Fuzzy Logic in Traffic Control

State Trafic Departement Baden Württemberg

realized by INFORM Software Corporation

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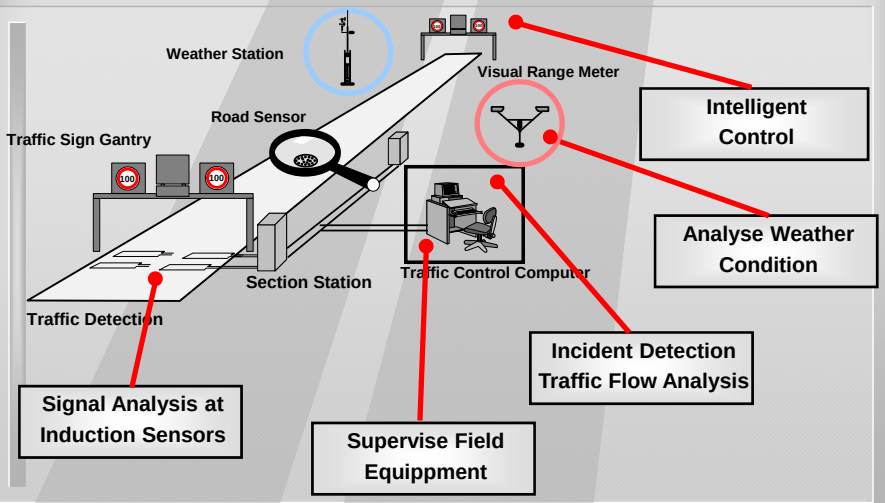
Bernhard Krause

Fuzzy Logic in Components of Traffic Control Systems



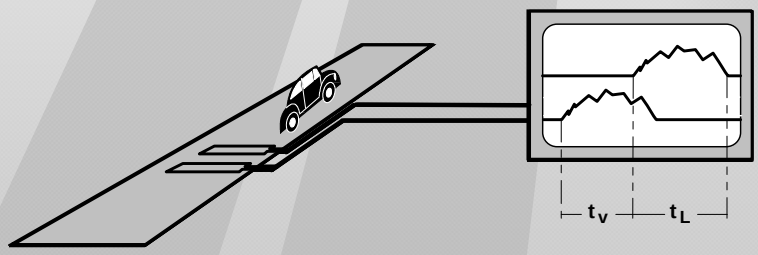
Vehicle Classification at Traffic Detection Sensors

Required Information: Vehicle Speed and Type

Evaluate Speed: $v_{Fahrzeug} = Sensorabstand / t_v$

Evaluate Length: $L_{Fahrzeug} = v_{Fahrzeug} / t_L$

to Classify Vehicles in Cars and Trucks



Vehicle Classification at Traffic Detection Sensors

Misleading: Talegating Cars are Detected as Trucks

Solution: **Use Car Speed as Additional Criteria**

L = 6 m and v = 120 km/h : Car
L =14 m and v = 100 km/h : Truck
L = 8 m and v = 100 km/h : Truck
L = 8 m and v = 140 km/h : 2 Cars

Implemetation: **Defining Borderes is not always Plausible**

L = 8 m und v = 120 km/h : 2 Cars
L = 8 m und v = 119 km/h : Truck

➔ **Use of Multiple Criteria results in Black Box System**

Vehicle Classification at Traffic Detection Sensors

Fuzzy Logic

Describe Criteria as

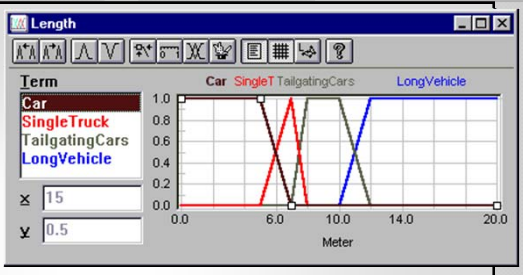
Linguistic Variable

Example Car Length:

- "typical Car";
- "Long Truck";
- "2 Cars";
- "Short Truck"

Example Car Speed:

- "fast";
- "regular";
- "slow"



