A GERMAN EXAMPLE FOR A PUBLIC PRIVATE PARTNERSHIP IN TRANSPORT RESEARCH
–ZIV–Institute for Integrated Traffic and Transport Systems at Darmstadt University of Technology–

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In 1998, a new partnership for transport research was founded in Germany's central region Frankfurt RheinMain by major transport authorities and operators, involving partners from industry and consultancy, and supported by the Hessen State Government. This ZIV is an institute at Darmstadt University of Technology, and improves the exchange between research and practice. The article provides organisational details of this public private partnership. The ZIV working areas cover Transport Infrastructure and Traffic Management, Traffic Engineering and Traffic Control, Public Transport, Organisational Concepts for Traffic Management and Mobility Services, Railway Systems and Railway Engineering, and Navigation and Positioning Systems. For each of these areas, basic intentions in research and some project examples are presented. This may also allow some view on the current status of transport research in Germany.

Key Words: Transport research management, Traffic management, ITS, Transport planning, Traffic engineering

1. INTRODUCTION

Mobility is a key factor for people and the economy to save and improve the quality of life in conurbation areas. However, continuous growth of travel demand faces its limits in environmental impacts, and the financing of transport systems has become a problem for our society. This situation results in a need for efficient and intelligent use of existing and planned transport infrastructure using optimised traffic control and comprehensive, reliable, real-time travel information. Modern technologies in telecommunication and informatics – often referred to as ITS (Intelligent Transport Systems) – recently created new opportunities to improve planning, control and organisation of public transport as well as of individual traffic. But the optimised use of the various transport systems requires not only integrated technical solutions but also functional, organisational and institutional integration.

These general statements are also valid for Germany, where the Darmstadt University of Technology is located. Darmstadt belongs to the Region Frankfurt RheinMain, which is a conurbation area with approximately 3.8 million inhabitants. Because of its polycentric structure, its prosperous economic conditions, its central location in Germany as well as in Europe, and because of high volumes of traffic through passing, the region faces a very high demand for mobility.

Considering future development needs, the key actors of the Region Frankfurt RheinMain in traffic and transport aimed to bundle the available competences at Darmstadt University of Technology and in the region, to support the development of innovative, sustainable concepts for integrated traffic and transport systems.

For the university, this idea matched very well to the rapidly changing framework conditions under which research has to be conducted in Germany. In the last two decades, the research tasks became much more complex and need more interdisciplinary approaches. Because of this, there is a clear trend to bigger projects which usually cannot be handled by one university institute alone, and there is an increasing need for staff with higher qualification and more experience than young research associates at the university can usually have. Furthermore, many deficiencies in the current traffic and transport practice have their origin not so much in missing development of new technologies but much more in finding appropriate ways to bring new technologies to useful, broad applications – and this calls for application-oriented research which can hardly be done by university institutes without those persons and institutions who are responsible for the application. In teaching, an improved partnership with the traffic and transport actors also promised advantages. Students would have more opportunities to learn about current projects in lectures and to work in practical projects. Research associates would have more activities in their environment, and better access to data and other experience for their research work.

In this situation, in an informal meeting of high-level representatives from the Government of Hessen (one of 16 German federal states), from regional key actors in traffic and transport, and from Darmstadt University of Technology, the idea was born to found a new application-oriented research institute in a public private partnership. In September 1998, the ZIV – Zentrum für integrierte Verkehrssysteme (Institute for Integrated Traffic and Transport Systems) at Darmstadt University of Technology was founded.

2. ORGANISATIONAL STRUCTURE

The ZIV was founded under German law as a GmbH (limited company, Ltd.). Shareholders of the ZIV are the Regional Public Transport Authority (RMV – Rhein-Main Verkehrsverbund), the Frankfurt Airport Authority (Fraport AG), the German Rail (DB Regio AG) and the Association for Promoting Integrated Traffic and Transport Systems (FIV – Förderverein für integrierte Verkehrssysteme e.V.), each of them with a 25 % share.

The Government of Hessen supported the founding of ZIV by its Ministry of Economics, Transportation, Urban and Regional Development, and the Vice Secretary of State is a member of the ZIV steering board. Darmstadt University of Technology, as a state university, is not a shareholder, but a special contract with ZIV details the form of cooperation. Its president has joined the ZIV steering board. Furthermore, the ZIV shareholder contract says that the university's professor for transport planning and traffic engineering of the Faculty of Civil Engineering and Surveying, currently Prof. Boltze, should be a manager of ZIV. But of course, the role of Prof. Boltze is limited to the scientific management, because as a full professor he has to divide his time between teaching and research at the university and at ZIV. Finally, it may be mentioned that the status of ZIV as an "Institute at Darmstadt University of Technology" depends much more on clear personal commitment of all acting partners than on formal contracts.

Today, under the scientific and executive management of three persons, about 25 research associates work together in ZIV on innovative concepts towards the optimisation of traffic and transport systems. So far, the researchers have brought experiences from transport planning and traffic engineering, regional and urban planning, electronics, physics, mechanical engineering and informatics. They are supported by a small number of non-technical staff and by about 15 students with fixed part-time contracts.

There is no basic funding for ZIV, but it is financed exclusively through orders for planning and consulting with a focus on application-oriented research and development. In the first year of ZIV, about 60% of all orders came from the shareholders, which was reduced to about 30 % in the third year. Other orders come from industry, transport operators, cities and counties, the Hessian Traffic and Road Authority, the German Ministry for Transport, Construction and Housing, the German Ministry for Education and Research, and from the European Commissions. The marketing strategy of ZIV is based on good references, publications, expert networks and personal contacts.

An important issue of ZIV is the close relation to the university. A very close cooperation already has been established between ZIV and the university's section of Transport Planning and Traffic Engineering. In addition to Prof. Boltze's role as head of both institutions, all research associates from this section frequently contribute to ZIV projects. On the other hand, university research projects and teaching are supported by ZIV staff. The section of Transport Planning and Traffic Engineering, which was founded as early as 1966 by Prof. Dr.-Ing. Dr.-Ing. E.h. Hans-Georg Retzko, traditionally holds close relations to Japanese research institutions. Prof. Boltze likes to continue this tradition, and researchers from Japan are most welcome in Darmstadt. During the past years, many Japanese guests have already participated in the research work at Darmstadt University of Technology and of course at ZIV.

