge about the traffic situation and the present and planned control-status of all relevant systems. The process of integration is necessary for a comprehensive illustration of the planning and implementation of the traffic management strategies.

The **conceptual-functional level** of integration should be the starting point to think about integration. This includes the functional interactions between systems and between systems and control centres, as required for the implementation of strategies. The necessary exchange of information between components of the traffic management system is a consequence of this.

Based on the functions, the links and interfaces between the system components can be defined on the **technical-physical level**. This includes communication techniques, data formats, measures to guarantee data integrity, and measures for the quality assurance.

On the **organisational-institutional level**, the processes for the development and implementation of strategies have to be established. Since for many strategies the cooperation of different institutions is needed, the organisational framework gains high importance. Solutions for the strategy development range from regular meetings of involved stakeholders or forming permanent working groups under cooperation agreements to founding superordinated regional traffic management authorities. Strategy agreements including regulations on the communication for strategy activation are proper instruments for the strategy implementation. The conceptual-functional level and the organisational level do have close interrelations.

Integration is not an end in itself. For effective integration, the strategies to be applied with all their integration requirements have to be known in advance. In turn, the existing or feasible integration has to be considered when elaborating traffic management strategies. In case the efforts of integration are too high for a specific strategy, alternative strategies have to be designed which get along with a feasible integration (BOLTZE, BRESER 2005).

Before starting with a more detailed planning of measures for integration, a general decision should be made about the basic form of integration. Figure 7 shows different basic forms of integration which could be applied, depending on local conditions, functional requirements, and organisational preferences. In Germany, we observe that the poly-centric integration is favoured in most cases since it allows good functionalities without need for shifting responsibilities.

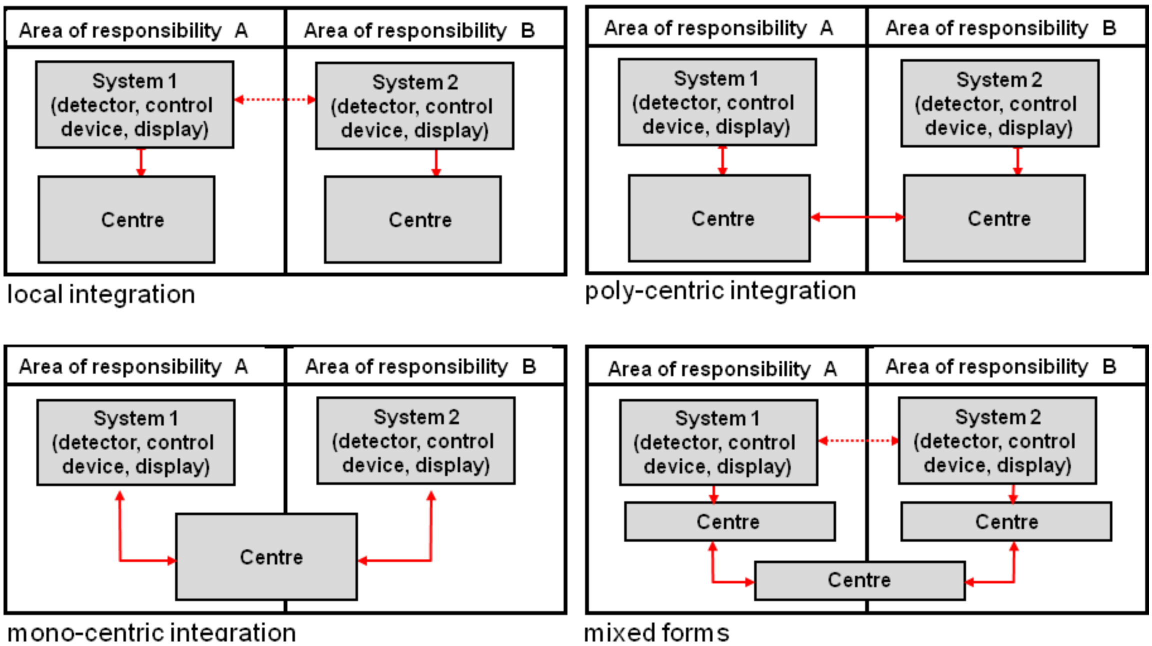

Figure 7: BASIC FORMS OF INTEGRATION
(SOURCE: TRANSLATED FROM BOLTZE, BRESER (2005))

