Intelligent Transport Systems
for
Interurban and Regional Traffic Control

German approach and research samples

Fritz Busch
17.06.2010
Average Daily Traffic (ADT) on various German road types

[Graph showing the increase in average daily traffic on different types of German roads from 1952/53 to 2005. The graph includes lines for Autobahnen, Bundesstraßen, Staatsstraßen, and Kreisstraßen, with a significant increase over time.]
Forecasted Changes (ADT) 2002-2020

- From regions to cities
- International traffic

Quelle: acatech
Traffic Management on German Motorways

Status: 2007

Network Size and task
- 12500 km (~ 2% of total network)
- carries ~30% of total milage driven

Traffic Control Centers (VRZ)
- 9 VRZ operational
- 6 VRZ planned

Section Control
- 950 km operational
- 250 km planned

Network Control
- 2000 km operational
- 500 km planned

Ramp Metering
- 80 sites operational
- 40 sites planned

Temporary Use of Hard Shoulders
- 250 km operational
- 150 km planned

Permanent Use of Hard Shoulders
(in preparation of enlargement to 6 lane)
- 250 km operational
- 100 km planned

100% Traffic Informationen
Motorways: Main problems in current focus

- Congestion due to
  - Overload
  - Accidents
  - Road construction

- Trucks
  - High lane occupancy
  - Parking facilities

- Environmental goals
  - In conurbation regions
Impact Evaluation - Germany

SBA A5 near Frankfurt
Total accident number - 30%,
Accident with injuries - 50%
Traffic fatalities - 60%

SBA A8 Stuttgart - Ulm
Decrease of accidents due to wetness (30%) and fog (86%)

Types of Accidents (that can be influenced by SBA):
- driving accidents,
- accidents involving cars traveling in the same direction
- 'special accidents'

SBA shows highest effects during heavy traffic load
- number of accidents: reduction of 15 to 30%.

Travel time savings are a significant economic benefit.
- same order of magnitude as for that one generated by accident reduction

[SIEGENER et. al. (2000)]
Objectives and Types of Motorway Control Systems

- Improvement of Traffic flow
- Increase in Traffic safety
- Reduction of Emissions
- Reduction of Time losses

Classified by spatial requirements into 5 types
1. Section control systems (SBA - Streckenbeeinflussungsanlage)
2. Opening of hard shoulders (SFG - Standstreifenfreigabe)
3. Network control systems (NBA - Netzbeeinflussungsanlage)
4. Interchange control (KBA - Knotenpunktbeeinflussungsanlage)
5. Ramp metering (ZFR - Zuflussregelung)
System Architecture of Motorway Control Systems

Verkehrsbeeinflussungsanlage
Traffic Management System on Highways

[www.signalbau-huber.com]
**Section Control (SBA)**

**Where?**
High traffic loads, safety critical or environmentally sensitive sections

**Main Control Objective?**
Optimizing traffic flows
Increasing traffic safety

**How?**
Control by variable message signs (VMS)
Section Control – standard system MARZ

Functions of Section Control (according to MARZ, 2000):

- **traffic dependent:**
  - harmonization
  - incident warning
  - congestion warning
  - entry and exit help

- **environment dependent:**
  - fog warning
  - slippery road / rain warning

- **special functions:**
  - lorry overtake ban
  - dangerous point
  - building site safety
Section Control - dynamic roadside warning system
COMPANION

Research and pilot applications
Flashlights on signposts
Activation manual
Intention:
automatic activation by in-car crash-sensor and/or by roadside detection and/or by section control

Source: BMW
Temporary Opening of Hard Shoulders (SFG)

Where?
Heavily overloaded motorway stretches with hard shoulders and video control.

