Calculation of Travel Time Savings by Dual Mode Route Guidance for the South Corridor in the Stuttgart Test Field

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Abstract—The dual mode route guidance system (DMRG) as a combination of the autonomous route guidance system and infrastructure supported dynamic guidance system is tested with respect to functionality and feasibility in Stuttgart, Germany. For calculation of the travel time savings in order to assess the system the southern corridor of Stuttgart is investigated. The approach images all relevant traffic issues and discriminates groups of drivers in dependence of familiarity with the area and equipment rate. The calculation was carried out with a macroscopic assignment model. On an inbound two-lane carriageway an incident was simulated affecting the complete flow bundle passing the erected bottleneck. Depending on the equipment rate 20-50% travel time savings were achieved. Similar calculations were carried out for a big evening event in a downtown stadion and "Octoberfest" area attracting 10,000 additional vehicles which result in travel time increase quantified in dependence of the equipment rate.

I. Introduction

As many other European metropolitan areas, the city of Stuttgart and parts of the neighbouring counties are densely populated and faced with a traffic situation which is characterized by a high portion of commuters and an oversaturation of parts of the road network with congestions during peak hours, especially on arterials.

Frequently, the road network operates at its capacity. Even small disturbances create large effects all over the network and actual traffic information, route guidance and intermodal operation are necessary. Due to the specific topography of Stuttgart, the guidance information should be given at a very early stage. There are only a few radial roads which collect the traffic. On the basis of these boundary conditions a dynamic route guidance system was designed for the metropolitan area of Stuttgart which operates in two modes. The first mode gives guidance recommendations at an early stage, operating on a combination of autonomous map matched route guiding and is actuated by traffic information referring to special locations transmitted by the Radio Data System (RDS) on a mute digital side channel. For traffic messages coding (TMC), 40 locations are defined in the city area of Stuttgart and each exit and autobahn rest area are coded *(Fig. 1)*.

The infrastructure mode uses bidirectional short range communication based on infrared beacons. Within the city of Stuttgart, 120 beacons are installed and additional 30 beacons are positioned on the autobahn and freeway network on the approaching arterials. For the test, 90 bimodal route guidance set ups are installed in passenger car fleets of state and city administration as well as in private cars. The dual mode route guidance field test is embedded in an advanced transport technology research and development project which is entitled STORM (Stuttgart Transport Operation by Regional Management) and is also connected to the European Research and Development project QUARTET.