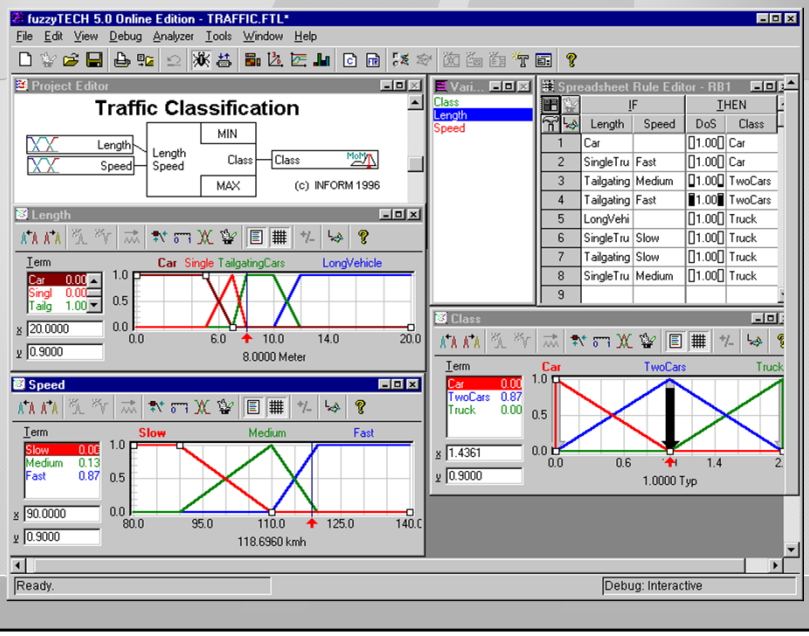
Describe Expirience as

Fuzzy Rules

"A detected signal showing a speed of 80 km/h represents usually a truck."

"A detected signal showing a vehicle length of 10 meter at low speed is assumed to be a truck, at high speed is assumed to be 2 cars."

Vehicle Classification



Traffic Control

Road Map and *Traffic Detection*

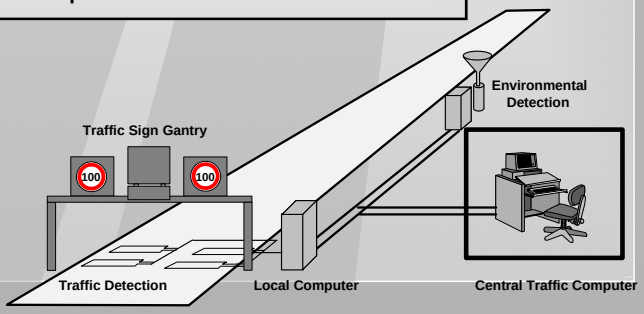
Road Map | Data Acquisition

Uses existing Detection Systems

Traffic: q_{Car}, q_{HGV}, v_{Car}, v_{HGV} (per time for every lane)

Road Map: Distance between adjacent cross sections (= section), location of ascents, descents, entrances, exits

➔ **Reduces required data volume**



Traffic Control

Substitute Values

History | Substitute Values
Road Map | Data Acquisition

Substitute missing Data by Time-Distance Traffic Forecast

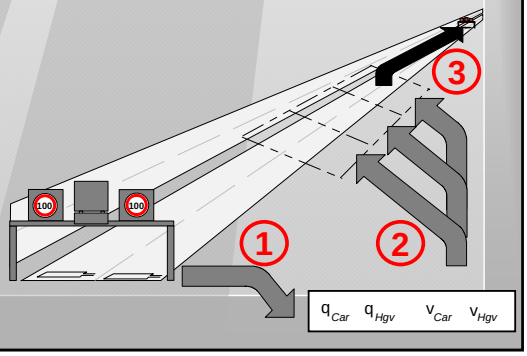
➔ **use previous cross section to forecast traffic on main and exit lanes**

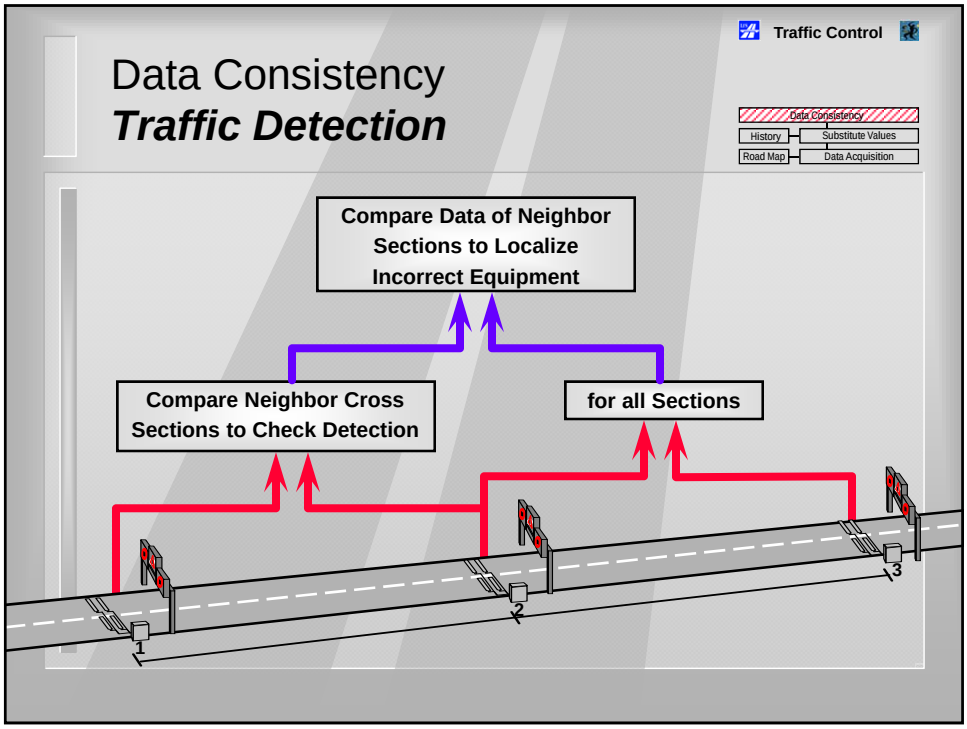
➔ **use following cross section to forecast traffic on entrance lanes**