Main Control Objective?
Raise capacity (to reduce congestion and prevent accidents due to congestion)

How?
Dynamic opening of hard shoulders at high traffic volumes
Network Control Systems (NBA)

Where?
At decision points of heavy loaded and overloaded stretches with available alternative routes

Main Control Objective?
Balance route saturations and demand distribution in a network, and optimize traffic flow on main routes → Congestion avoidance, reduction of travel times

How?
additive or substitutive variable direction signs
Interchange Control Systems (KBA)

Where?
On motorway interchange (AK) or three way motorway interchange (AD)

Main Control Objective?
- Adapt capacity to traffic demand
- Minimize conflicts of merging streams

How?
variously allocate an additional lane
\[ \rightarrow \] local increase of capacity
Alternative solution:
lane specific speed limits
Ramp Metering (ZFR)

**Where?**
Access points

**Goal?**
congestion avoidance, reduction of travel time

**How?**
Traffic signal on ramp:
- entering of vehicle platoons is prevented,
- total entering volume is limited,
→ traffic flow on main road remains stable
Ramp Metering - Coordinated System

- Research and several pilot installations
- Goal: harmonized and balanced flow onto the main road along critical road sections
- Interaction between local systems needed
Traffic Control via Information – Radio Broadcast

Germany: ~ 35000 locations, 50 radio programs
EU: most services are free of charge, publicly operated
Added value offers by commercial organizations
Traffic Control via Information - Variable Information Signs
Integrated Network Control in Conurbation Area Munich

Information

Source:
MOBINET Consortium, 2003
ABDS, 2007
Integrated Network Control in Conurbation Area Munich

Recommendation

Source: MOBINET Consortium, 2003
ABDS, 2007
Integrated Network Control in Conurbation Area Munich

Guidance

Source: MOBINET Consortium, 2003
ABDSB, 2007
Integrated Network Control - Event Management

Cooperative remote control center:

• motorway control
• urban traffic control
• parking guidance
• police
Integrated Network Control - Event Management

Guidance on motorways

Source: ABDS, 2007
Integrated Network Control - Event Management

Guidance and signal control on main roads

Chair of Traffic Engineering and Control
Univ.-Prof. Dr.-Ing. Fritz Busch
Integrated Local Network Control – Hot Spot Management

Combined control measures:

- Traffic adaptive signaling
- Route guidance
- Lane control
- Ramp metering
Integrated Local Network Control – Hot Spot Management

Lane control Messe München-Riem

• Normal Operation
Integrated **Local** Network Control – Hot Spot Management

Lane control Messe München-Riem

- Arrival to Congress/Event
Integrated **Local** Network Control – Hot Spot Management

**Lane control Messe München-Riem**

- Departure from Congress/Event
Data Acquisition / Measurements - Categorization

• **Objective**
  - Precise and concise information about current situation
  - Basis for control and archives

• **Relevant Data**
  - Traffic
  - Environment
  - (system status)

• **Detection types**
  - Infrastructure based
    - local point related
    - local section related
  - Vehicle based, mobile
  - Momentary / aerial observation

• **Challenges**
  - Plausibility and consistency
  - Availability
The goal is to recognize vehicles at different cross-sections. This way, travel times can be determined and the traffic conditions can be better described. From travel times, travel speeds can also be derived.

**Procedures under research and/or in market:**

- License plate recognition
- Image analysis
- RFID tagging
- Vehicle signatures over inductive loops (ISAR)
- Vehicle classification and vehicle-group information
- Bluetooth ID recognition and tracing
- Mobile phone tracing
Section Oriented Traffic Measurements

Analysis and correlation of signatures

- Inductive loops
- magnetic field detectors
- laser scanners
- status: in operation as well under research for advanced applications
Section Oriented Traffic Measurements

License plate recognition

Donnerstag, 02.12.2004
Zeitdifferenz Kam 1-Kam2 [hh:mm:ss]

Reisezeit [min]

Uhrzeit [hh:mm]

Chair of Traffic Engineering and Control
Univ.-Prof. Dr.-Ing. Fritz Busch
Mobile Detection

- **Floating Car Data**
  - FCD: vehicle-ID, Position, time
  - xFCD: additional vehicle-telemetry data

- **Moving Observer**
  - Observation of surrounding and opposing traffic

- **C2X communication**
  - Vehicle networks
  - Vehicle to infrastructure based control

- **Floating Phone Data**
Mobile Detection - the FCD-Principle

Munich

Munich Airport

Floating Car Data

Zeit [min]

Weg [km]
Mobile Detection and Interaction - c2x Offers Further Options

- improving the driver's knowledge
Data Completion & Interpretation: Fusion of mobile and local data using flow models