ZIV Scientific Advisory Board

Another important element to strengthen the relations between ZIV and the university and to establish a competence centre for traffic and transport was the founding of the ZIV Scientific Advisory Board. This Board currently consists of 12 professors who have a relationship to traffic and transport: Environmental Planning, Road Engineering, Transport Planning and Traffic Engineering, Flight Systems and Control, Ergonomics, Interactive Graphics Systems, Multimedia Communication, Physical Geodesy and Satellite Geodesy, Management, Management of Technology and Marketing, and Mathematical Stochastics and Operations Research. These professors meet on a regular basis every six months for scientific exchange and consultation of ZIV. Furthermore, they join and support many ZIV projects with their specific knowledge and experience.

FIV — Association to Promote Integrated Traffic and Transport Systems

FIV is a registered society which was founded in 1998 together with ZIV to allow a formal involvement of more partners in this initiative. FIV supports the coordination of projects and partners in regional traffic management, and it promotes the cooperation of science, public authorities and economy. The 13 members of FIV come from industry and consulting, and of course from the ZIV shareholders. Because fees for a full membership caused problems for many public authorities, a free associated membership was introduced in 2001. So far, five cities from the region, two regional planning authorities and two universities became associated members. FIV members have regular full meetings every half year, additional meetings in working groups. Twice a year a conference on a specific subject is organised by FIV. The administration work for the FIV is done by ZIV.

Networks of Transport Professionals

To support the transfer of knowledge, information and technology between research, development and practice, essential contributions are provided by ZIV to various networks of researchers and practitioners in traffic and transport. In addition to the more regional activities in FIV, ZIV members join many national and international committees of transport professionals. This includes the Committee of the World Road Association on "Interurban Roads" (C4), and many working groups of the German Road and Traffic Research Association, including the chair of the working groups "Urban Traffic Control" and "Optimisation and Decision-Support in Traffic and Transport".

Office Premises

The ZIV office (about 800 m^2) is located with very good connection to all transport networks, close to Darmstadt Main Station. It is outside the university, but in direct neighbourhood of the TIZ – Technology and Innovation Centre (incubator for university spin-off companies). When founding the ZIV, this location was appreciated very much by the City of Darmstadt, because there was a new urban development which needed some stimulation.

3. CURRENT RESEARCH ACTIVITIES

3.1 Overview

With currently about 60 running projects in ZIV, this article can only provide a general view on the current activities and highlight some project examples. This may also give information on some issues of current transport research in Germany.

Main objective of the ZIV is applied research in the field of traffic and transport, with a special focus on initiating new developments in the field of traffic management. Traffic Management means to influence traffic and transport with a bundle of measures to bring travel demand and supply of transport systems in an optimised balance. As shown in Figure 1, it includes measures to avoid traffic, to shift traffic (in time, mode and location of destination), and to control traffic. By the employment of modern technology – particularly the usage of communication technology and informatics, often referred to as transport telematics or ITS – the ZIV is a competent partner for establishing reasonable traffic and transport concepts. However, ZIV members are always aware that using technologies has no end in itself but has to be oriented towards the goals of traffic management[1, 2]. ZIV competences are available in public transport as well as in all modes of individual traffic, and special emphasis is given to innovative multimodal solutions. ZIV is also a platform for better communication and information exchange between the various partners of the regional traffic management, and it offers research management by concept development for research programs and by supporting their realisation.

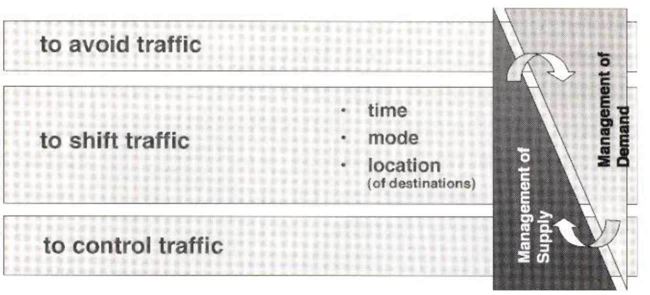

Fig. 1 Areas of traffic management measures

Currently, the ZIV activities may be described with these project and research areas:

- Transport Infrastructure and Traffic Management
- Traffic Engineering and Traffic Control
- Public Transport

- Organisational Concepts for Traffic Management and Mobility Services
- Railway Systems and Railway Engineering
- Navigation and Positioning Systems

All these project and research areas have strong relationships with each other. To promote the necessary exchange of knowledge and to gain flexibility in allocating staff to projects the affiliation of ZIV members to one specific group is not clearly defined. But nevertheless, there is a clear focus of all ZIV members on one or two of these areas.

3.2 Transport infrastructure and traffic management

The ZIV contributes to many infrastructure development projects by consulting and introducing advanced investigation methods. In all infrastructure projects, ZIV aims at integrating the needs of operating the transport network as early as possible and at making use of advanced methodologies and procedures such as microscopic simulation of traffic flow, geographic information systems (GIS), or advanced optimisation and evaluation methods. A major task in such projects is the acquisition and processing of data to feed the modelling of infrastructure, travel demand and control measures. Furthermore, the linking of models for different transport modes and with different levels of detail (e.g. macroscopic and microscopic simulation of traffic flow) causes a lot of attention.

Another important contribution of ZIV in regional infrastructure projects is to support the consultation process with the various regional stakeholders in traffic and transport. Prerequisites for this support are good relations to the key persons in relevant institutions. Usually, a steering group with representatives from all relevant stakeholders (up to 30 members) is set up at the very beginning of a project. Regular meetings are held during all phases of the project. This includes early discussion and agreement on the working programme, the applied investigation methods, and on the database to be used. Further meetings aim at common understanding and conclusions from intermediate and final results. The preparation of such meetings may need many single contacts with the stakeholders to allow an effective and successful steering group meeting. Furthermore, it is of major importance to present the results during the meetings in a way which is clear and easily understandable (e.g. using micro-simulation). But all these efforts are more than justified if consultation is gained and conflicts of stakeholders can be avoided.

