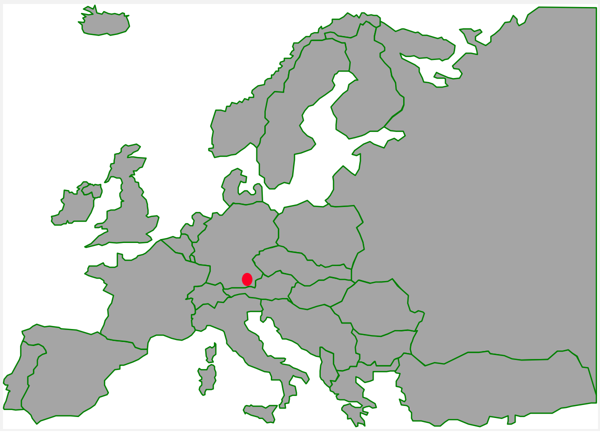
DEMONSTRATION SITE:	(INTERSECTION BAUBERGER-STR./DACHAUER-STR) MUNICH/GERMANY 
NAME OF THE DEMONSTRATION PROJECT (CASE STUDY):	BALANCE URBAN TRANSPORT CONTROL WITH INTELLIGENT PT PRIORITY
DURATION OF THE PROJECT:	FEBRUARY 1996 - STARTED MAY 1998 - COMPLETED
NAME OF THE TAP PROJECT:	TABASCO

URBAN PROFILE

Munich has a population of 1.296.710 million inhabitants and is the capital and major centre of Bavaria. The city is home to industrial manufactures like BMW, Siemens, MAN and is a centre for banking, high technology development and services.

ABSTRACT

BALANCE is an urban network control system that has been designed to manage the competing demands of general traffic, public transport, environmental impact and pedestrians. It can be applied in a single intersection or for a complete urban network by drawing on data from detectors all over the network. It operates at a tactical level, optimising the overall delay within the whole network and at an operational or local level reacts to short-time changes in traffic by a microscopic control within the boundaries set by the strategic level. At this level the complementary EPICS (Enhanced Public Transport Intersection Control Strategy) system provides an optimal solution within PT priority for intersections with a lot of competing PT demands, where a classic "first come - first served" approach to PT priority becomes ineffective.

In the Munich demonstration on one intersection , Bauberger-Str./Dachauer-Str. in the north of Munich, the benefits of BALANCE in dynamically optimising traffic light timings with respect to overall network flow and in improving priority for public transport users (in particular by integrating the EPICS system) have been clearly shown to be three times greater (in Munich) than investment costs even on a hard economic basis. When socio-economic benefits are accounted for, the argument for the system is overwhelming. The system will soon be installed at 25 junctions in the locality of the new Munich trade fare area.

The BALANCE system has been implemented in and adapted to a number of environments (London and Glasgow) and the technical transferability of the software into existing traffic management operating systems has been demonstrated. As with nearly all similar complex projects, however, there have been problems with making a trouble free integration and adaptation of local controllers has been necessary. The software, however, has the potential to truly integrate and multi-modally optimise a large network of junctions.

The system has a particular benefit in that it can be effectively applied to optimise any number of junctions, thus allowing for gradual system growth. For effective application on the tactical level, however, it is necessary to put in place a network of functioning detectors and a system of identifying public transport vehicles in traffic flow.

BACKGROUND AND OBJECTIVES

TABASCO is a European demonstration project implementing multi-modal information and control systems as a contribution towards solving transport problems of cities in regions. Thus the focus of the project was the user-oriented validation of transport telematic systems implemented in cities and in their surrounding regions, and on the integration of these systems to produce a more efficient transport system as a whole. Within the TABASCO project, the demonstration sites Munich, Glasgow and London co-operated in validating and demonstrating advanced approaches for Urban Traffic Control with a particular emphasis on the requirements of different user groups. The common basis of this work was the traffic light network control method BALANCE that was developed and tested within the DRIVE/ATT project LLAMD-COMFORT. Thus the opportunity to demonstrate and evaluate the application of one method at different European sites was given.

