Implementation of traffic effect estimations for intermodal dynamic routing services on VIELMOBIL - an ITS-platform for the RheinMain region

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Rising mobility of people and goods will increase current traffic volumes and cause more and more infrastructural bottlenecks and congestions within the traffic networks. Besides expanding the public transport service, one main goal is to improve the overall traffic information regarding specific traffic conditions in order to achieve a temporal, spatial and modal shift of trips based on the available network restraints. In order to use the available network capacities effectively and constantly optimize traffic flow, new innovative mobility and information services need to be developed. The following paper describes the development of an integrated intermodal routable network graph, related quality management procedures and the implementation of a new dynamic routing approach using real-time traffic data provided by public authorities to operate VIELMOBIL - an innovative intermodal mobility information service for all modes of transportation.

Keywords: Intermodal network generation, Intermodal Routing, Dynamic Routing, Traffic Message Detection, Traffic Model, Congestion and traffic disruption effect estimation, Dynamic Routing Strategies

1 Background

Our society is increasingly mobile and the traffic volume is continuously growing. Hessen with its metropolitan area RheinMain is a traffic hub in Central Europe. Mobility in Hessen also means mobility in rural areas. This is where the majority of the citizens of Hessen live – people who often have to travel long distances on their daily routes.

There are numerous approaches for sustainable mobility. They all require complex changes on many levels - including behaviour, technology, organization and cooperation. The project "Mobility 2050" expands the view on the complex relationships between our life, consumption, economy and mobility. Young people, experts and citizens are asked to develop ideas for new forms of life, work and economic activity for the year 2050, allowing and supporting sustainable mobility.

One approach towards sustainable mobility is to improve information about the available alternative forms of transport. Existing information services usually do not cover characteristics like situation-and position-depending information or ad-hoc information and realistic intermodal alternative route suggestions. Providing this information within one single service is the key to a lasting change in mobility behavior of the population. To achieve this objective the Hessian state government co-financed VIELMOBIL, an intuitive and easy to use information platform for pre-trip planning and on-trip route guidance. VIELMOBIL sets a new standard of mobility services on the internet and on mobile devices. The basis of an improved information service are quality assured real-time data-sets for public transport services and individual traffic as well as historical traffic flow data. In addition
VIELMOBIL also processes regional and local traffic management strategies based on information about road works and parking capacities.

2 Avoiding information overflow - supporting intuitive planning

It is the aim of VIENMOBIL to deliver only as much information as necessary to support a targeting pre-trip planning and on-trip pilotage. It is not about incorporating as much information as possible about all available modes of transportation in one information service. This would inevitably lead to a confusing and unusable service. VIENMOBILs goal is to assist the user in the preliminary planning and accomplishment of his mobility. A survey among potential users within the scientific monitoring of the project clearly showed that travel planning is done in successive ways and is getting more and more accurate by using more information. Users do not expect the only recommendable route to be delivered by a mobility information service. Rather they expect an information platform that delivers a reasonable set of alternative connections to choose from and the necessary information to gradually customize one or the other suggested routes. Therefore, VIENMOBIL does not ask for a long list of personal preferences unclear how the individual input would influence the further routing results. Right after the entry of start and destination VIENMOBIL offers a manageable number of route suggestions, displayed in a list to choose from and a large map to be adjusted to personal preferences. Moving a waypoint to one of the displayed bike-and-ride facilities will promptly create a route using the bike and public transport. Deactivating or reactivating one transportation mode will change the number of suggested routes and possible intermodal connections.

Another finding of the scientific monitoring is that users request to use different communication channels depending on the time of their planning (pre-trip or on-trip) and their technical skills. Therefore, VIENMOBIL will use the advantages of the different communication techniques according to their individual strengths and will support the alternating use of stationary and mobile systems. Intensive pre-planning will then be done on a PC with a large screen and comfortable to interact with mouse and keyboard. On-trip pilotage of a previous planned trip uses the advantages of a smartphone - always on, fast, personalized and detecting its current position.

3 Traffic information as a part of regional traffic and mobility management

Increasing mobility costs, growing demand for mobility and differentiated mobility services as well as the growing availability of internet-based and mobile information services, particularly in metropolitan areas, make traffic information a necessary and meanwhile natural planning instrument for individual mobility. However, the demands on these information services increase. Actuality, completeness and the linkage of the available information to individual tailored services are often mentioned by users as a potential improvement of the already existing services.

However information must also reflect the users every day "experiences" - route recommendations need to consider the actual and expected traffic situation, account intermodal changes (e.g. parking search time) as realistic as possible and need to factor in the availability of the transport network due to road works or events.