A wide range of projects has already been conducted in ZIV since its founding. This includes both, small projects (such as designing car parks or developing optimised layouts for intersections) and outstanding large projects (such as the planning of landside transport infrastructure for the extension of Frankfurt International Airport).

For the City of Hamburg the feasibility of a light rail system in the urban road network was investigated using microscopic simulation of traffic flow. In a project conducted by the European Commission major requirements of the regions concerning the access to the TEN – Trans-European Networks (road, rail, and air) were elaborated. And with regard to a more local problem, for German Rail, the City of Darmstadt, and other regional stakeholders the effects of connecting Darmstadt with a station to the new high-speed train line Frankfurt Rhein-Main – Mannheim Rhein-Neckar were investigated (see project example in section "Railway Systems and Railway Engineering"). Specific comprehensive expertise is available at ZIV in traffic management for special events such as World Exhibitions[3, 4]. Currently, ZIV also develops the traffic and transport concept for Frankfurt's application to host the Olympic Games in 2012 in this early stage of a national competition. Another example for ZIV projects in this area is the support of the Japanese Institute of Behavioural Studies (IBS), Tokyo, in collecting data from German cities for an international comparison of urban traffic and transport infrastructure.

Project Example: Landside Transport Infrastructure for the Extension of Frankfurt Airport

Currently, an extension of Frankfurt International Airport with a fourth runway and a third terminal is planned. For the Frankfurt Airport Authority (Fraport AG) different alternatives for the location of the third terminal and for the necessary road and rail transport infrastructure have been elaborated, detailed, and assessed since 2000. ZIV supported the consultation process with the various stakeholders in the region and also prepared documents for the formal legal planning process. Based on a regional database for travel demand a detailed transport modelling of the airport and its region has been developed. Linking macroscopic assignment and microscopic simulation of traffic flow in a large network is a valuable method to support the planning process. With this modelling, not only infrastructure measures can be assessed, but also changes in land-use around the airport and comprehensive traffic management measures. By this integrated and comprehensive view on land-use, transport infrastructure, and operation it is possible to gain a well-defined balance of travel demand and supply, and transport planning develops from solely reactive planning towards influencing not only land-use but even the use of single buildings and details such as working hours or shop opening hours. In addition to the large-scale planning of the airport extension, ZIV contributes with detailed design and detailed operational concepts for landside airport facilities, e.g. for the curb, for car rentals, or for taxi stands. New communication and information technologies are integrated where they can contribute to more smooth, reliable, and efficient operation of transport infrastructure. All these activities around airports are in close relation to the newly developed lectures at the university in air transport planning and airport design.

At this occasion it must be mentioned that nearly all projects of ZIV supply the traffic and transport relevant lectures of Prof. Boltze at the Darmstadt University of Technology as well as that students get insight into research and practical engineering projects.

3.3 Traffic engineering and traffic control

Increasing capacity problems in the available traffic infrastructure (Figure 1) require comprehensive traffic management and intelligent traffic control to make best use of available resources, to increase safety, to reduce economic costs and to reduce environmental impacts. The ZIV contributes to the necessary developments using innovative research results and technologies. ZIV members from this working group push many supplementary activities in different German research committees and are involved in the development of German technical guidelines for traffic control. On the other hand, approaches which are developed in ZIV are discussed in those research committees which provides valuable input to the development process.

The range of projects in this area goes from feasibility tests for new traffic sensor technologies, investigations on the optimum location of road traffic sensors, and the development of detailed control algorithms, as far as to the development of comprehensive traffic control strategies.

Development and application of expert systems are considered as one innovative approach. These systems make it possible that complex and extensive quantities of data can be analysed and consulted for control processes. Knowledge-based systems, fuzzy logic, neural networks etc. are applied for different problems.

Quality management for traffic signals has been established as a field of special expertise during the last two years. ZIV developed methods on how to conduct the necessary checks of signalised intersections regarding traffic safety and level of service with minimum efforts. Computer-based tools have been developed to support this task.

The integration of different traffic control and information systems, which are operated by different institutions, is another field of competence in ZIV. To allow immediate reaction in case of problems in the transport network, strategies (concepts for actions) have to be defined in advance by which one or more selected measures (e.g. alternative routing) are realised using the various available systems (e.g. variable direction signs, radio broadcasting).

A comprehensive methodological background for the development of strategies for a dynamic traffic management has been elaborated in a research project for the German Ministry of Transport, Construction and Housing[5, 6].

Synergies with other ZIV activities, e.g. in the area "Navigation and Positioning Systems", have to be emphasized. As an example, the acceleration of rescue vehicles or public transport at traffic lights by using high performance mobile positioning technology can be mentioned.

Project Example: Traffic Sensor

The Traffic Sensor (Figure 2) is a result of the cooperation of basic research and industry. It represents a high-tech development in the area of the magnetic field sensor technology of Prof. Dr. Uwe Hartmann from Saarland University, Saarbruecken. This magnetic field sensor records small variations within a magnetic field, which are induced by metallic objects, e.g. motor vehicles, bicycles, rail vehicles or airplanes. The sensor is very small,

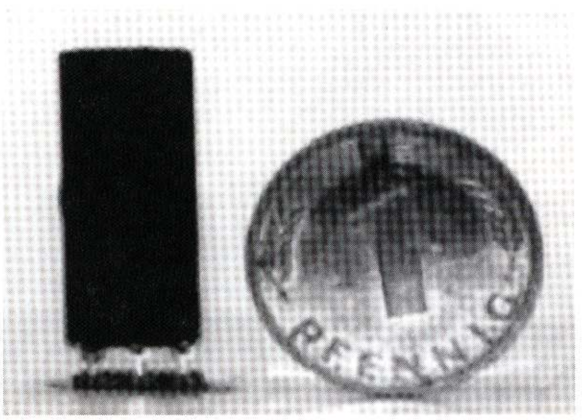

Fig. 2 Traffic sensor

low-priced and has an extremely low energy consumption combined with minimum maintenance costs and a long life span. Further characteristics are its high sensitivity and band-width. The detection is not impaired by darkness, weather or contamination. Vehicles can be detected from the bottom, top or side. It is also applicable on reinforced concrete bridges and at protective side barriers.