Because BALANCE has been designed to manage the competing demands of all traffic types, it is an ideal system for the intersection Bauberger-Str./Dachauer-Str. in the north of Munich where there is a high traffic load at the intersection, especially during the morning peak hour, and importantly in addition the intersection is a connection point for different bus and trams lines. Both buses and trams had absolute priority against the car traffic. The high public transport demand caused congestion in the Bauberger Str. and the Dachauer Str. especially in the morning peak hour and because there were frequently competitive situations between the buses and trams, conflicts and unreliability in the PT also appeared.

The main objective was to provide an effective signal control to all road users and in particular to public transport by balancing the requirements of the different user groups. Apart from the needs of the road users the system design should provide an optimal and cost-effective solution for the system operator.

The main measurable targets were to achieve the following :

- Reduced passenger journey times,
- Increased reliability of bus and tram service,
- Reduced delays to buses and trams,
- Reduced delays to car traffic within an improved public transport priority,
- Reduced pollution,
- Reduced fuel consumption,
- Improved acceptability of public transport priority for non-users of public transport.

PRESENT STAGE OF IMPLEMENTATION

The Munich demonstrator was used for evaluation of the BALANCE system. For the demonstration phase, test equipment with respect to hardware and communication facilities was used. For this reason, the operation of the system was stopped although the evaluation showed high benefits. Due to the positive results of the demonstration, the City of Munich decided to implement the BALANCE control system for 25 junctions in the locality of the Munich new trade fare area. This area is characterised by a strongly changing demand pattern and therefore an adaptive control method for the 25 intersections is expected to be very useful. The system is now in test operation (open loop) and will go into regular operation by October 1999.

Financing and Resources Used

For the calculation of the normal operational costs of the BALANCE system, an implementation scenario with an urban sub-network of 20-30 intersections, a linear depreciation of the equipment over 10 years and an equal and constant discounting of costs and benefits have been assumed. On this basis, the total operation costs per intersection and year amount to 2,600 EUR.

Individual investment and running cost breakdown was roughly estimated as follows in EUR:

Item	**Cost in EUR**
Overall System Costs Macro BALANCE	2.000 / junction
Overall System Costs Intersection Controller EPICS	1.000 / junction
Communication Path	3.000 / junction
Total implementation costs	**6.000 / junction**
Discounted yearly cost	**2.600 / junction / year**

When implementing BALANCE the full costs were/will be funded by the city authority only if they are lower or at least equal to the costs imposed by the standard vehicle actuated control systems including costs for maintenance. These costs do not include investment in basic detection technology.

TECHNICAL PROFILE OF PROJECT

The Munich field trial area was the intersection Bauberger-Str./Dachauer-Str. in the north of the City. The adjacent intersections Dachauer-/Moosburger-Str. and Dachauer-/Hugo-Troendle-Str. are also in the traffic model but are not controlled by BALANCE. BALANCE is an urban network control system that has been designed to manage the competing demands of general traffic, public transport, environmental impact and pedestrians and can be applied in a single intersection as well as in a complete urban network.

There are two levels of operation, both of which are based on traffic models and optimisation procedures.