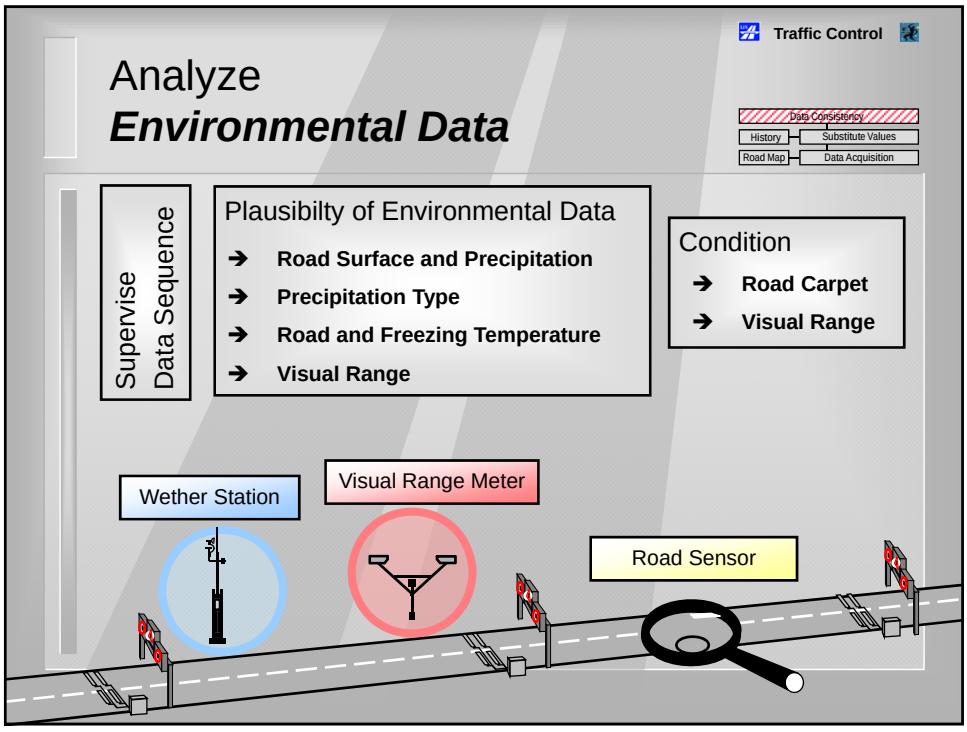
➔ **use historical data when neighbor cross section not available**

Time Distance Forecast

- Detect ariving vehicles at cross section,
- Trace vehicles during the sector by using detected vehicle speed,
- calculate number of cars, that arrive at subsequent cross section for observed time interval.




Traffic Control
Data Consistency
Traffic Detection
Data Consistency
History
Substitute Values
Road Map
Data Acquisition
Compare Data of Neighbor Sections to Localize Incorrect Equipment
Compare Neighbor Cross Sections to Check Detection
for all Sections
1
2
3


Traffic Control
Data Consistency
Analyze
Environmental Data
Data Consistency
History
Substitute Values
Road Map
Data Acquisition
Supervise Data Sequence
Plausibilty of Environmental Data
Road Surface and Precipitation
Precipitation Type
Road and Freezing Temperature
Visual Range
Condition
Road Carpet
Visual Range
Wether Station
Visual Range Meter
Road Sensor

Traffic Control

Data Consistency
Road Condition

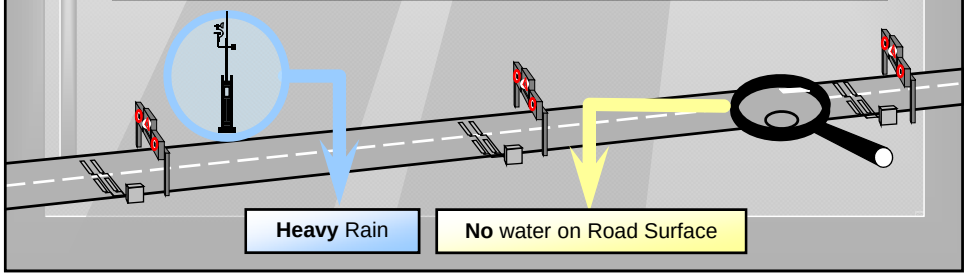
Data Consistency
History — Substitute Values
Road Map — Data Acquisition

Biological Hazard in Precibitation Intensity Sensor

During heavy rainfall, the road surface must be wet.