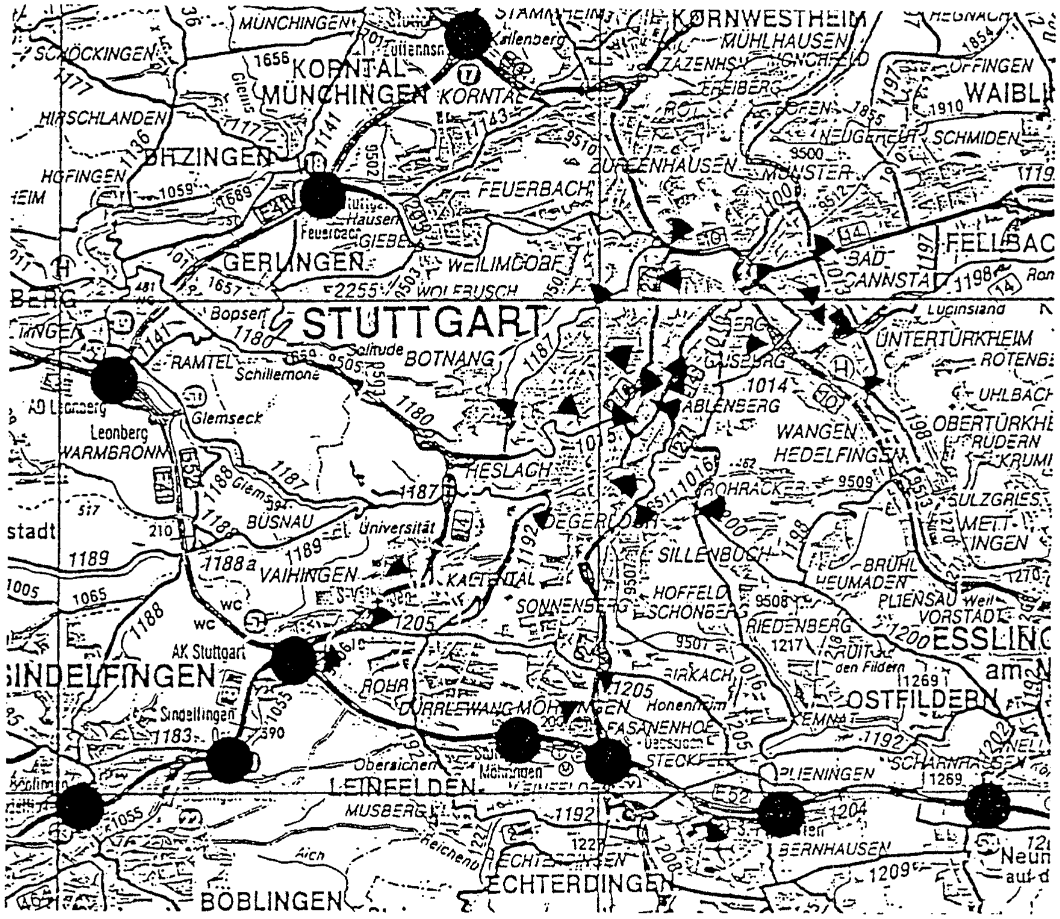

Fig. 1 - TMC-Location in the city; TMC-Location on the autobahn

II. Concept of the Route Guidance System

The concept of the dual mode route guidance system is shown in *Fig. 2* defining the different functions. The approach differs from other route guidance system like ADVANCE [1] in Chicago using two operating modes. Acting as an autonomous system outside of a beacon equipped urban area are decentralised. Route calculations are based on autonomous routing algorithms feeded with data from wheel sensors, from a compass and a digital road map for dead reckoning by map matching. Using the traffic message channel as a one-way communication link, the second mode relies on the infrastructure of 120 beacons within the Stuttgart area and 30 beacons on the autobahn network in the surrounding. This mode consists of a two-way communication link. The two-way communication link is transmitting from the infrastructure to the vehicle. the guidance vectors for guiding in the near segments and in return receiving travel time and destination information from the vehicle for further processing in the central routing computer.

Since there is an extremely low data rate, the traffic messages have to be coded in a specially dedicated ALERT-C-protocol [2]. For decoding the traffic messages, an object-oriented procedure is used which links traffic information with location information and information on driving conditions, weather conditions, traffic restrictions as well as on road conditions.

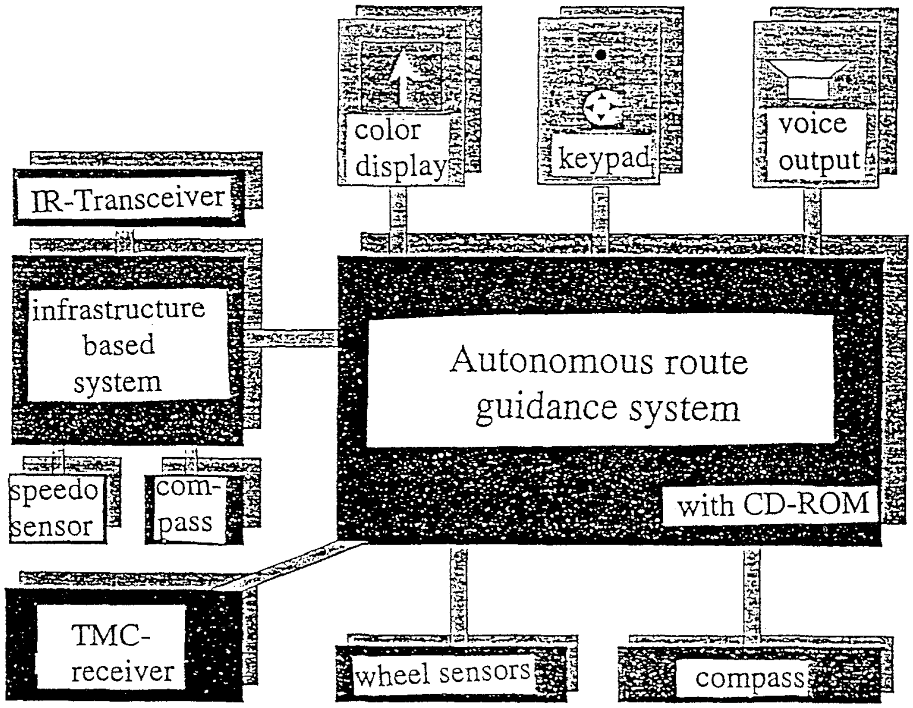

Fig. 2 - Components forming the dual mode route guidance system

If several vehicles with different destinations pass a beacon, all of them receive the same data package. Each vehicle then filters out the data relevant to its programmed destination. The basic recommended route calculated in the guidance computer is always the fastest. To achieve this, the central guidance computer must perform substantial computing work: Every 5 minutes it has to determine the shortest distance in time between every origin (beacon) and every destination (destination area), on the basis of arriving real-time traffic data. The real time data are received from the system by the backward channel, they are converted into journey and congestion times for each route section.