Verification and adjustment by local measurements

\[
v = v_{frei} \cdot \left[1 - \left(\frac{k}{k_{\text{max}}}\right)^{\alpha}\right]^\beta
\]
Data Completion & Interpretation - Model Based Estimators

- Added value / customer benefit:
  - incident detection, propagation of congestion, travel times, virtual cross sections
Data Completion & Interpretation – Incident Detection based on FCD

Vehicle based incident detection

Section related incident detection

Stationäre Störungserkennung
Data Completion & Interpretation - Incident Detection based on FCD

Traffic state

Infrastructure

M.-Frankfurter Ring
M.-Freimann
M.-Fröttmaning
AK M.-Nord
Garching-S.
Garching-N.
Echina
AK Neufahrn

Messquerschnitte [km]

Geschwindigkeit [km/h]

0 2 4 6 8 10 12 14 16

8 10 12 14 16 18 20

Zeit [h]

Geschwindigkeit [km/h]

0 20 40 60 80 100 120 140

8 9 10

Zeit [h]

Belzner, 2005
Data Completion & Interpretation: Pattern recognition for determination of typical situations
Data Completion & Interpretation: 
Forecast of network-wide propagation of traffic patterns

Research on use of historical data for regional traffic management

Chair of Traffic Engineering and Control
Univ.-Prof. Dr.-Ing. Fritz Busch
Environmental Data

www.vt.bv.tum.de/umfelddaten
Environmental Data:
Key parameters of interest

Visibility
Precipitation
Windspeed / -direction
Air temperature
Relative humidity
Road surface condition
Road surface temperature
Environmental Data - Data Fusion & Interpretation

- Research on fusion of stationary data and extended Floating Car Data
- Intended usage for advanced motorway control and for improved road maintenance services (pavement status, winter service, ...)

Chair of Traffic Engineering and Control
Univ.-Prof. Dr.-Ing. Fritz Busch
Quality Management - General Approach

Intended overall concept for German motorway systems

concise multi-level top-down approach:

1. technological level (sensor, sign, cable, …)
2. data and information level (speed, occupancy, …)
3. module function level (algorithms, …)
4. integrated system function level (algorithms, strategies, …)
5. acceptance level (behavior versus signage)
6. effects level (system effects towards objectives)

Sources: BASi/BMVBS-projects
BENCHMARKING BAB [2005-2006]
Traffic-IQ [2009 ff]
Quality Management - Automatic Surveillance of Detectors

Failures detected

Failures corrected
Advanced Motorway Control

On the move to

a **fully integrated** even **"virtual" motorway control system**

1. Including "all" control objectives into one concise optimization function $\rightarrow$ holistic control of traffic (safety, traffic, environment)

2. Replacing roadside infrastructure (VMS-gantries) by advanced in-car devices (driver-HMI) $\rightarrow$ the virtual control system
Advanced Motorway Control - Model Extension

- Hardware
- Communication
  - Data management
  - Situation detection
  - Transverse adjustment
  - Longitudinal adjustment

INCA

- new logic for congestion warning and traffic harmonisation
- integrated into the existing "MARZ- Architecture"
Advanced Motorway Control - Model Extension
Inclusion of traffic safety into the control decision

Chair of Traffic Engineering and Control
Univ.-Prof. Dr.-Ing. Fritz Busch

INCA Control System, 2008
Safety and efficiency are parts of an integrated objective function on top of the standard German MARZ-section control model.

\[ G[\text{€ / km}] = \frac{C}{V} + p \cdot C_A \]

- \( C \): value of time in Euro/h
- \( C_A \): cost of an accident in Euros and per kilometer,
- \( p \): risk (probability of an accident under different conditions)
- \( V \): speed in km/h
- \( G \): value of distance in Euro/km

Estimation of \( p \): Average and acute accident densities
Advanced Motorway Control – Virtual Gantries
Virtual speed funnel by situation-specific in-car information

C2X:
Congestion/Hazard detection:
• Everywhere
• Faster
Congestion/Hazard Warning:
• Everywhere
• Faster
• More Adaptive
Virtual speed funnel by situation-specific in-car information

Traffic dependent congestion warning (speed funnel)

