Experiences with Adaptive Signal Control in Germany

by

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Abstract

Germany has a long tradition of traffic actuated and of coordinated signal control. In recent years a specific approach of traffic actuation, called model-based systems or adaptive control has found its way into practice. A scientific research on the performance of these systems has been conducted in the city of Muenster/Germany. The coordinated signal control system on the 6 km long arterial “Albersloher Weg” with 24 signalized intersections has been completely renewed by three steps: the old system, a rule-based traffic actuation, and an adaptive system. This process has been evaluated by a university research team using empirical studies. The results showed that the conventional actuated signal control has improved the traffic performance in a first step. By the additional use of the adaptive signal control system MOTION another significant improvement in traffic performance could be achieved. Speaking in rough figures, the traffic flow performance could be improved by 30 percent. Nevertheless, further developments are required to meet the expectation by city engineers and by road users. Especially switching between optimized signal plans which is an essential feature of the system MOTION must be improved.

1 INTRODUCTION

Methods of urban traffic control by traffic signals can be classified into three basic systems:

- Traditional pre-timed signal control: here the signals are switched according to a fixed plan with constant cycle time. Different plans can be selected according to the current traffic situation. This is a solution which still has its attractiveness since it performs quite well for coordination of signals at a sequence of intersections along an arterial. The application of this technique in Germany is usually combined with rather flexible controllers which allow switching of each individual signal at each second independently from the other signals.

- Traffic actuated control – rule based (Rule Based Traffic Actuation, RBTA): Here the changing of signal indication is controlled by a computer based on “if-then”-rules which react on inputs from loop detectors. E.g. a green-time extension may be provided as long as the headways between vehicles remain below a threshold value (e.g. 3 sec) up to a maximum green. These rather complex “if-then”-rules are usually developed for each case of application. These individual algorithms, in practice, are difficult to be modified. In any case they do not lead to a mathematical kind of optimization. Instead they are primarily a pragmatic approach depending on the experience of the programmer. This type of traffic actuation has been widely used in Germany especially in context with public transit (trams and busses) priority. In case of network-wide coordination of traffic signals the RBTA-techniques are usually superimposed to a basic pretimed signal concept. The concepts for this provide a rather large variability of sophistication.
- Adaptive control – model based (Adaptive Signal Control Technique, ASCT): This kind of technique tries to optimize traffic flow performance on the background of mathematical models of traffic flow on urban street networks.

The use of traffic actuated signal control (both RBTA and ASCT) focuses on a flexible reaction to the variability and unpredictability of traffic demand on arterial systems. The responsible agencies, thus, try to introduce an automatic reaction on regularly changing demand (daily or weekly patterns of traffic demand) as well as on unexpected traffic demand due to holidays, specific events, and also to road closures by road work or accidents.

Objectives of adaptive Signal control may be:
- Reduce travel times and improve travel time reliability; thus: generate economic benefits, especially to commercial vehicles
- Reduce the amount of stops
- Reduce control-based delays for public transit vehicles to near zero.
- Reduce fuel consumption and emissions.
- Improve road user’s satisfaction with urban transportation policy.

There seems to be a significant cultural difference between the Anglo-American hemisphere and German practice regarding ASCT. The American practice has been well documented by a recent NCHRP-Synthesis report (1). In the Anglo-American countries the two systems SCOOT (Split cycle offset optimization technique; British origin) and SCATS (Sydney Coordinated Adaptive Traffic System; Australia) dominate the market. They are, however, more or less totally unknown in Germany.

In Germany two systems for ASCT are offered:
- Motion (Siemens)
- Balance (GEVAS)

The general functionalities of MOTION are explained by Mück (2, 3, 4, 5). Details about the ASCT-systems usually are not accessible to the public. They are treated as industrial secrets by the vendors to secure the competitiveness of their products like with many other commercially developed systems. Because these systems react on the traffic situation it is not possible to predict the exact effect of MOTION. Therefore, the consumers, i.e. the city administrations, have problems to understand if the ASCT-system is delivering the desired results in advance to installing the systems.