ZIV is searching and developing useful applications of this sensor technology in traffic and transport. First field tests concerning the basic functionality of the sensor and specific applications were conducted and gave positive results. The application areas are manifold. As a major application field the detection of moving vehicles on motorways and at traffic lights appears. Other specific applications may be, for example, the detection of vehicles approaching car park barriers or occupying a single parking space.

Another application field is the monitoring of vehicle and aircraft movements at airports. Due to increasing air traffic, capacity bottlenecks in the aircraft movement areas already arise on major airports and can substantially affect safety. Surveillance of taxiways (Figure 3) and gate positions are sample applications for the monitoring of the aircraft movements. In a further step, this monitoring may lead to a comprehensive guidance system for aircrafts and a support system for monitoring and planning of ground handling services.

Project Example: Traffic Management Strategies at Frankfurt International Airport

In the context of the project WAYflow in the Region Frankfurt RheinMain[7] the ZIV examines traffic management measures improving the traffic network at Frankfurt International Airport. In the area of the airport several control systems such as variable direction signs and a dynamic parking guidance system are already in use (Figure 4).

Fig. 3 Traffic sensor tests for the surveillance of taxiways

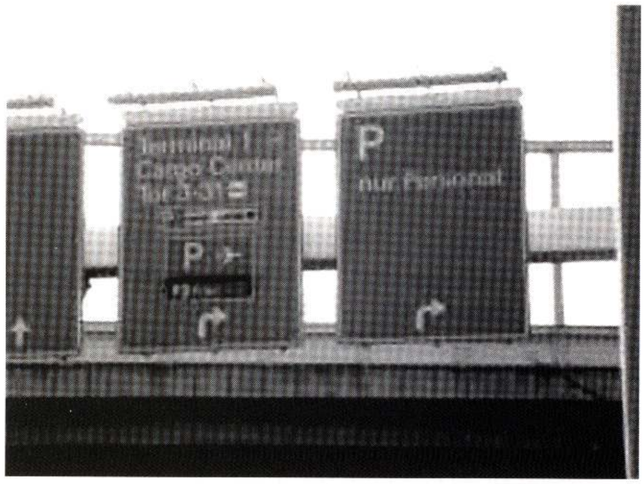

Fig. 4 Parking guidance system at Frankfurt International Airport

The aim of this project is to secure an undisturbed arrival and departure of all vehicles, private traffic and public transport, at the airport under all circumstances. A basic prerequisite to reach this aim is the coordination of regional and local road authorities and the airport authority. As a part of this project the effects of the rising number of passengers on the landside traffic network are investigated. The capacity of the traffic infrastructure will be evaluated. Measures and control strategies for improving the existing network will be developed. Various scenarios with detailed control strategies are demonstrated and visualised by a microscopic simulation with AIMSUN2[8].

3.4 Public transport

Compared to individual traffic, the technical level and the standard of service of public transport systems are still mostly lower. This is founded on:

- economic-political deficiencies (particularly the still missing perfect competition between public transport carriers),
- unavailable online data-sets on demanded transport relations as well as on transport processes (for exact planning and guidance),
- missing flexible conjunction with other transport systems (intermodal transport conception),
- long-winded decision making by public authorities due to mostly extensive projects, and
- still existing entry barriers for customers due to the tough implementation of technical innovations and the missing integration in the comprehensive transport system.

Within the scope of public transport and ITS, the ZIV develops sustainable solutions for these problems also by integrating other fields of activities inside the ZIV.

The tasks of this group range from concept development and detailed system layouts to the evaluation of planned and already implemented systems. This includes systems for operation control, traveller information and electronic ticketing, innovative operational concepts, and many other aspects. In many cases, major contributions from this group are integrated in projects of infrastructure development, traffic management and mobility services.

Project Example: FreeFloat

Based on the political demand in the European Union to promote competition between railway carriers in Europe, all carriers have to get an unrestricted access to the railway network without any discrimination at any time. In this context, the task of the project *FreeFloat* is to realise both flexible planning (offline) and flexible operating schedule (online) on the railway network using advanced technologies for positioning, communication and information processing. *FreeFloat* will enable an optimised railway network utilisation while maintaining the possibility to find routes for various railway carriers in the network during the daily operating schedule. In this process, standards for optimisation and prioritisation are needed in particular when tensely demanded railway sections and concurrent carriers claim access.

The major task of ZIV in this project for the German rail network operator (DB Netz AG) is to define suitable and comprehensible parameters for all parties which are involved in the railway process to allow transparent decisions by the railway network operator. In addition, the potential assets and drawbacks of *FreeFloat* for customers should be analysed and respectively evaluated within the overall transport processes (planning, ordering, transacting, controlling).

Project Example: ÖDiBus – Management System for Public Transport in Rural Areas

Today the increasing economic needs are forcing the authorities to reduce even public transport services. In particular, the fixed-route service in rural areas with relatively low demand are mostly reduced. One solution to perpetuate the public transport service is to operate it only on request. In the early 1980's first methods to plan and first systems to manage demand responsive services (scheduled or non scheduled) were developed and tested in Germany. But they never were applied to public transport in rural areas, because these systems were based on sophisticated and costly management systems as they are available for public transport in most large cities. Therefore, the successful re-launch of a demand responsive scheme in rural areas depends on a feasible online control system which may be used not only for demand responsive services but also for fixed-route services to reduce the expenditures for personnel and material. The requirements on such a system include centralised management of riding requests and for fleet supervision, the utilisation of standard low cost equipment, and the usage of already available communication systems.