Comparing road sensor with precibitation intensity sensor detects failure.

- ➔ **Automatical detection of road condition**
- ➔ **Avoid wrong display**
- ➔ **Initiate maintenance of local equipment**



Heavy Rain

No water on Road Surface

Traffic Control

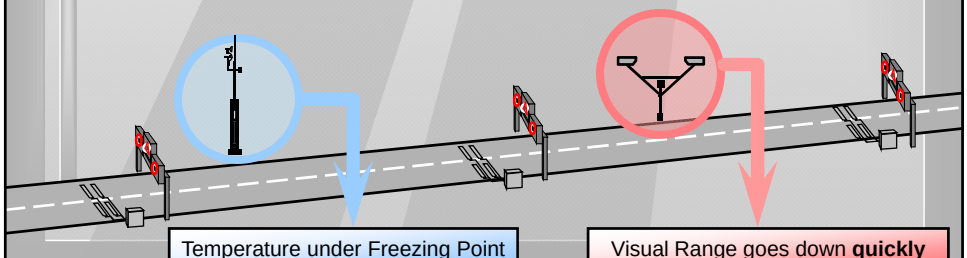
Data Consistency
Visual Range

Data Consistency
History — Substitute Values
Road Map — Data Acquisition

Wrong Fog Warning caused by icing Visual Range Meter

Fog occures slightly, a quick descent of visual range can be compared with other environmental data as air temperature and humidity.

- ➔ **Automatical detection of environmental condition**
- ➔ **Avoid wrong display**
- ➔ **Initiate maintenance of local equipment**



Temperature under Freezing Point

Visual Range goes down **quickly**

Environmental Condition
Indicate ***Hail***

Traffic Control

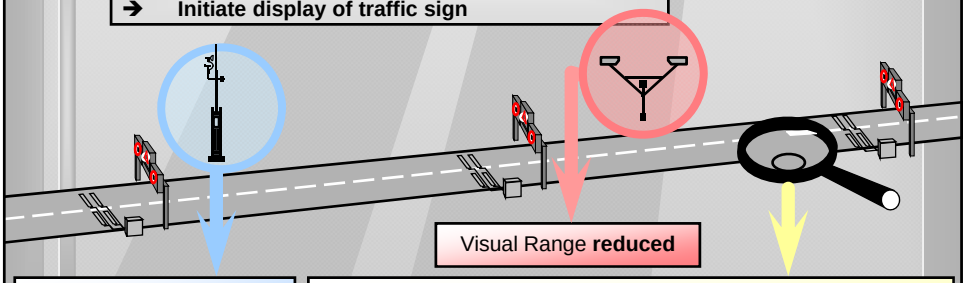
Road Fog Environ.
Data Consistency
History Substitute Values
Road Map Data Acquisition

Indicate Precibitation Type

compare environmental data from different sensors

➔ **Automatical detection of** precibitation **type**

➔ **Initiate display of traffic sign**



Visual Range **reduced**

Air Temp. higher to **20°C**
Heavy Wind
Heavy Precibitation

Temperature on Road Surface **higher** than Air Temperature
Road Surface **wet**
Road Temperature **goed down quickly under 15 °C**

Analyse Traffic Data
Incident Detection

Traffic Control

Jam Road Fog
Traffic Environ.
Data Consistency
History Substitute Values
Road Map Data Acquisition

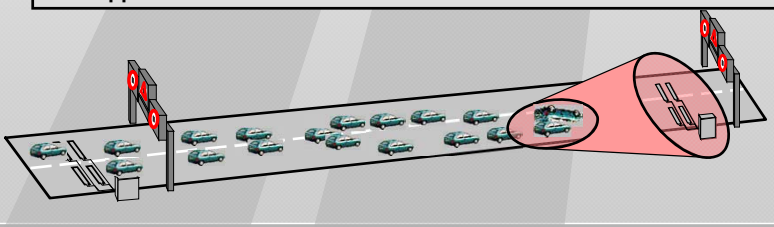
If vehicle drivers reduce speed, a reason must be asumed.

Vehicles detected at a cross section **must** occure at the following cross section after the time they need to pass the section. Otherwise there is an incident.