Since guidance recommendations are generated in one central guidance computer, direct interventions in traffic occurrunces are possible. As an interface to the driver, the route guidance system consists of a coloured display showing arrows for straight ahead, left or right turn supported by an audio output which gives guidance information in advance in dependence of the road category to all freetimes.

III. SIMULATION STUDY

For the real Stuttgart network in parallel to the building up of the dual mode route guidance system, a simulation study was carried out in order to support the system's design and to assess the effects of dual mode route guidance. For realistic modelling, the relevant traffic aspects for different driver groups and different traffic situations are defined and investigated. The main problem is to obtain a reliable reference case describing the uninformed and unguided driver whose routing is proped on individual experiences and estimations. Five driver groups are discriminated with different information levels: These groups are defined in Table 1. The uninformed, unguided driver as a reference case chooses its routes preferrably on the main road network. To complete the description of the uninformed and unguided driver, questionnaires were distributed among the test drivers who were personally interviewed.

TABLE 1
Individual guidance system

Vehicel group	Behaviour
local driver	route choice mainly on the major road network
local drivers with traffic information by radio	incidents are known after 60 minutes, after reaching a minimum congestion length of 3 km and detours are made round these incidents
local drivers without trafic information by radio	no detours are made round incidents
drivers with dual mode route guidance following the recommended route	Travel-Pilot-RDS/TMC-route at the start, in the beacon area EURO SCOUT-route, TP route when leaving
drivers with dual mode route guidance, take the recommended route to some extent only	behaviour like group 4 with a probability of 70% like group 3 with a probability of 30 %

The traffic situation depends on the regular traffic demand and on unregular events like hindering by accidents. Depending on the traffic volume, the benefits of a route guidance system will be different. Therefore, various traffic situations are simulated and introduced in the complete assessment in dependence of their frequency. The simulation study uses the real network of the origin-destination relations and trip matrices for the morning peak (6:00 to 10:00 a.m.). In addition, an extra-ordinary event as an evening session in a big stadion together with an additional traffic demand of 10,000 vehicles was regarded. The highest benefits are expected of the dual mode route guidance system in reacting on heavy incidents. In order to model these incidents realistically, the incident messages transmitted by the local broadcasting station concerning accidents, big traffic demand and stalled trucks during an observation period of 8 months.

For the assessment of the effects of dual mode route guidance, a macroscopic assigment model (TRIPS) was used which allows the simulation of the complete network and the presentation of the diversion effects. The route guidance strategy was modelled by stepwise assignment using the partly filled network as a respective starting situation [3]. The modelling approach concerning the different modes consists of different dead times (automonous and RDS/TMC-supported mode: dead time 20 minutes; beacon supported mode: dead time 10 minutes). These reaction times on actual traffic disturbances are derived from the message generation chain starting with incident detection and ending with transmission of the message including a control and a plausibility test.

The macroscopic simulation with a successive assignment with the Capacity-Restraint Method is based on volume-speed-relations depending on the specific road section. The assignment is carried out in four layers of different size which reproduce increasing and declining traffic volumes and, in this context, different route choices for the vehicles.

Travel time is the criterion for route choice in all layers. It is calculated in each case from the already realised load in the network and with the speeds deduced from the section-dependent volume-speed-relation. The size of the layer is selected in such a way that the total of all calculated loads corresponds to the measured values. The travel times for the individual layers are calculated from the load after assignment to the layer and according to the section specific volume-speed-relation. The average overall travel time in a weighted mean of the individual travel times. Vehicles equipped with dual mode route guidance are supposed to be better informed on the current traffic situation. To reproduce the route choice behavior in the model, a part is split off of every layer in correspondence to the equipment rate. This part is assigned in small portions according to the respective layer (*Fig. 3*). For the travel time calculations of the vehicle group with and without route guidance only the corresponding parts of the layers are used.