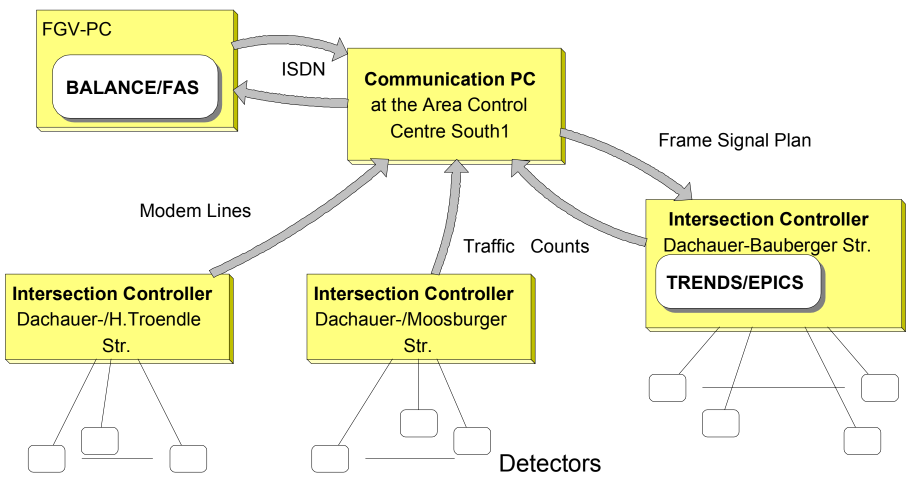
The tactical level (MACROBALANCE) performs a macroscopic optimisation of the delay within the network. It receives traffic flow information from detectors, determines the entry/exit relations within the network and optimises the control parameters of the particular intersections (the Signal Frame Plan). The signal frame plans defines latest start and earliest stop times for each stage within the stage cycle. In addition, the signal frame plan specifies a priority level, which defines the degree of priority to be allowed for public transport vehicles. These frame signal plans do not need to be updated more frequently than every 5 - 10 minutes and therefore transmission costs can be kept very low. The tactical level is implemented at a central unit.

The operational or local level reacts to short-time changes in traffic by a microscopic control within the boundaries set by the Signal Frame Plan. The local control is continually using local vehicle counts to determine the optimal stage duration, within the limits of the signal frame plan, to optimise a performance function. The calculation interval length is 1 sec. In Munich the operational level is realised by the standardized TRENDS control system of the TABASCO partner GEVAS and the EPICS (PT priority) system of the TU-Munich/ both of which have been implemented at the local intersection controller.

Public transport priority is performed when necessary at the local level within the boundaries of the tactical MACROBALANCE network control. A conventional vehicle-actuated PT-priority was in operation before TABASCO (the TRENDS control). Though it was effective and reliable, there was some potential for improvement especially at intersections with a high load of public transport by changing the PT control strategies. If more than one PT vehicle arrived the demands were processed by a 'First-Comes-First-Served' strategy which could not guarantee an optimal solution for intersections with a lot of competitive PT demands. Furthermore there was no traffic model which could handle additional information about the PT vehicles (e.g. accordance to the schedule or number of passengers) to perform a demand-oriented delay minimisation. Within TABASCO the existing PT-priority facilities have been replaced by the EPICS system (Enhanced Public Transport Intersection Control Strategy). EPICS is an adaptive PT intersection control which is able to deal with the requirements described above by introducing a traffic-model based PT-control on the intersection level under real-time conditions. EPICS was embedded into the TRENDS control using the basic IO-functions of TRENDS.

The MACROBALANCE central control was for demonstration purposes connected to the local TRENDS/EPICS control via a communication station at the area control centre South1. The communication PC samples the incoming detector traffic counts and sends it to BALANCE by ISDN. In the other direction the BALANCE Frame Signal Plan is sent by a modem line to the intersection controller.

The MACROBALANCE central control has been integrated into the signal control environment of the City of Munich. For testing and assessment purposes, software (FAS from TABASCO partner GEVAS) for the monitoring of PT operation was employed. This enabled the gathering of large sample sizes for public transport priority. A first version of a graphical man-machine interface for BALANCE is now being implemented for the configuration, maintenance and monitoring of BALANCE control at the new trade fare area. This windows based software integrates features like a user-friendly graphical network editor, menus for configuration and graphical monitoring of online operation.