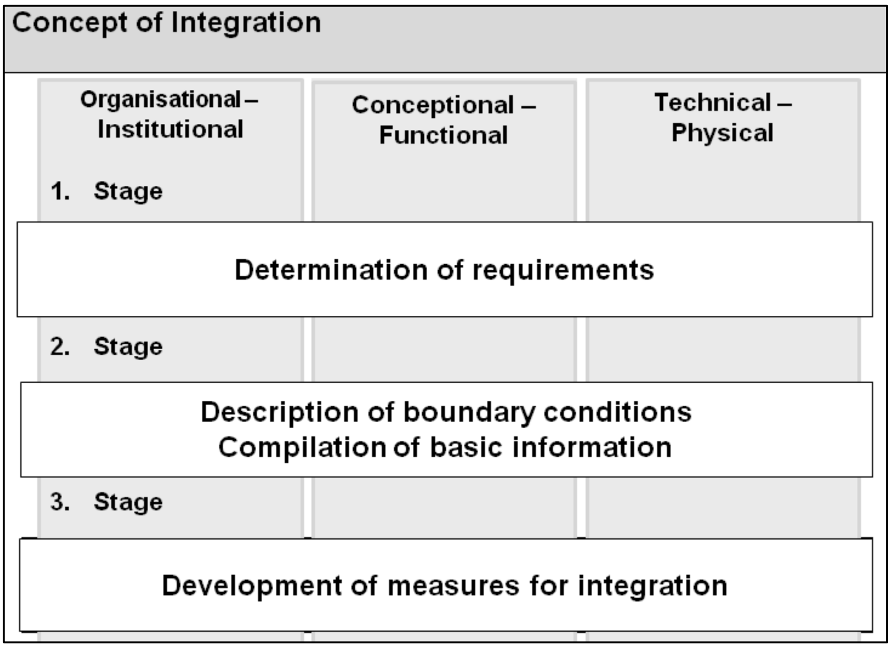

Figure 8: CONCEPT OF INTEGRATION
(SOURCE: TRANSLATED FROM BMVBS (2006))

Similar to the development of strategies, the conception of measures for integration is divided into several stages which are illustrated in Figure 8.

On the first stage, the requirements for the integration have to be identified. As for the offline development of strategies, the compilation of basic information (as the boundary conditions) is an important step (second stage). It needs quite many efforts, but most of it is similar with the basic information for the strategy development process. The third stage addresses the development of measures for the integration. Different options for implementation have to be designed, respecting the fulfilment of specific requirements and boundary conditions.

6 APPLICATIONS OF DYNAMIC TRAFFIC MANAGEMENT STRATEGIES

In this chapter, the contents and results of four further related research projects at Technische Universitaet Darmstadt will briefly be described.

6.1 STRATEGIES FOR AIR POLLUTION PREVENTION IN OFFENBACH AM MAIN

Dynamic traffic management aims to react on changing situations. These situations are not only related to traffic conditions but also to environmental conditions. Hence, traffic management strategies can be developed to reduce emissions and local pollution levels in situations when specific pollution thresholds are exceeded. Besides the general traffic management objectives, specific objectives such as compliance with particulate matter thresholds, compliance with yearly mean values of nitrogen oxide, minimization of short term pollution and general reduction of traffic-related environmental pollution can be defined for such cases. Of course, noise pollution can be treated in the same way. In general, environmental problems are not existing permanently since they depend strongly on weather conditions, background pollution, and other factors. Since most of the measures to reduce the pollution level have negative impacts on drivers (e. g. longer routes and longer travel times) or at other locations, it is obvious that dynamic, situation-responsive strategies are very appropriate to cope with environmental problems.

In this research project which has been elaborated for the German City of Offenbach am Main, a situation-adaptive strategy has been developed to influence traffic with the objective to reduce the traffic related air pollution. Consequently, the environmental pollution level and additional factors have to be detected besides the traffic condition. By analysing and assessing different measures with a regression model (KOHOUTEK et al. 2012) which has been calibrated by pollution measurements at an intersection in Offenbach am Main, temporal metering of traffic by a traffic signal has been identified as one of the most effective measures to reduce environmental pollution at a specific hotspot and to sustain a good traffic flow at the same time.

The planning process described in this paper has been extended to this category of environmental problems. A general concept for the selection of suitable measures, for the strategy development as well as for the assessment of the strategies for the City Offenbach am Main has been elaborated. The estimated reduction potential of the identified measures, which has also been calculated with the developed regression model, clearly indicate that a situation-adaptive, environment-oriented traffic control can significantly contribute to adhere to legal environmental thresholds (BOLTZE et al. 2011; KOHOUTEK et al. 2012).