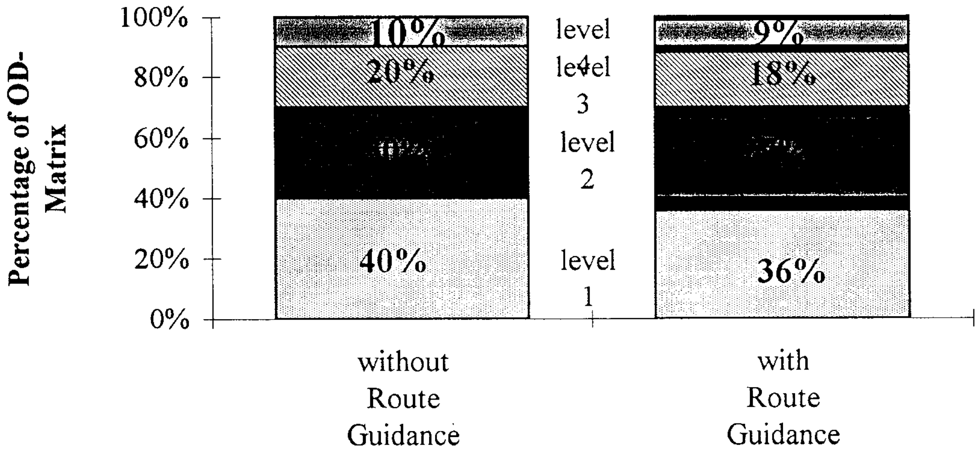

Fig. 3 - Traffic assignment model

An incident designates an extraordinary event which is not known to the road users in advance. Without additional installations the driver chooses the same route as in the "Without Case".

One of the main accident focus with large impacts for the whole road network is the radial „Neue Weinsteige". This radial is chosen for a simulation as a bottleneck and the vehicle group passing that radial coming from all sorts of origins going to all sorts of destinations is regarded *(compare Fig. 4)*.

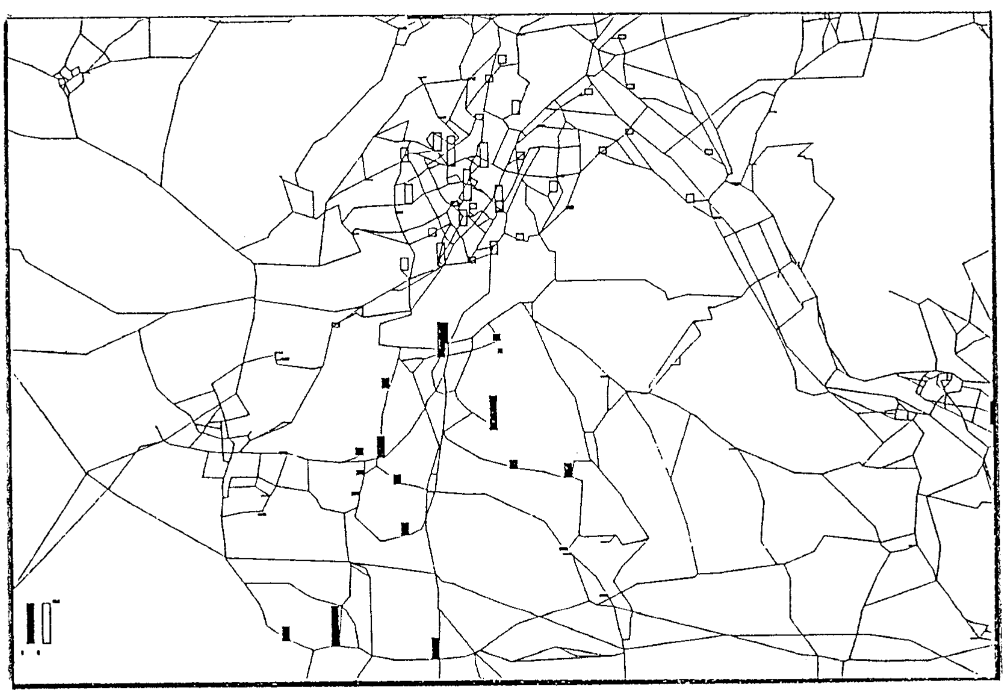

Fig. 4 - Distribution of origins and destinations for all vehicles passing "Neue Weinsteige" inbound directions

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For simulating an incident, a lane reduction from two lanes to one lane in inbound direction is regarded. Without route guidance equipment, drivers choose the same route and form the "Without Case". A direct translation of the incident into the assigment model needs a recursive method in order not to overload the section covering the unrealistic regime of the model due to the capacity restraint approach. Avoiding the capacity cross-overs the road choice in the last level of the successive assignment procedure is carried out arbitrarily. This means that even drivers without route guidance systems take a detour which corresponds to a backup congestion and a general information via radio to detour the incident area. This concerns only for the last part of the assigment procedure in order to avoid overload. This detailed modelling serves as a reference case. *Fig. 5* shows the results in dependence of the equipment rate for travel time and trip length.