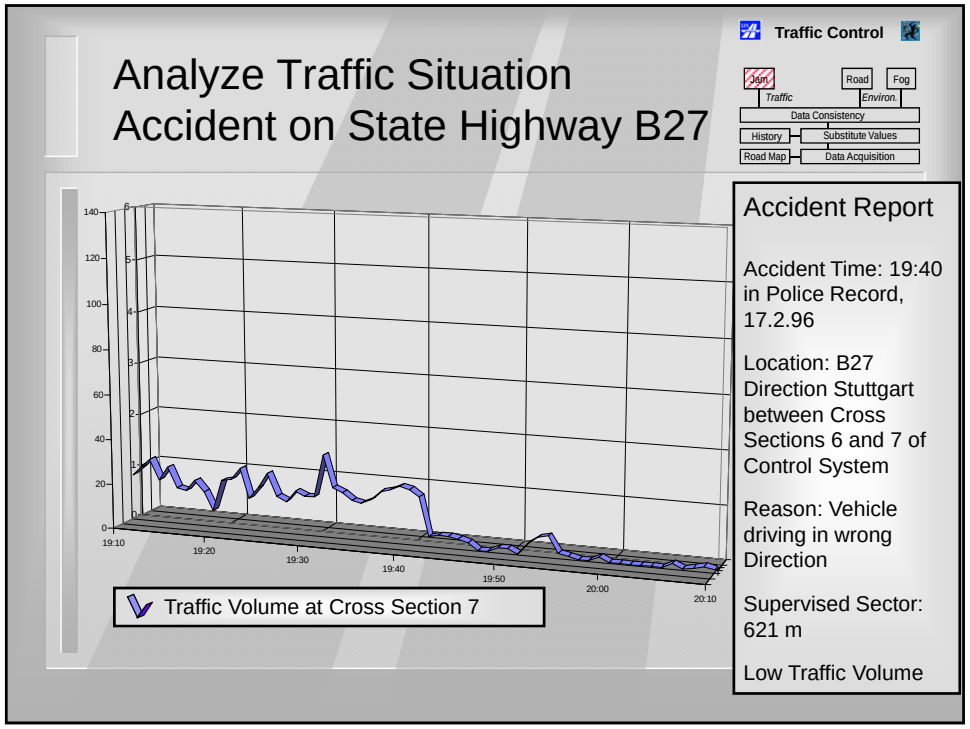
➔ **Incidents (e.g. accidents) can be detected when vehicles, that have passed the previous cross section, do not occur at the following.**

➔ **Detection by observing the traffic behind the incident.**

➔ **Appliable to section with distance >4 km between observation.**



Analyze Traffic Situation
Accident on State Highway B27



Accident Report

Accident Time: 19:40 in Police Record, 17.2.96

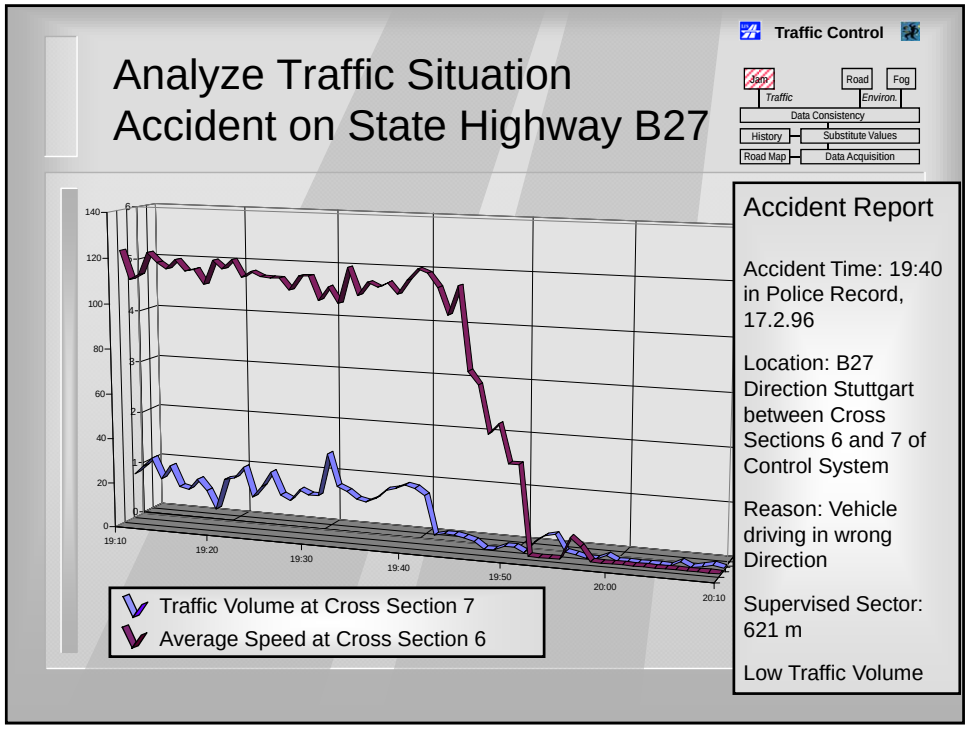
Location: B27 Direction Stuttgart between Cross Sections 6 and 7 of Control System