Traffic safety, traffic efficiency
Advanced Motorway Control - Virtual Gantries

Virtual speed funnel by situation-specific in-car information

Conventional Dynamic Traffic Control

Delay times:
- 5 % veh*hours
- 10 % veh*hours
- 10 % veh*hours
- 26 % veh*hours

compared to reference scenario without any traffic control
FOT - sim\textsuperscript{TD}
Large scale field operational test for cooperative systems

Vehicle fleet and test site:
- **100** manageable and fully equipped test vehicles
  - **20** test vehicles with “experts”, manage the fleet and can initiate defined traffic scenarios
  - **80** test vehicles with “normal” drivers for impact evaluation
- **300** vehicles with “normal” drivers, not manageable
  - e.g. commuters, taxis,…

sim\textsuperscript{TD} Test Site

Chair of Traffic Engineering and Control
Univ.-Prof. Dr.-Ing. Fritz Busch
FOT- simTD
cooperative functions under investigation

Mobility/Traffic

Basic Services
• Data collection in the infrastructure by the vehicle
• Identification of road weather traffic situation traffic events / incidents

Traffic information & navigation
• Foresighted road / traffic information
• Road works information
• Advanced route guidance & navigation

Mobility/Traffic

Traffic management
• Alternative route management
• Optimized urban network usage based adaptive traffic light control
• Local traffic-adaptive traffic light control

Driving and Safety

Driving Assistance
• In-vehicle signage / traffic rule violation warning
• Traffic light phase assistant / traffic light violation warning
• Extended electronic brake light
• Intersection & cross-traffic assistance

Driving and Safety

Local danger warning
• Obstacle warning
• Congestion warning
• Road weather warning
• Emergency vehicle warning

Additional Services
• Internet-based services
• Location-dependent services

Chair of Traffic Engineering and Control
Univ.-Prof. Dr.-Ing. Fritz Busch
And there is more and more and more...

Sharing knowledge, learning from each other, cooperating where possible, training and educating continuously are more important than ever!

Some options at the end
Set up the national communities
Link to the international ITS-scene to share knowledge
International *Knowledge Transfer*: PIARC and FISITA

**PIARC ITS Handbook - 2nd Edition**

Recommendations from the World Road Association (PIARC)

+ cooperative activities, e.g. JTF PIARC-FISITA on VII/C2X
New Educational Offers: e.g. M.Sc. in Transportation Systems

- **Beginning:** every October
- **Duration:** 4 semesters (24 months)
- **Overview:**
  - 3 semesters of course works (including a project seminar)
  - 8 weeks internship in transportation related industry or authority
  - 4 months Master’s thesis

**Contents:**
- Traffic Flow Theory, Modeling, Simulation
- Intelligent Transport Systems
- Integrated Traffic and Mobility Management
- Design of Transportation Networks
- Interactions of land-use and transport
- Regional and Local Planning Methods, Governance
- Design of road networks / public transport networks
- Public transport planning
- Design of railways, airports and harbours
- Passenger and freight logistic concepts
- Transport economics
- Intercultural aspects, soft skills

[http://www.transportation.bv.tum.de/](http://www.transportation.bv.tum.de/)
Harmonizing and Extending International Teaching: **ITS-EduNet**

*an International Network for training, education and outreach in the field of ITS*

**Aim:** To improve training and education in ITS and allow a better exchange of ITS knowledge.
Transport Systems in 2015

**Visions of ITS-students** at TUM, 2006

---

**ITS Visions Competition**

*2nd prize is hereby awarded to:*

*Technische Universität München*

Silja Asenmacher, Elisa Biermann, Alex Eber, Claudia Frei, Christian Gmeiner

Elisabeth Michael, Tobias Schwindt, Christian Schütt, Christoph Sünnermann

*Awarded by:*

Professor E. Sampson

Department for Transport

Date: 12 October 2006

---

*TRL*

---

*Drive 5 km/h to catch the next green light*
Thank you for your patience!

Contact:

Technische Universitaet Muenchen
Lehrstuhl fuer Verkehrstechnik
Arcisstrasse 21
D – 80333 Muenchen
fritz.busch@tum.de
www.vt.bv.tum.de