Data flow structure of the overall control system

RESULTS & IMPACTS

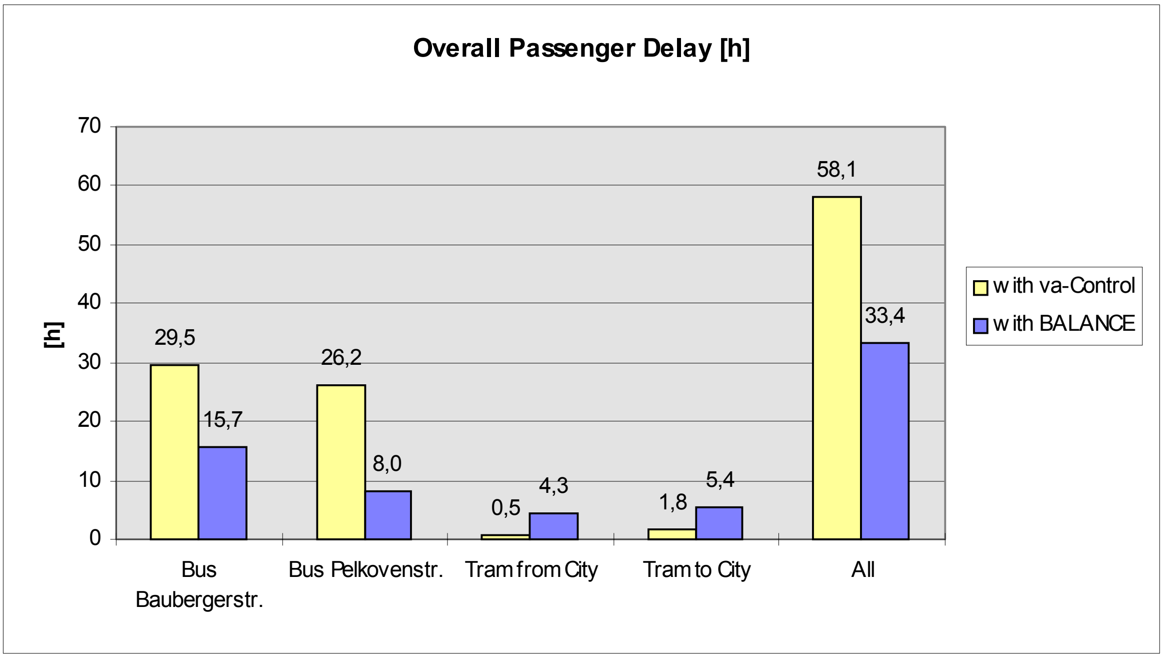
A number of measures have been made of the impact of the project including calculation of PT operating costs reduction, before and after delay and emissions reductions for all the relevant actors (PT passengers and car users).

Estimated savings in EUR / year are summarised per intersection in the following table :

Item	EUR
Reduction of Public Transport Operating Costs	7,400 / junction
Reduction of PT-Passenger Delay	28,400 / junction
Reduction of Delay for Private Traffic	12,000 / junction
Reduction of Emissions and Fuel Consumption	3,000 / junction
Total yearly benefits	**50,800 / junction**
Total yearly costs	**2.600 / junction**

The quality of service for public transport users has been measured by the indicators PT-journey time and passenger delay. On average, BALANCE reduced PT journey times from 78 to 70 seconds, i.e. by 10%. Even more impressively, the overall PT vehicle delay has been reduced by 54% from 17 to 9 seconds per vehicle and the passenger delay even by 57% compared to the reference case with bus priority under vehicle-actuated control. In line with these improvements is also the reduction of the standard deviation of the PT journey times by 22%, indicating an increased reliability of the bus and tram services.

While improvements for public transport were a core objective of the BALANCE implementation in Munich, the local authority saw it at the same time as imperative to avoid disturbances to the car traffic flow caused by public transport in order to ensure the acceptability of the PT priority measures. The indicators chosen to demonstrate this were queue length and car delay, and both have been reduced by BALANCE/EPICS even though the quality of PT priority has been improved. The average queue length could be reduced from 46 to 40 m, i.e. by 13%, and the average delay from 48 to 44 seconds per car, i.e. by 8%.