Reason: Vehicle driving in wrong Direction

Supervised Sector: 621 m

Low Traffic Volume

Analyze Traffic Situation
Accident on State Highway B27



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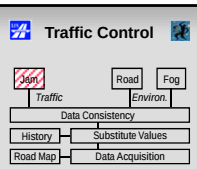

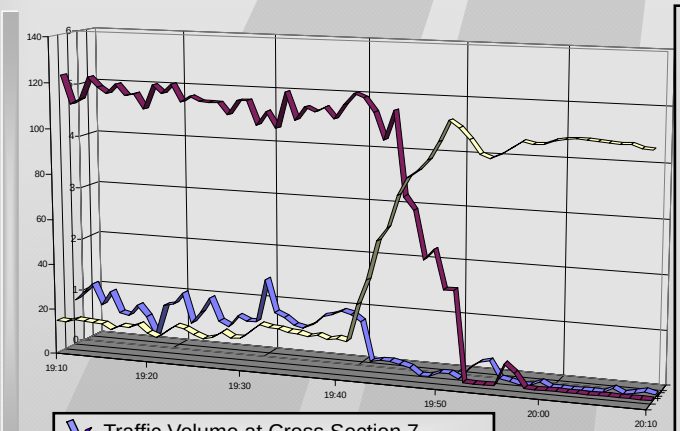

Traffic Volume at Cross Section 7
Average Speed at Cross Section 6
Traffic Density between Cross Sections

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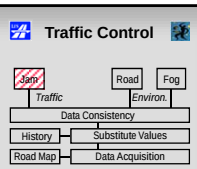
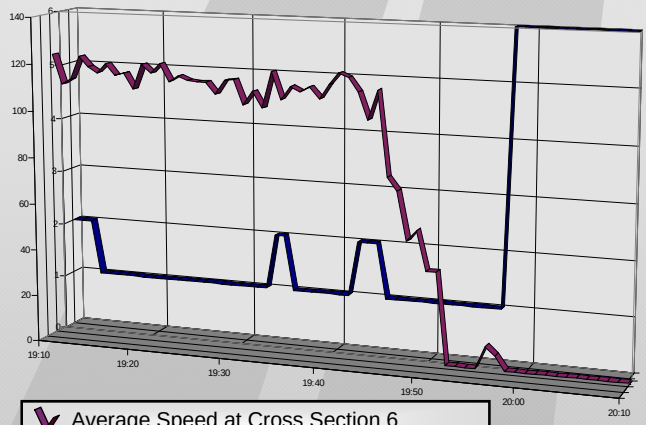




Average Speed at Cross Section 6
Traffic Condition of Conventional System

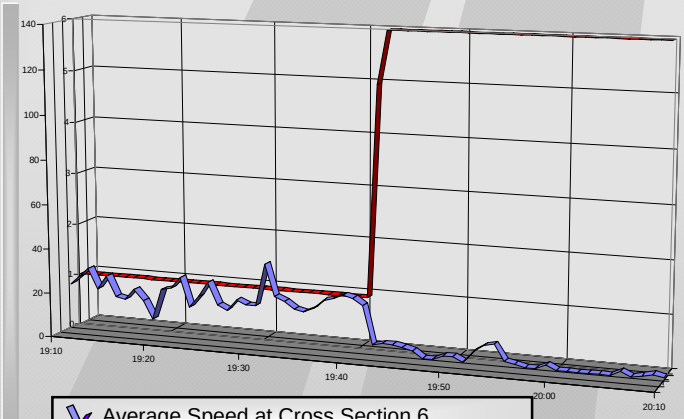
Incident Detection

➔ **Conventional Approach: Congestion Warning requires 18 Minutes**

Analyze Traffic Situation
Accident on State Highway B27

Traffic Control

Jam / Traffic | Road / Fog / Environ.
Data Consistency
History | Substitute Values
Road Map | Data Acquisition



Average Speed at Cross Section 6
Traffic Condition computed by Fuzzy Logic

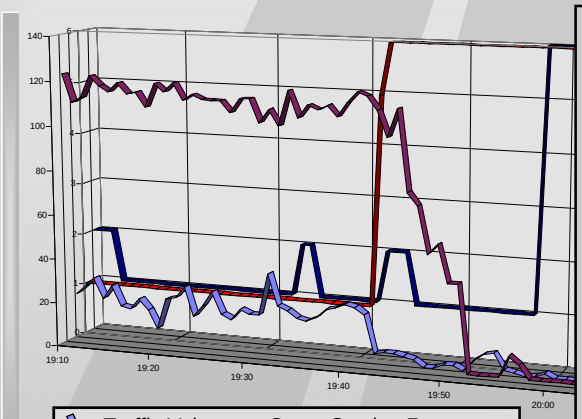
Incident Detection

➔ **Fuzzy Logic Congestion Warning requires 3 Minutes**

Analyze Traffic Situation
Accident on State Highway B27

Traffic Control

Jam / Traffic | Road / Fog / Environ.
Data Consistency
History | Substitute Values
Road Map | Data Acquisition