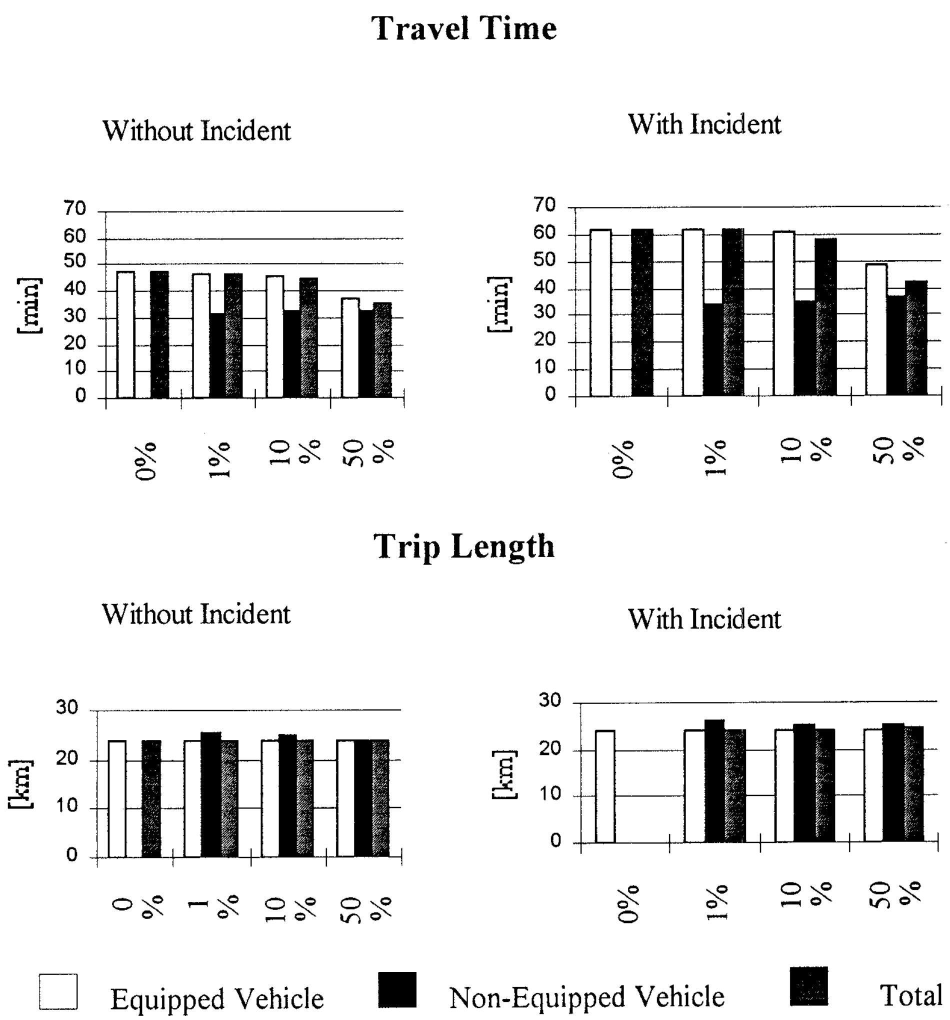

Fig. 5 - Simulation results: vehicle group „Neue Weinsteige“ inbound

The incidents last the whole simulation time. The simulation produces as an interesting result: also a travel time benefit is observed for the non-equipped vehicles in case of high equipment rates. This means that the detouring portion due to route guidance equipment is so high that overload even in the case of an incident is avoided and an overall benefit is given. Looking for the trip length, equipped vehicles have longer trips than unequipped vehicles due to bigger detours, but with travel time savings. Results are also gained for travel time and trip length for all trips. Travel time savings and trip length increasingses in this case are not so impressive, because only a small portion of the vehicles are affected by the incident and by the necessity of detouring.

IV. Outlook

Simulation results and the first test results based mainly on drivers' inquiries show that specific approach of the dual mode route guidance system using autonomous and infrastructure-supported elements fit the requirements of a dynamic route guidance system in an excellent way. Short reaction times and high spatial resolution of the fix situation detection is needed concerning the actual traffic. The dual mode route guidance approach does guarantee this due to discrimination between the city area with dense road network and many choices and the outer area more delute network. An economic balance between investments for infrastructure and investments for in-car equipment shows the dual mode route guidance system as a promising approach. It is an improvement of existing autonomous guidance system and avoids the large expenses for a complete area wide installation of beacon infrastructure as was tested in the Berlin field trial LISB [4]. For the Stuttgart metropolitan area, an operating company in marketing travel and traffic information and route guidance services (COPILOT) was founded. This company intends to equip 6,000 subscribers in a first attempt based on existing EURO-SCOUT technology having as a good in the dual mode route guidance approach. The combination with intermodal information including transit connections at Park & Ride lots makes the dynamic route guidance system in Stuttgart additionally valuable.

V. References

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