Traffic information is also an important tool for municipalities to manage their traffic network. In particular for communities without technical actuating elements such as dynamic variable message signs, traffic information is a way to implement their mobility policy, traffic planning goals and concepts. This is where today’s commercial information and routing services fail. As they usually propose the optimal route for the user and sometimes ignore the opposing interests of municipal traffic
planning, they inhibit the optimized use of existing traffic infrastructure and mobility services. However, individual mobility does not act independently in an overall transportation network. The demands for quality and reliability in future mobility will decide to what extent individual needs can be fulfilled in the transport system.

VIELMOBIL provides an opportunity to the local authorities to constitute their local strategies regarding traffic and mobility management. VIELMOBIL is a tool to support the participation of various municipalities of differing sizes and a successful method to enforce the consideration of their strategies within information and routing services. Therefore, VIELMOBIL is a major step towards a regional integrated traffic management system. Thus a platform that promotes regional cooperation in transport and mobility management is an essential task of ivm in the RheinMain region - namely the establishment of an integrated regional transport and mobility management system.

The integration and cooperation of different regional partners within VIELMOBIL is based on a task sharing model. There is a shared responsibility between regional actors. Each partner is responsible for particular services and for the delivery of data or information in a prescribed quality. For the further development of VIELMOBIL common goals and further steps that need to be realized by each partner will be defined. This task sharing model ensures the long-term use of the existing components and the sustainability of developments and investments that have been made or will be made in the future.

Regional traffic management and especially the integration of different regional partner and their services require not only a new form of cooperation. But also a technical integration of the available data. This technical integration is realized by an intermodal network graph. Based on standardized data form NAVTEQ and ATKIS the network graph can be edited and adapted to temporary or permanent changes in the road network. The different dynamic and static data is referenced to the network graph and will be the basis not only for VIELMOBIL, but also for other regional information services.

Information is not only displayed on a map but already considered in the intermodal routing. Regarding historical and real-time traffic flow as well as road works and traffic management strategies, new routing algorithms are required. In addition, powering an intermodal information service, this routing algorithm needs to be fast and effective. To realize these requirements, it was decided to design and build a specific routing engine – free to be used and adjusted for other routing services.
4 Generation of an intermodal routable network graph

The generation and later update of a routable network graph is a general task for each routing and traffic information service. Different approaches for this problem have been implemented in diverse projects:

- direct use of a commercial graph (like Teleatlas or NAVTEQ)
- use of open data, like OpenStreetMap
- use of data generated by authorities.

All of these alternatives have been used at ivm in different projects and each of them has shown clear shortcomings. The bicycle network data is based on ATKIS (provided by the surveying authority) and shows high geometry precision, it is up to date but lacks many attributes relevant for routing (e.g. speed limits). The routing of motorised traffic is based on commercial network data, which are fully attributed but show inconsistencies in geometry alignment and are not fully up to date, especially in the lower level road networks.

For this reason a new model of network fusioning was developed. It is based on a stepwise special algorithm, which allows a continuous refinement and improvement of the matching rate between the two networks. It starts with an automatic detection of junction features and matching these junctions. In the next steps network routing is used to collect the matching network edges and relate them to each other. As a result both or more networks are integrated in one database and referenced to each other, without losing any information available in either network.

A web-based editing client allows updating routing attributes as well as adding new edges and change edges. All these changes are automatically integrated in both networks in parallel, thus securing data consistency and reducing redundant editing efforts. In order to allow high quality information services the network information is enhanced with navigation relevant information. The resulting data pool consists of:

- Integrated network data as routing basis. TMC location codes are referenced to the network in order to allow direct integration of traffic messages provided via TMC.
- Points of Interest used as potential navigation points, including park&ride information. A specific editing client was developed for continuous update.
- Address data for location searches. Integrated regularly from public authorities as information source.
- Traffic messages, integrated from national and federal official information sources. A dedicated messaging client is used for adding more specific information, especially related to up to date construction site information. A sophisticated messaging system for the real-time exchange of all traffic messages was developed, which allows high performance information integration and information provision (using standard formats like TMC and DATEX2).

In a first phase of system definition the data listed above were integrated and referenced to each other. The tools for continuously enhancing the data were created by developing dedicated easy to use editing clients.
The update of the network base information is an additional challenge, since the data are edited externally and additional internal edits are available, which shall not be lost in case of updating. A complex procedure for updating the network base information was devised for solving this issue, as shown below (figure 1):

Figure 1: Generation of an intermodal routable network graph

The resulting data pool is intermodal and includes information about different modes of transport equally. Traffic data is permanently updated in order to generate the dynamical traffic situation. The synthesis of these manifold traffic data is the dynamical traffic situation information. It integrates a number of different information sources about current traffic information, such as traffic messages, roadworks, roadside events, park&ride information and many more.

All these information sources are integrated on the basis of the integrated graphs, which serve as the reference platform for these information and the services of VIELMOBIL based on them.