6.2 DYNAMIC TRAFFIC MANAGEMENT STRATEGIES IN RAIL-BOUND TRANSPORTATION SYSTEMS

The presented method described in chapter 3 has been utilized to develop strategies for cases of incidents for a German railway operator. In general, one can state that the method developed for road traffic is well applicable for railway systems, too. However, since a rail-bound transport system is considered, some adjustments within different stages of the strategy development are necessary. For example, it has to be considered that for the German railway system the responsibility area is divided according to operator specific regulations which are different from the road network. Furthermore, some specific operative and technical aspects of the railway system must be taken into account. In that context, different measures can be identified and integrated in the strategy development compared to the measures of the road traffic (e. g. turn-over of trains, division of trains, additional wagons, closure of train stations, etc.). However, the road network is still an essential element of the measures for the railway traffic, as well, since it can be utilized for compensating measures (utilization of alternative means of transport (busses)). The entire method and several advises for the strategy development have been summarised in a handbook. Currently, the handbook and its results are processed and further developed within a German railway operator and are supposed to be realized within the next years (CHU, FORNAUF 2010; CHU, FORNAUF 2011; FORNAUF et al. 2012).

6.3 REAL TIME MONITORING OF TRAFFIC IN HANOI

The current research project REMON “Real Time Monitoring of Traffic in Hanoi” is developing traffic management strategies for the capital of Vietnam, Hanoi. The key objectives of the REMON project are the reduction of air pollutants and emissions as well as the reduction of energy consumption in the urban transport sector due to suitable traffic management measures and strategies, respectively. The consortium of German and Vietnamese partners will establish a real-time traffic information system in Hanoi, which helps to increase the efficiency of Hanoi’s transport system and thus reduce environmental impacts of traffic, in particular traffic congestion, traffic induced emissions and energy consumption. The monitoring of the traffic conditions is one of the most important issues in order to develop and to apply appropriate strategies. Therefore, a comprehensive data collecting system will be established in Hanoi by using floating car data (FCD) and GPS-based floating phone data (FPD) at the same time. Thus, the FCD and FPD system equals a dynamic sensor for traffic flows, vehicular emissions, and transport related issues such as accessibility and travel patterns and can be utilized as a planning and monitoring tool for the strategy development (LORBACHER 2012).

Moreover, the challenge in this project is to analyse, if the method and the measures for the strategy development presented in this paper, which have originally been elaborated for cities in an industrialised country, are applicable in a developing country with different traffic and other framework conditions, as well. It is also a purpose of this project to investigate which adjustments have to be done in order to get the method and the strategies work in a developing country.

6.4 TRAFFIC MANAGEMENT STRATEGIES IN CASES OF DISASTERS

The previously described method has also been addressed in the doctoral thesis of MINHANS which deals with traffic management strategies in cases of disasters. Motivation for such research arised from the observation that traffic management obviously was inadequately addressed in many cases of disaster, in respective disaster management plans and real-time processes, which was and still is crucial to save lives and properties. In his thesis, MINHANS links the method of developing traffic management strategies with the processes of catastrophe management (disaster mitigation, preparedness, response, and recovery). He elaborates and provides a framework for the development and implementation of traffic management strategies for all stages, and a preselection of suitable traffic management measures for types of disasters. An important part of this thesis is the development of traffic management strategies which are segregated into public transport, non-motorised transport, individual motorised transport, multi-modal and intermodal measures. The study contributes to the development of a better understanding on disasters characteristics and disaster management processes. Furthermore, the study identified important traffic management problems and issues in cases of disasters, and it provides a list of complimentary measures and strategies for application in cases of disasters (MINHANS 2008).

7 CONCLUSIONS AND OUTLOOK

In this paper, a basic method has been presented on how to develop and implement dynamic traffic management strategies for cases of incidents, based on German guidelines and research projects. Increasing complexity of traffic problems and appropriate counteractions are forcing to overcome non-optimised ad-hoc actions with carefully planned and implemented strategies. The strong need for cooperation of different stakeholders in traffic operations even strengthens this requirement. Although we can clearly identify the basic need for such strategy management, we have to be aware that it requires severe efforts.

From practical case studies we can conclude that the presented method has not only proven its worth for the application in the urban and interurban road traffic in developed countries but it is also a proper framework for cities of developing countries. It is also applicable for railway systems even though some adjustments according to the specifics of railway traffic have to be done. Within international publications, a comparable method to develop such strategies systematically could not be identified in the traffic and transport sector.

Even though German researchers have been working on this topic for more than a decade and several publications and guidelines have already been published, there is still more need for research within this broad field of strategy development and implementation. We like to mention these examples:

- Strategy assessment: One aspect the authors will focus their research work in future is the assessment of strategies. Guidelines should be developed on which methods should be applied for different levels of situation complexity.
- Strategy optimisation: Based on proper strategy assessment, methods for offline and online strategy optimisation should be developed.

- Support by information technologies: Tools should be developed to allow a more efficient strategy development, strategy administration, and strategy communication.
- Standardised strategy description: Such standard is not available yet, but it might help the communication between different institutions and allow the fast communication and analysis of modified or ad-hoc developed strategies.
- Environment-responsive strategies: All over the world, the environmental problems need more specific and situation-adaptive solutions. First methodological approaches developed for this purpose need broader verification and further development.
- Quality management: Efficient methods should be developed to monitor the quality of applied dynamic traffic management strategies with the aim to establish a comprehensive quality management system for dynamic traffic management.