The system MOTION, which plays the major rule in this paper seems to have a structure like this: The system generates a framework for signal timing after a period of Δt minutes where usually Δt = 15 min. This plan constitutes some kind of mathematical optimization of a fixed-time signalization based on traffic flow measurements during the previous time interval. Here, also an algorithm is integrated which is able to estimate traffic volumes also from detectors situated close to the stop lines. Local RBTA elements are then superimposed on this framework, here especially bus prioritization.

This paper describes research on a complex new ASCT-system in the city of Muenster. This project was of key importance for the development of ASCT in Germany since many other cities focused on the outcome of this project before they made their own decisions. Due to the rather significant success, this project paved the way for further distribution of ASCT in Germany. A detailed research report (in German) can be downloaded from the City of Muenster’s server (6). Application of the system, however, made clear that further improvements are required.
2 TRAFFIC CONTROL SYSTEMS IN THE CITY OF MÜENSTER

Münster is a regional center in the north-west of Germany with 285000 inhabitants. The network of urban streets is controlled by 254 traffic signals. The system as it existed around 2005 was based of concepts from the 1980ies. It could not longer satisfy current demands. Therefore, after 2005 concepts for improved traffic control have been started. Here, among other aspects, the complete hardware was considered to be replaced to incorporate modern computer technology and current traffic control methodologies which should be embedded into a city-wide traffic management system.

The first step was the installation of a modern central computer to control the whole network of urban streets. According to financial resources and to get experiences with timely control techniques the renovation of the hardware was first concentrated on one radial arterial, the “Albersloher Weg”. After the successful implementation of modern control devices, the experiences should be applied to improve the signal control also in the other parts of the town.

The target was to apply the most up-to-date technology, i.e. ASCT. The city officials, however, were disaffected just to rely on the vendor’s information before ordering a new system. Therefore, together with renovating the signal system the city contracted the Ruhr-University Bochum as an independent research institute to evaluate the benefits of the new system. The purpose was to identify, to which extend the new ASCT would better perform relative to the former signals on one side and to a conventional traffic actuated (RBTA) control system.

3 SITE

“Albersloher Weg” is one of the major arterials of the town. It is a radial street connecting the southern suburbs to the city center over a distance of 6 km. There is only little direct access from the adjacent development to the arterial street. Two thirds of the arterial are 4-laned (2 lanes for each direction, mostly with a central median). The rest is more like a 2-lane road. For right-turn and left-turn movements there are separate lanes. In the center section, this arterial has an interchange to the ring-expressway (B 51) of Muenster. Overall 24 intersections are controlled by traffic signals. At the starting point these signals constituted a mix of pretimed and traffic actuated control originating from several generations of former signalization technique. All intersections provide signals for pedestrians at each approach. Since Muenster is the “capital of cycling” in Germany, special attention had to be paid to cyclists which usually are guided on separate paths.

Most parts of the arterial are not operating at full capacity. Also in the peak hours no longer queues are observed at most points – neither on the main nor on the side street approaches. Only the final intersection at the northern end suffers remarkable queues, especially in the morning peak.

The street in its total length is also used by transit busses. One of the major purposes of restructuring signal control was to provide priority at signals for busses.

Other important aspects were:

- The system should offer a high quality of signal coordination along the whole arterial. This is a major expectation by road users. Failure in coordination usually causes many public complaints which are to be avoided in favor of city government’s reputation.

- To improve traffic safety a new philosophy for pedestrian and cycle signalization was applied, i.e. protected left turns plus pedestrian green indicated only when all visible signals along one sequence of crosswalks can be green simultaneously, particularly for pairs of crosswalks across one arm of intersection interrupted by a median.
4 METHODOLOGY

4.1 Structure of the experiment

The test of the signal system was performed in 3 steps as mentioned in Table 1. For the purpose of comparison, in the initial stage, the existing signal control was evaluated regarding traffic performance. This situation constituted a mix of pretimed and traffic actuated signals originating from several generations of former signalization techniques.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Method of control</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Original stage of signal control; partly pre-timed; partly traffic actuated</td>
<td>BEFORE</td>
</tr>
<tr>
<td>1</td>
<td>Conventional; i.e. with pre-timed coordination supplemented by rule-based traffic actuation</td>
<td>AFTER-I</td>
</tr>
<tr>
<td>2</td>
<td>ASCT by MOTION</td>
<td>AFTER-II</td>
</tr>
</tbody>
</table>