Within the research project *ÖDiBus* (ÖV-Disposition in ländlichen Busnetzen) the major aim of developing the management system was strictly set to these requirements. The *ÖDiBus* system (Figure 5) is already being used and tested in a research version since 1999 in

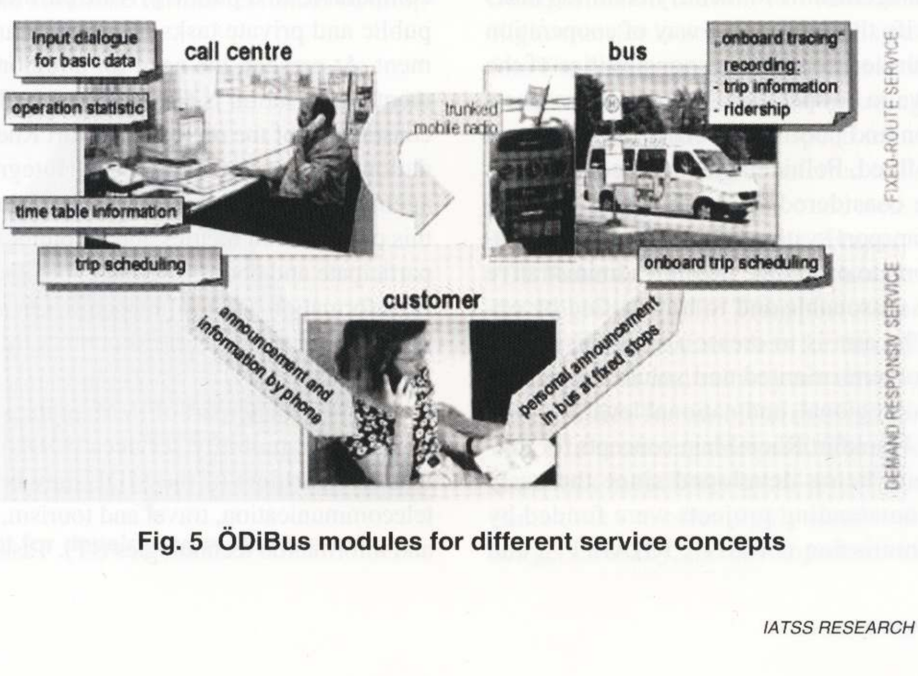

Fig. 5 ÖDiBus modules for different service concepts

the rural district of Erding (near Munich airport), controlling now five route deviation services. Costs of this system are as low as 1.9 % of the total expense for the five routes. Since 2001, the *ÖDiBus* development is being used by a commercial distributor and added with the functions of a non-scheduled dial-a-ride taxi dispatching system. In a further research project, ZIV now tries to optimise both the planning process and the managing of several demand responsive services in a region. To minimise operation costs, the requesting system should be integrated in a single service centre for the whole region of Rhein-Main Public Transport Authority (RMV).

3.5 Organisational concepts for traffic management and mobility services

Organisational Concepts for Traffic Management

Since many traffic problems cannot be solved by measures within one transport mode, one system, or one institution alone, the implementation of an integrated traffic management system is necessary. This requires the coordination of different measures and systems, and as a consequence the cooperation of different institutions. Therefore, it is necessary to provide an appropriate organisational framework.

In the past decades, the single partners of traffic management have developed good competences for their isolated responsibilities and tasks. Nevertheless, coordination and cooperation in many cases takes place only occasionally and on a voluntary basis. Furthermore, urban and regional systems are not linked consequently. Because of this, possible benefits are lost.

A major part of developing an organisational concept for traffic management is to identify common tasks clearly and to specify the appropriate way of cooperation for each task. In further steps, the responsibilities of the single partners have to be specified, and detailed aspects (e.g. data detection and pooling, information flow, and finances) must be fixed. Political and legal requirements always have to be considered. In general, the cooperation of different transport systems always should be promoted, but the efforts to overcome existing administrative fringes have to be reasonable and to be justified by expected benefits. The aim is to create an organisational framework for problem-oriented and solution-oriented actions on the local, regional, and national level.

In the region Frankfurt RheinMain concepts for traffic management are being developed since the early 1990's. The first outstanding projects were funded by the European Commission (FRUIT[9], RHAPIT[10], and ENTERPRICE). In these projects, common objectives in traffic management and tasks for the different regional partners were defined, which still today are the basis for further developments in the region. Based on this experience, today the development of solution-oriented and progressive organisational concepts for traffic management is one of the ZIV core competences. Combining theoretical approaches with practical experience as well as maintaining an intensive cooperation with involved institutions enabled the ZIV to further developments of organisational concepts in the region Frankfurt Rhein-Main and elsewhere.

Project Example: WAYflow – Organisational Concept for a Regional Traffic Management

At present, WAYflow[7] is the most outstanding traffic management project in the Frankfurt RheinMain area. Its major objective is to promote the mobility in the region by using new ideas and technologies for data transfer and data pooling as well as by implementing easy-access information systems. One of the WAYflow work packages deals with organisational conditions for the conception and the step-by-step implementation of an Integrated Regional Traffic Management considering all traffic modes. Although this is a highly sensitive task for all regional stakeholders, ZIV could contribute by developing and assessing various alternative concepts for the future organisation of traffic management in the region. This work has been performed since 1998 under a contract of Rhein-Main Public Transport Authority (RMV) and funded by the German Federal Ministry of Education and Research.

The current idea for an organisational concept is – comparable to a public private partnership – to separate public and private tasks of mobility and traffic management. At present, the need for a regional traffic management organisation is already fixed by law in the regional constitution of the region Frankfurt RheinMain. The foundation of an organisation IVM (Integrated Traffic Management Region Frankfurt RheinMain) is under way. In this organisation 8 cities and 8 counties of the region will participate and coordinate their specific measures for traffic information and traffic control. On an operational level the existing traffic control centres in the region will be linked.

As a counterpart of IVM, at the same time a private provider for mobility services (MDL) shall be founded. Possible partners of the MDL may be institutions from telecommunication, travel and tourism, financial services, and information technologies (IT). Tasks of the MDL may be electronic-ticketing, e-commerce, and m-commerce.

Mobility Services

At present, in Germany many mobility services find their way into practice. Usually mobility services deal with information on travel conditions (e.g. information on travel routes, forecasts of travel speeds, information on departure and arrival times) as well as with additional services (e.g. reservation and payment).