Traffic Volume at Cross Section 7
Average Speed at Cross Section 6
Conventional computed Traffic Condition
Traffic Condition computed by Fuzzy Logic

Accident Report

Accident 17.2.96, 19:40

Location B 27 Direction Stuttgart in Supervized Area of Control System between Cross Sections 6 and 7

Sector Length: 621 m

Low Traffic Volume

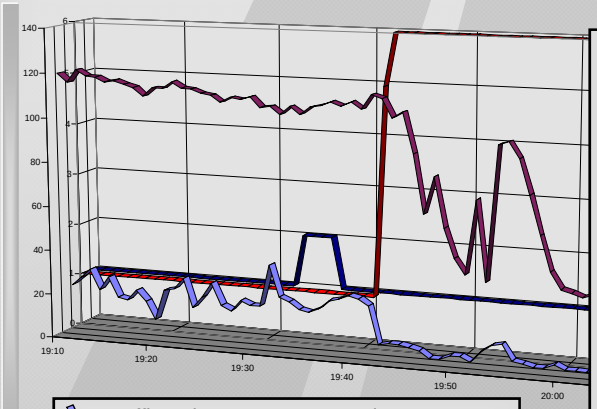
➔ **Required Time Fuzzy: 3 Minutes Conventional: 18 Minutes**

➔ **Fuzzy Logic enables More Reliable and Faster Detection**

Analyze Traffic Situation
Accident on State Highway B27

Traffic Control

Jam Road Fog
Traffic Environ.
Data Consistency
History Substitute Values
Road Map Data Acquisition



- Traffic Volume at Cross Section 7
- Average Speed at Cross Section 6
- Conventional computed Traffic Condition
- Traffic Condition computed by Fuzzy Logic

Large Sector Length

Accident 17.2.96, 19:40

Location: Analyze
Cross Section 5 and 7
Direction Stuttgart

Sector Length: 1640 m

Low Traffic Volume

➔ **Required Time for Detection:**
Fuzzy Logic:
3 Minutes

Conventional:
No Detection

Analyse Traffic Data
Traffic Condition

Traffic Control

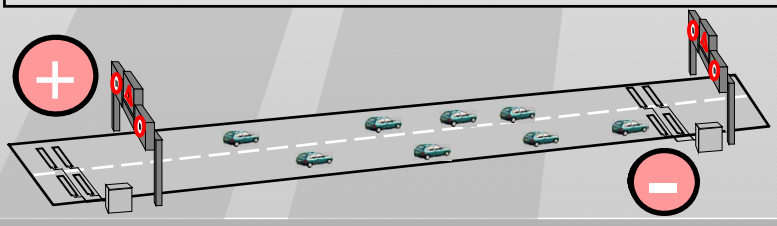
Jam Cond. Road Fog
Traffic Environ.
Data Consistency
History Substitute Values
Road Map Data Acquisition

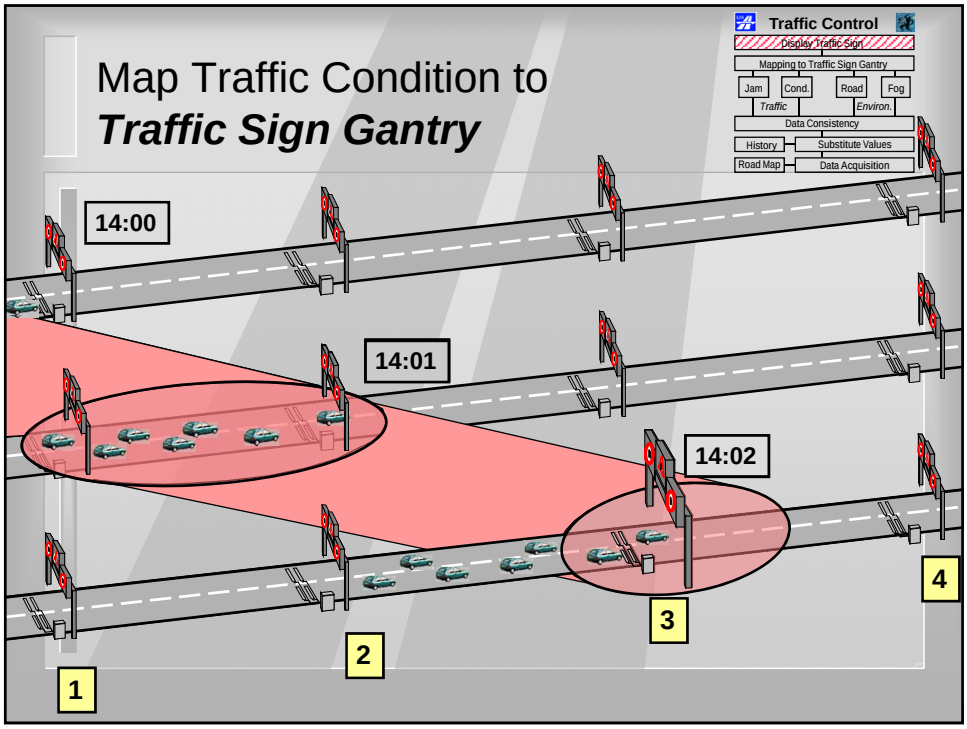
Usually the traffic flow is regular.