In the first stage of renewal the whole signal control hardware was rebuilt. As the control strategy a combination of pre-timed signalization together with RBTA was implemented. The pre-timing included a time-framework for coordination which was modified by local RBTA. This kind of control included e.g. green time modification or exchange of sequence of phasing (ESP). The RBTA included also rules for prioritization of busses with the target to bring their signal-induced delays down close to zero. This was mainly based on ESP, but also on green time extension.
In the second stage the control strategy was the ASCT-system MOTION. The version which was applied was developed especially to fit the needs of the project in Muenster and became the basis for the further development of MOTION.

<table>
<thead>
<tr>
<th>LOS</th>
<th>definition acc. to HBS 2001 (6): Percent of not-stopped vehicles</th>
<th>definition acc. to Brilon, Schnabel (7): travel speed with a speed limit of 50 km/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>( \geq 95 )</td>
<td>( \geq 40 )</td>
</tr>
<tr>
<td>B</td>
<td>( \geq 85 )</td>
<td>( \geq 30 )</td>
</tr>
<tr>
<td>C</td>
<td>( \geq 75 )</td>
<td>( \geq 25 )</td>
</tr>
<tr>
<td>D</td>
<td>( \geq 65 )</td>
<td>( \geq 20 )</td>
</tr>
<tr>
<td>E</td>
<td>( \geq 50 )</td>
<td>( \geq 15 )</td>
</tr>
<tr>
<td>F</td>
<td>(&lt; 50 )</td>
<td>(&lt; 15 )</td>
</tr>
<tr>
<td>%</td>
<td></td>
<td>km/h</td>
</tr>
</tbody>
</table>

4.2 Measurement of traffic performance

Measurements were based on probe vehicle tracing. For the experiment 10 passenger cars were operated on the test arterial. These cars were following five different routes, i.e. also important turning movements from and into the main street were under observation. These routes were kept constant throughout the experiment. The cars were distributed over several sizes of cars starting from very small passenger cars over powerful sedans up to a van. Drivers were students and employees of the research institute who were advised to obey the traffic rules and to apply a driving style comparable to the average of other vehicles on the street. At the terminal points of their trips, they had to be stopped for a varying period (1 to 2 minutes) to ensure that they would not always start in a specific stage of signalization. Overall, nearly 1600 probe vehicle trips were performed over a total distance of 1800 km.

Measurements were performed during the morning and afternoon peak hours (7 – 9 a.m. and 4 – 6 p.m.) on weekdays (Tuesday through Thursday). Timing of the measurements made sure that not special events nor work zones were scheduled during these times.

Each probe vehicle was equipped with a front-side video camera which recorded the traffic situation together with a precise time stamp continuously while driving. The videos were later used to clarify reasons for unexpected data and to estimate traffic volumes. The kernel of the measurement equipment was a GPS receiver on top of each car. The GPS-data were recorded on a computer which was also part of the equipment.

The Albersloher Weg is used by 3 public bus lines, where two lines are travelling through the whole section with several stops along the arterial. The control system of the bus operator was able to record the position of each bus continuously. These data were used to analyse bus operation during measurement periods.

Pedestrians and cyclist were analysed by specific observations at some intersections. Information was noted manually. Only crosswalks across the main street were observed, not crosswalks parallel
to the arterial. Here duration of delay was noted at the initial crosswalk. If there occurred further delays at the median these were not observed. This kind of measurement was marked to be improved for next time measurements.

Results from different measurement campaigns could only be compared if they occurred under comparable traffic volumes. Thus, also a rough registration of traffic volumes had to be combined with the measurements. This was based to the larger part on the technique of floating car estimation of traffic volumes which goes back to Wardrop, Charlesworth (7) and has been improved by Leutzbach (8). In addition the city administration used automatic devices to count traffic volumes at one intersection in the middle of the test site. The results showed that the traffic volumes were nearly identical during all of the periods of analysis. If there was a change, then this indicated a slight increase of traffic demand over time. This means: If analysis showed an improvement of traffic flow performance, then this was not induced by reduced street usage.