Aggregated public transport passenger delay

The clear qualitative impact stems from the improvement in the overall reliability of public transport which should improve the image, comfort and attractiveness of this mode.

Reductions in delays and queue lengths also lead to reductions in most emissions: HC, CO and CO2 emissions dropped all by around 3 %, the only exception being NOx which increased by 0.4%. Furthermore, also fuel consumption was 2.6 % lower through the use of BALANCE.

The above costs and benefits imply that for the normal operation of a BALANCE network with 20-30 intersections and traffic (and socio-economic) conditions similar to the demonstration area (high demand for both public transport and private traffic) a ratio benefit to cost RBC of 19:1 can be expected. Even without accounting for socio-ecomomic benefits a saving ratio benefit to cost RBC of 3:1 can be expected.

All set objectives have been well met by the BALANCE / EPICS system in Munich.

BARRIERS & CONFLICTS

The biggest problems faced were convincing decision makers on the usefulness of adaptive control methods in terms of socio-economic benefits, entering the market of signal control soft- and hardware and coming to an arrangement with the respective suppliers.

The main technical obstacles were met in implementing the new software in the existing operating system of the controller and in getting the necessary data transmitted from the controller to the central unit. For test purposes the problems were overcome by adaptation of the operating system of the relevant controller. Problems concerning data transmission were solved by using an expensive ISDN dial-up line.

In order to overcome the problems after the successful demonstration, tenders for new controllers (e.g. trade fare area) were specified according to the requirements of the new control method BALANCE. For data communication a new fieldbus system is employed there.

Problems still exist with respect to the implementation of BALANCE in existing controllers and for the given legacy communication network. At present the city is working on the development of a general open system architecture for traffic control. This is expected to facilitate in future the implementation of any control method.

TRANSFERABILITY

To demonstrate transferability was a major objective of TABASCO. Therefore BALANCE was not only implemented in Munich but also in London and in Glasgow. There it was shown that the modularity of the method can fit into different environments and in particular different user requirements. Thus instead of the vehicle actuated local control component TRENDS that was used in Munich, an adaptive local component MICROBALANCE was employed in UK. In this way significant costs can be saved compared to the new installation of a centralised system.

The system has a particular benefit in that it can be effectively applied to optimise from one to any number of junctions, thus allowing for gradual system growth. For effective application at the tactical level, however, it is necessary to already have in place a network of reliably functioning traffic detectors and a system of reliably identifying public transport vehicles in the traffic stream (which provide essential data input into the optimisation system).

Costs would be charged by the providers for software license and eventually for configuration and implementation if required. Significant costs can be incurred in adapting existing controllers to be compatible with the system.

The city can provide advice and specific experience for implementation.

LESSONS LEARNED

During the course of the project it was learned that it is important to have a clear basic idea of the technical system and the respective potentials; and good co-operation of the partners involved in the project. Solutions for an open system architecture need at least to be started in parallel with system development. In addition, the development of a new control system needs a commercial perspective for at least one partner (or even better more than one), otherwise the project will be stopped at the end of the demonstration and before deployment.

BALANCE represents an evolutionary approach that can be started by the installation of one intersection. It also provides the potential to be extended to a whole network as is being implemented at the trade fare area in Munich including 25 intersections. Apart from this, BALANCE offers a truly integrated solution for public transport priority. Public transport priority only needs to be configured with a small amount of additional data, thus not causing any extra costs. Additionally it was demonstrated that the method could be implemented at different European sites using the existing equipment of different suppliers.

For these reasons and because of the high benefit to cost ratio, BALANCE can be immediately recommended to all follower sites with sufficiently complete basic traffic detection equipment in place.

ADDITIONAL INFORMATION

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