On the one hand, mobility services are provided by public authorities. In this case, they usually are part of measures for traffic management, and the objective is to influence the traffic situation (e.g. peak spreading by information on forecasted traffic situations). On the other hand, mobility services are also provided by different private transport agencies, airports, airlines, travel agencies, television and radio stations, automobile clubs, automotive industry, telecommunication companies, etc. Possible objectives for these providers may be to earn revenues by selling data and information (e.g. charged traffic information services provided by telecommunication companies), to use mobility services as a marketing instrument (e.g. information services provided by automobile producers), or to carry out processes more efficiently (e.g. information and payment services provided by railway companies and airlines).

In ZIV, product ideas and concepts for mobility services are developed and detailed. Each customer, his specific demands, and the specific scope of application have to be considered consequently. It is of major importance to link the user needs and demands with technical features and technical feasibility. On this basis, applications can be developed which at the same time will generate further demand and stimulate further technical development (Figure 6). Finally, the developed mobility services have to meet institutional requirements as well as economic aspects. The investment and operational costs have to be covered by yielded economic benefits.

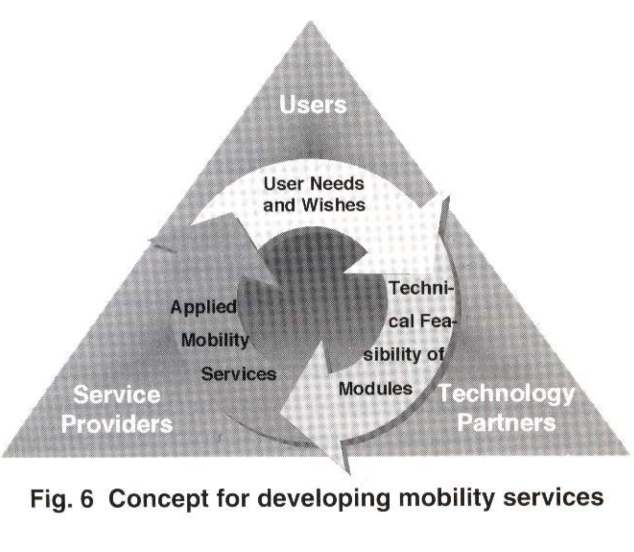

Fig. 6 Concept for developing mobility services

Developing product ideas for mobility services means to work creatively and systematically. Linking these processes with the technical competencces (e.g. techniques for road and rail traffic control, techniques for positioning and navigation) enables ZIV to develop mobility services which meet the market situation and can be implemented in line with practical requirements.

Project Example: Intermodality at Frankfurt Airport

Intermodality at Frankfurt Airport describes the linking of the transport systems air and railway. It is the objective to offer 'seamless travel' to the passenger, which means to create mobility services which combine the different travel services (transport of passengers, transport of baggages, check in/check out, ticketing, information, orientation and security services) along the entire travel chain.

Linking air and railway is of major importance for the intermodality partners. In 1998, the German Airline Deutsche Lufthansa AG and German Rail signed a "Memorandum of Understanding" which expresses the common objective of both partners to transfer short-distance flights on the railway. At Frankfurt International Airport the AIRail-terminal was opened in 1999. This station links the airport with the high-speed railway network. In the year 2000 German Rail, Lufthansa, and the Frankfurt Airport Authority (Fraport AG) have joined the AIRail partnership. In a concerted action, the "train to flight" has been offered since March 2001. On the relation Stuttgart Main Station to Frankfurt Airport the train-flight-transfer is now organised like a flight-flight-transfer. The Lufthansa passenger checks in at Stuttgart Main Station. Here he receives the boarding pass and the baggage receipt. With a high-speed train the passenger and his baggage are being transferred to Frankfurt Airport.

The ZIV study is conducted under contract of Frankfurt Airport Authority (Fraport AG), German Rail (DB Reise & Touristik AG), Deutsche Lufthansa AG, and the Regional Public Transport Authority (RMV) since spring 2000. Product ideas for an ongoing and expanded linking of air and railway are developed. Therefore, the possibilities for an off-airport passenger and baggage check in are being analysed. The objective is to transfer the check in facilities to off-airport locations and – at the same time - to offer highly comfortable services to passengers. Finally, the developed services will be assessed considering specific criteria, e.g. strengthening the benefit for the passenger, logistical and technical feasibility, and compatibility with business objectives of each intermodality partner. The result of the study will be an advice for action with reference to selected rail corridors in Germany.

3.6 Railway systems and railway engineering

The ZIV group for Railway Systems and Railway Engineering was established in 2001 to extend the applied research, engineering and planning in the field of railway bound traffic and transport systems and to cover all railway-related aspects of integrated transport systems. There is a close cooperation with the section Railway Systems and Railway Engineering at Darmstadt University of Technology.

Specific fields of competence of the ZIV experts are planning, design, construction and operation of railway infrastructure facilities, capacity studies in railway operation, technical and economical feasibility studies, electronic data processing for railway operators, marketing and tariffs, surveys and data acquisition, project planning and project management, statistics and mathematical methods in railway engineering, organisational studies and operational studies including work and information flows.

In 2001, several projects for German Rail (Deutsche Bahn AG), Rhein-Main Public Transport Authority (RMV) and Rhein-Neckar Public Transport Authority (VRN) have been successfully finished. The projects included studies on the operation and track layout of the secondary railway network like the Vogelsbergbahn in the northern part of the State of Hessen. This project reflects that nowadays, secondary railway networks earn increasing attention in Germany. The privatisation process and institutional and organisational changes in the German railway system during the last decade made it obvious that these parts of the railway network have severe problems in terms of maintenance needs, reconstruction needs and profitability. Nevertheless, regional transport concepts promote secondary railway lines, mainly because of environmental reasons.