5 Dynamic Traffic Route Model

As one core function the operating module provides a routing engine for all transport modalities (road, bicycle, pedestrian). In the first stage these three routers (individual transport, cycling and walking) are
static and implemented with the Dijkstra algorithm (see figure 2). Since maps and the provided information differ for each routing result according to individual requirements, the routing modules are implemented entirely separated. The intermodal logic is capable to request results from the modal partial routers in order to set up an intermodal route. Possible transition points can be considered either by the inter-modal logic or the user. The parameters strongly depend on the user's needs and purpose of travel, and can be optimized by a variety of criteria. The goal is to provide a workable mixture of recommendation (= optimum system) and user intervention through interaction. The transport mode of choice is implemented by setting intermodal heuristics to define the individual attractiveness of routes (number of inter-changes, arrival- departure time, maximum car distance, maximum range of electric vehicles, maximum footway distance, maximum cycleway distance, park&ride capacity, public transport frequentation, last connection with public transport). The graph network contains edge attributes defining the characteristics of road segments. The algorithm calculates the optimal route between two places and possible “via” nodes including the attributes and criteria of individual road sections. Besides displaying the shortest and fastest route connecting to the road network topologies, more complex routing constraints such as environmental zones, turn restrictions and direction-specific attributes are considered as well.

Figure 2: Procedure of dynamic routing module

The basic dynamic routing concept is based on a multi-criteria cost function. The routing path travel time calculations depend on daytime or traffic conditions (construction, events, accidents, diversions, traffic management strategies) with the resulting segment specific resistant. Within the dynamic route calculation, the time of day dependent, segment-specific capacity restraints are merged with the reduction factor to reflect and differ between peak hours and periods of low traffic intensity. The user can see different alternatives in the graphical web interface for a requested route. As shown in Figure there is a convenient overview of the different route results. The length of the duration bar symbolizes the duration of a route and can be compared to other results. There are also symbols representing the transport methods used in each result. Since the duration for routes can change depending on daytime and traffic conditions, there is a slider at the top of the menu that can be used to change the daytime. Thereby, new route requests are computed which change the routing results simultaneously. This provides intermodal dynamic routing considering different restraints which are implemented by the reduction factor.
The Reduction factor (RF) automatically reduces segment speeds proportional to the amount and density of traffic situations on the route (figure 4). The general attenuation of network graphs is based on traffic information and control strategies derived from public authorities (Landesmeldestelle Hessen) using DATEX2 format.

\[ RF = 1 - (A_1 + A_2 + \ldots + A_n) \times (1 + g) \times p_j \]

- \( RF \) = Reduction factor
- \( A_1 \) = derating factor 1 (e.g. accident)
- \( A_2 \) = derating factor 2 (e.g. weather)
- \( g \) = saturation level (daytime related)
- \( p_j \) = probability based occurrence factor

Dynamic Routing results depend on Datex2 format coded types of traffic messages which have different effects on the network. The combined traffic reports inside RheinMain region are geocoded with a traffic message client into different categories according to the Datex2 standardized format.
Weather-related effects on the segment specific capacities are generally described in six state categories. These are equivalent to the Datex2 format (normal, ice, snow, water, precipitation, etc.). The reduction factor simulates the expected capacity minimization of a network segment. Weather conditions also have different effects on certain incident categories and reduce separately. For example an accident (Accident) in combination with icy precipitation gives the reduction factor 1 and thus corresponds to a complete blocked road. The Dynamic Traffic Route Model considers hourly, daily and seasonal fluctuations of the traffic flow as well as the effects of incidents, their extension, duration and expected frequency. More complex models like multiple interfering traffic events are correlated and processed as segment-specific reduction factors as well. Other more complex road network influences such as Activities (Events) are too heterogeneous to forecast decreasing road speeds and a changing reduction factor.

### 6 Conclusion

The acceptance of any public information service depends strongly on the quality of the information provided: it must be up to date, accurate and problem specific. For this reason the development of the new service VIELMOBIL was strongly coupled with a new approach for data management. The innovative network fusion and editing concept allows a combination of the advantages of commercial network data with those of public authority data. As a future development process it is planned to sequentially integrate municipalities into the data generation and updating process, thus further improving the information quality.

The high performance framework behind VIELMOBIL allows easily integrating and combining additional traffic information from floating car data (FCD) or static sensors to calibrate the dynamic routing engine input parameters. The dynamic traffic route model provides realistic route related travel times based on traffic effect estimations and could help to significantly improve mobility and intelligent transportation systems (ITS) for all road users in the RheinMain region. Therefore Vielmobil will not only be a platform to develop, implement, test and evaluate new features for innovative mobility management and information services. Besides these technical aspects, Vielmobil will also be a chance to build up an area-wide traffic management not only including the major state-wide authorities but also the small-sized municipalities and their requirements.