Finally, the authors wish to have more international exchange on this challenging topic. Experiences from different countries should be brought together to improve the methods to be applied for the development and implementation of dynamic traffic management strategies.

LITERATURE

AS&P - Albert Speer & Partner GmbH et al.: TASTe - Analysis and Development of Tools for Assessing Traffic Demand Management Strategies. Final Report. Project Funded by the European Commmission (DG VII). Frankfurt am Main (Germany), 1999.

Andree, R., Boltze, M., Jentsch, H.: Entwicklung von Strategien für ein dynamisches Verkehrsmanagement (Development of Strategies for Dynamic Traffic Management). In: Straßenverkehrstechnik 45, vol. 12, pp. 610-620. Bonn (Germany), 2001.

BMVBS (Bundesministerium für Verkehr, Bau und Stadtentwicklung): Leitfaden Verkehrs-telematik - Hinweise zur Planung und Nutzung in Kommunen und Kreisen (ITS Manual – Recommendations for the Planning and Application in Municipalities and Counties). Berlin (Germany), 2006.

Boltze, M., Breser, C.: Vernetzung dynamischer Verkehrsbeeinflussungssysteme auf Ringstrukturen überörtlicher Straßen und städtischen Verkehrsnetzen unter Einsatz dynamischer, kollektiver Wechselverkehrszeichen (Linking Dynamic Traffic Control Systems in Ring-Structures of Regional Roads and Urban Road Networks by Using Dynamic, Collective Variable Traffic Signs). In: Journal Series "Verkehrstechnik" der Bundesanstalt für Straßenwesen, Heft V 132. Bergisch Gladbach (Germany), 2005.

Boltze, M., Kohoutek, S., Krüger, P.: Entwicklung von Strategien zur Luftreinhaltung für die Stadt Offenbach am Main (Development of Clean Air Strategies for the City of Offenbach am Main). Proceedings of HEUREKA 2011. Forschungsgesellschaft für Straßen- und Verkehrs-wesen, Cologne, 2011.

Chu, F., Fornauf, L.: Strategies for dynamic traffic management in regional rail-bound public transportation systems. Abstract in: The Young European Arena of Research. 2010.

Chu, F., Fornauf, L.: Vom Katastrophen- und vom dynamischen Straßenverkehrsmanagement lernen – Störfallprogramme bei Betriebsstörungen im Schienenverkehr (Learning from Catastrophe Management and Road Traffic Management - Stratgegies for Opeartional Incidents in Railbound Traffic). Proceedings of HEUREKA 2011. Forschungsgesellschaft für Straßen- und Verkehrswesen, Cologne, 2011.

Chu, F., Fornauf, L., Böhme A., Wolters, A.: Methode zur Erarbeitung von Störfallprogrammen (A Method to Elaborate Traffic Management Strategies). In: Deine Bahn. Berlin, 7/2012.

FGSV (Forschungsgesellschaft für Straßen und Verkehrswesen): Leitfaden für Verkehrsplanungen (Guideline for Transport Planning). Cologne (Germany), 2001.

FGSV (Forschungsgesellschaft für Straßen und Verkehrswesen): Hinweise zur Strategieentwicklung im dynamischen Verkehrsmanagement (Recommendations on Developing Strategies for Dynamic Traffic Management). Cologne (Germany), 2003.

FGSV (Forschungsgesellschaft für Straßen und Verkehrswesen): Hinweise zur Strategieanwendung im dynamischen Verkehrsmanagement (Recommendations on the Application of Strategies for Dynamic Traffic Management). Cologne (Germany), 2011.

Kohoutek, S., Weinbruch, S., Boltze, M.: Reduction Potential of Environment-Responsive Traffic Control on Roadside Particulate Matter and Nitrogen Oxide Concentrations. Journal of the Transportation Research Board, No. 2270, pp. 162-170. Transportation Research Board of the National Academies. Washington, D.C., 2012.

Lorbacher, M.: Real Time Monitoring of Urban Transport - Solutions for Traffic Management and Urban Development in Hanoi. Project Fact Sheet. Berlin (Germany), 2012.

Minhans, A.: Traffic management strategies in cases of disasters. Doctoral Dissertation. Technische Universitaet Darmstadt, Chair of Transport Planning and Traffic Engineering. Darmstadt (Germany), 2008.

ZIV (Zentrum für integrierte Verkehrssysteme) et al.: Verknüpfung von Strategien, Maßnahmen und Systemen des regionalen und städtischen Verkehrsmanagements (Linking Strategies, Measures and Systems for Regional and Urban Traffic Management). Project Report. Darmstadt, Frankfurt a. M., Aachen (Germany), 2000.