Project Example: High-speed Line Frankfurt Rhein-Main – Mannheim Rhein-Neckar

To extend the high-speed railway network in Germany and to increase the overall network capacity, a new high-speed line is planned between Frankfurt and Mannheim. The City of Darmstadt and the surrounding region wants this high-speed line to go via Darmstadt Main Station to have reasonable access for the City and the region to the high-speed railway network. German Rail, as the investor for the new track, aims not to stop in Darmstadt, because within 30 km distance there are two other high-speed train stations at Frankfurt International Airport and at Frankfurt Main Station. In this situation of conflict between German Rail and the region around Darmstadt, the ZIV was asked to conduct scientific investigations on the advantages and disadvantages of a high-speed train stop in Darmstadt in advance of the formal legal planning process. This work was done in 2000 and 2001 together with experts for architecture and town planning and for economic development on behalf of German Rail, the City of Darmstadt with surrounding counties, the Rhein-Main Public Transport Authority, the Darmstadt Chamber of Industry and Commerce, and other regional institutions.

Alternatives for the track finding (Figure 7) and track layout were developed and assessed, including the location of the new train stop at Darmstadt main station or outside of the city. Furthermore, the passenger was demanded and distribution was modelled, the stations were designed, an operating concept on the new high-speed line was developed, and studies on the integration with the local public transport systems were conducted. An important task during these investigations was the moderation of meetings to gain concertation with all partners on the results. Finally, an agreement on all major impacts of the different alternatives was gained with all project partners. Nevertheless, the basic conflict of interest could not be solved. But German Rail and the local authorities have now, when the legal planning process starts, a good basis to exchange their arguments in a factual way.

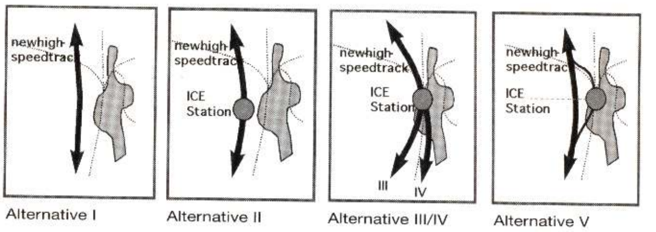

Fig. 7 Alternatives for connecting the city of Darmstadt with a new high-speed train line

Project Example: Simulation and Optimisation of Mannheim Main Station

In this project conducted in 2001, a simulation model was set up to optimise the network design and the railway infrastructure facilities of Mannheim Main Station and all depending stations and lines. Proposals for an optimised operational concept in 2010 were developed with regard to local and inter-city passenger traffic, freight traffic and shunting movements. The study was conducted with the infrastructure and timetable management program RailSys[11].

RailSys is a simulation tool which ZIV uses for analysis, planning and optimisation of operational procedures and facilities in railway transport networks of any size. Operational procedures are realistically displayed on desktop computers, and the investigation of whole systems is just as easily accomplished as the processing of specific, local problems. Using a flexible and comprehensive simulation tool like RailSys supports the ZIV in iterative planning processes. It renders the possibility of the output and display of raw data, intermediate and final results, the running of plausibility checks, and the updating and revising of specifications and raw data based on the results.

3.7 Navigation and positioning systems

The functionality of determining the current position in an accurate and reliable manner is one of the essential requirements for ITS applications in a safety and/or business sensitive context. Consequently, the design of an appropriate navigation unit has to be adapted towards the individual needs of each single application. Therefore, the development of navigation and positioning systems is not an independent process, but rather embedded into complete traffic and transport systems.

In the current description, the term navigation unit incorporates the capability of determining all relevant states of motions and their derivatives, up to six degrees of freedom in a three dimensional space. Aspects of guidance and management functions are achieved in combination with databases, human machine interfaces and communication. These technologies are not addressed within the scope of this paper.

Development and Analysis Environment

Continuous and robust position estimation is essential to improve on-board safety and efficiency. Because of costs being multiplied by the number of fleet vehicles, the vehicle on-board system is designed to be scaleable from a low cost to a high performance version. Here, the navigation module turned out to be the essential unit to gain performance or to save costs for the overall system. Since the navigation unit is the key element for the performance/cost ratio of the overall system, a complete environment for development and verification of such a unit

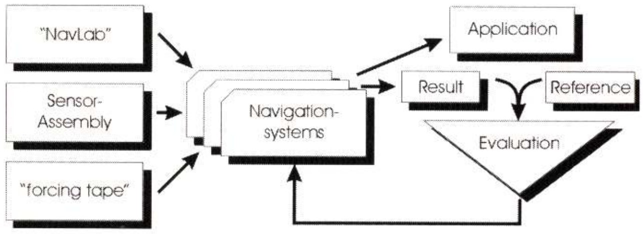

Fig. 8 Environment for development and verification of the navigation unit

was established (Figure 8). In the first stage, the simulation package *NavLab*[12] is applied to generate ideal sensor data for a defined trajectory. Using ideal measurements, the navigation result should match the true trajectory, which is only known in simulations. Hence, the programmed code can be analysed and algorithmic errors can be eliminated. In the next step, real sensor data are fed into the validated software, in order to obtain realistic performance values for the designed navigation unit. For the evaluation of the results from executed test trials, it is necessary to know the true trajectory, or at least a very accurate and reliable estimate of it. Therefore, the combination of a high performance Inertial Navigation Unit (INU) with a dual frequency GPS receiver is used.

The measurements are recorded in parallel to the other sensor outputs from the data acquisition system. The processing of the reference trajectory is done in an offline mode. The experience from the real sensor measurements has been used to improve the error models of the simulation package *NavLab*. Thus the simulatizon has the capability of producing realistic sensor raw data, too. The range from possible noise effects incorporates additive stochastic noise with white and coloured correlation functions, random walk, random constant, scale factor error and misalignment. Through the continuous improvement of the simulation over several years, the *NavLab* software is now capable of projecting the resulting performance of a navigation system to a large extent. Test trials are executed for validation purposes and confirm the already obtained simulation results. The available sensor pool is shown in Table 1, where the available or planned sensor technologies are sorted into four categories. From this tool chest, the appropriate sensor combination can be selected and optimised for an individual purpose.