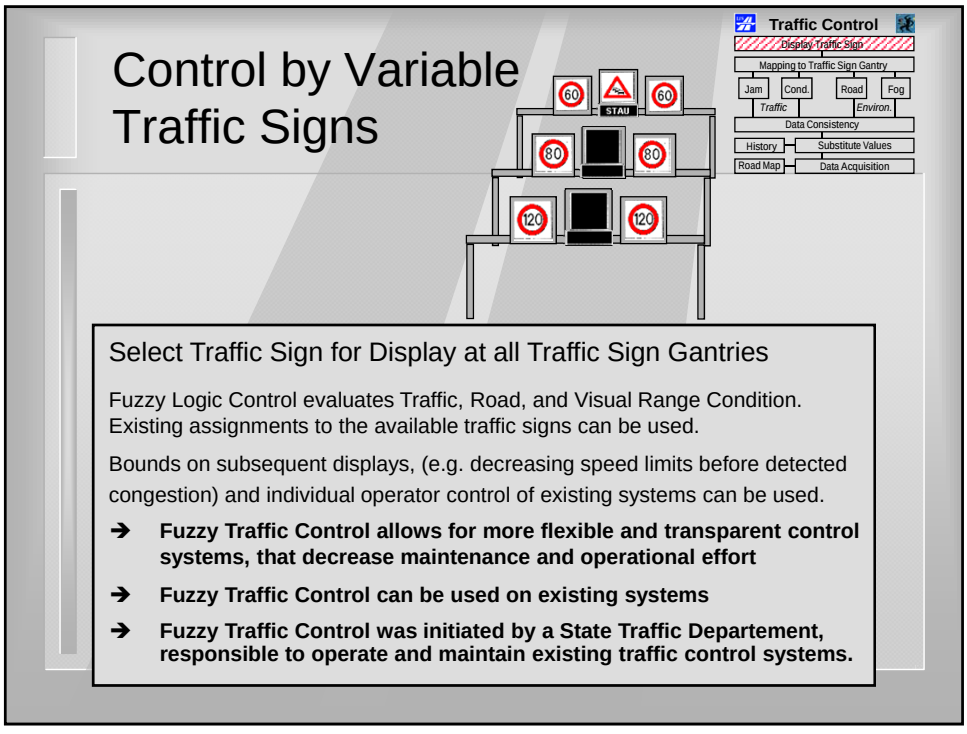
Within regular traffic flow, the results evaluated at local observation points can be used to describe the traffic situation for the complete section.

➔ **Use regular traffic flow to estimate the number of cars that are currently between two croos sections (real traffic density estimation).**

➔ **Use a subsequent calculation of arriving and departing vehicles to estimate the real traffic density in unstable traffic situations.**




Map Traffic Condition to
Traffic Sign Gantry
Traffic Control
Display Traffic Sign
Mapping to Traffic Sign Gantry
Jam
Cond.
Road
Fog
Traffic
Environ.
Data Consistency
History
Substitute Values
Road Map
Data Acquisition
14:00
14:01
14:02
1
2
3
4


Control by Variable
Traffic Signs
Traffic Control
Display Traffic Sign
Mapping to Traffic Sign Gantry
Jam
Cond.
Road
Fog
Traffic
Environ.
Data Consistency
History
Substitute Values
Road Map
Data Acquisition
60
60
STAU
80
80
120
120
Select Traffic Sign for Display at all Traffic Sign Gantries
Fuzzy Logic Control evaluates Traffic, Road, and Visual Range Condition. Existing assignments to the available traffic signs can be used.
Bounds on subsequent displays, (e.g. decreasing speed limits before detected congestion) and individual operator control of existing systems can be used.
➔ Fuzzy Traffic Control allows for more flexible and transparent control systems, that decrease maintenance and operational effort
➔ Fuzzy Traffic Control can be used on existing systems
➔ Fuzzy Traffic Control was initiated by a State Traffic Departement, responsible to operate and maintain existing traffic control systems.

Traffic Control by Fuzzy Logic

(using variable traffic signs)

State Traffic Departement Baden-Württemberg