Optimal Navigation Filter

The core of any hybrid navigation system is the sensor fusion algorithm, which has an impact on the achievable quality of the resulting navigation parameters. Starting with the equations of an iterative, extended

Table 1 Available or planned sensor technologies

Position	Height	Attitude	Distance
GPS	GPS	GPS (V_{North}, V_{East})	Accelerometer
LORAN-C	Barometer	Fluxgate	Odometer
Map-Matching	Map-Matching	Map-Matching	Optical Corr.
Cell-Phone-EOTD		Wheel-Shaft-Encoder	Doppler Radar
Galileo		Vibrating-Structure-Gyro Ring-Laser-Gyro Differential Odometers MEMS-Gyro	

Kalman filter, based on non-linear system and sensor models, the structure of the filter is essential for the correct implementation. The filter process becomes independent of the sensor assembly and ranks all sensor information equally (Figure 9). This architecture has been called: *Mathematical Navigation Monitor* (MNM)[13, 14]. This MNM is an optimal filter structure for navigation applications. Since the MNM is getting all sensor information through the update step, the design of the filter propagation has to be adapted. This is achieved through the prediction-correction-concept.

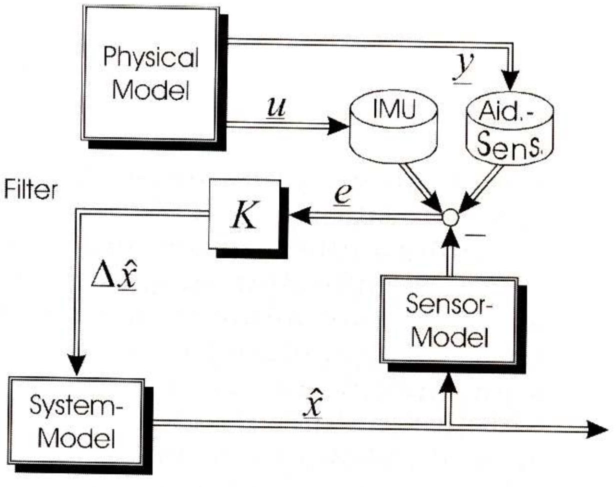

Fig.9 Mathematical navigation monitor

The established development environment in conjunction with the optimal sensor fusion algorithm MNM provides a rapid prototyping concept for the implementation of navigation systems. This concept has been enhanced by the strategy of the *Navigation Array*. Different sensor configurations have been proposed and evaluated according to their performance in comparative tests. Adequate position accuracy, reliability, and availability are attainable by selection of appropriate sensor assemblies. By using dissimilar sources of information, the dependence on a single device can be minimized. This facilitates the handling of sensor outages and failures. The *Navigation Array* is composed of a set of available sensors vs. possible application demands.

Project Example: GLORIA - GNSS and Loran-C in Road and Rail Applications

The European Commission (EC) has funded the GLORIA project under the Information Society Technologies (IST) programme. The GLORIA approach can significantly improve the market penetration of GNSS services by integrating the terrestrial Loran-C positioning system and possibly other systems such as dead reckoning (DR) components. This combination improves the reliability of position determination and opens the door to new applications and major improvements in the redesign of existing road and rail applications. Applications that have not reached a significant market share by employing satellite navigation systems as sole means include road pricing on major highways, electronic payment of parking fees, electronic ticketing for public transport, advanced Surface Movement Guidance and Control System (A-SMGCS), control of traffic flow for public transport, public transport in rural areas, monitoring of hazardous goods, and support of Automatic Train Control (ATC). GLORIA also contributes to ongoing research activities assessing the integration of Loran-C into the Galileo Ground Network. The GLORIA project will be completed by the end of 2002.

4. CONCLUSIONS AND OUTLOOK

The description of the ZIV activities since 1998 may show that the strong points of this research institute are the wide range of competences within ZIV, the easy access to outstanding expertise within the university, as well as the good relations to many public and private partners in traffic and transport. This allows to develop integrated solutions for traffic and transport problems and to transfer knowledge between the different transport modes and areas of application.

After three and a half years a positive balance can already be drawn for this public private partnership which allowed the founding of ZIV. The region gains benefits from a strong research institute with comprehensive competences in the field of transport planning and traffic engineering, and ZIV has established as an integrating actor between different transport modes and different institutions in the region. The university also has advantages. The university's research associates have gained much more opportunities for research topics and to work in application oriented projects. The students have plenty of opportunities to work in research projects and to share the latest results in lectures. And professors from different faculties of the university found a new platform for communication on transport related topics. Though also consulting in practical engineering is carried out, the main area of ZIV is research with highest priority.

Of course, there are also several problems. One example is that young researchers at ZIV have reasonable problems in finding time to write their doctoral thesis. They are financed by projects which have clear economic limits for scientific work, often have not the necessary scientific scope, or which are based too much on team work and therefore are not suitable for the purpose of personal qualification. As another problem it may be mentioned that supporting non-profit activities related to traffic and transport in the region (e.g. education, organisation of conferences) has its limits when financing the ZIV by project revenues only. And of course, the different locations of ZIV and the most relevant university institutes are not optimal.

Today, the development of ZIV at an age of only three and a half years, cannot be considered as concluded. There are many ideas for further promotion of the basic ideas underlying the ZIV concept. A short-term goal is to strengthen the already existing work areas in ZIV. As mid-term goals the addition of further working areas and more international activities may be mentioned. In the future, with the introduction of new financing tools for the university, it seems to be possible and advantageous to go for further integration of the ZIV and the university's Institute for Traffic and Transport. Sharing office premises in the same building would allow an even better integration for the staff of both units, strengthen the competences, and allow further synergies (e.g. library and other supporting services). There are also other structural changes under way at Darmstadt University of Technology which may affect ZIV. A new interdisciplinary study program "Master of Science in Traffic and Transport" for post-graduate students will be introduced by the three faculties of Civil Engineering and Surveying, Mechanical Engineering, and Economic Sciences, and this study program can make use of competences available in ZIV. Furthermore there is the idea that ZIV organises trainee programs for traffic and transport professionals integrating the ZIV shareholders and other partners in traffic and transport as well as the competences at the university.

Finally, the conclusion can be drawn that public private activities as they have been realised with the ZIV at Darmstadt University of Technology are a successful way to strengthen the competitiveness of university institutes and to keep the advantage of outstanding research and teaching in one institution as an important contribution to our society.

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