### 4.3 Performance index

Traffic flow performance on urban arterials under coordinated signal control can be evaluated by different methods:

- The German HCM (HBS 2001, (9)) evaluates the quality of signal coordination by the percentage of vehicles not being stopped by traffic signals (see TABLE 2)
- Brilon, Schnabel (10) proposed a scale for LOS of urban streets depending on travel speed over longer sections of urban arterials (see TABLE 2).
- Performance index PI

The first two methods can only evaluate traffic performance along the coordinated direction. Traffic quality on the side streets is neglected.

For this study the idea of the performance index PI, which was first described by Robertson (11) and which is embedded into the British software tools TRANSYT and SCOOT, has been applied. PI is defined as

\[
PI = \left( G_w \cdot \sum_i \sum_z (W_{i,z} \cdot Q_{i,z} \cdot g_i \cdot g_z) + G_h \cdot \sum_i \sum_z (H_{i,z} \cdot Q_{i,z} \cdot g_i \cdot g_z) \right)
\]

(1)

where:

- \(PI\) = performance index [-]
- \(G_w\) = weight for delays [-]
- \(G_h\) = weight for stops [-]
- \(g_i\) = weight of street link i [-]
- \(g_z\) = weight for vehicles of kind z [-]
- \(W_{i,z}\) = average delay for vehicles of kind z on link i [sec]
- \(H_{i,z}\) = average number of stops for vehicles of kind z on link i [-]
- \(Q_{i,z}\) = traffic volume for vehicles of kind z on link i [veh/h]

For the analysis described in this paper the delays of probe vehicles on each link (= real travel time from the upstream stop line to the stop line under consideration minus travel time under allowed speed) were used to calculate the average delays. The average number of stops was obtained from the number of all stops for probe vehicles (stop = speed below 2 km/h) on the link divided by the number of probe vehicle trips through the link.
PI is a weighted average for delays and stops. The absolute value is not of too much meaning. PI gains only importance if two different solutions for coordinated traffic control are compared. Then the lower value denotes the better solution. For an improved comparability a relative PI was defined:

\[
PI_R = \frac{\sum_i \sum_z PI}{Q_i \cdot g_z} 
\]

(2)

This variable \(PI_R\) relates the sum of delays and stops to the number of vehicles which are affected by delays and stops. This relative PI, later on, was treated as the most important indicator of traffic performance.

For the weights in eq. 1 it is usual to relate them to fuel consumption which leads to an equivalent of 60 sec delay to 1 stop. As kind of road users \(z\) in this study mainly passenger cars (the probe vehicles) and busses are of interest. Relative weighting between these vehicles was made according to the estimated number of passengers (1.2 Pers./car). For busses the average number of passengers was provided by the bus operator with a distinction by travel direction (inbound and outbound; e.g. 75 pax/bus for morning inbound) and time. Also pedestrians and cyclists (as observed at one intersection) were included as road users by a specific class \(z\), each with a weight of \(g_z = 1\). All street links were treated as equally important (i.e. \(g_i = 1\)).

The numbers of stops as well as the delays, suffered by the probe vehicles, were evaluated from the GPS recordings. Corresponding variables for transit busses were evaluated from the central computer of the bus companies.

5 RESULTS OF MEASUREMENTS

5.1 Effects for private traffic

The analysis of data revealed quite a large variety of results. Here only the most significant aspects are treated. FIGURE 2 and FIGURE 3 show graphical comparisons for the average delay and the average number of stops in the AFTER-periods compared to the BEFORE-situation. Each point in the diagram represents the average for one intersection approach along the arterial.

FIGURE 2 shows no significant effect in the transition from BEFORE to AFTER-I. However, the transition from BEFORE to AFTER-II (FIGURE 3) shows that a majority of data points is located below the diagonal indicating both a reduction of delays and stops by the ASTC-system. AFTER-II was also better then AFTER-I which means that the ASTC performed better than the conventional RBTA-method. This can be treated as a first indication of benefits obtained from the application of the ASTC-system MOTION. These results are also represented in TABLE 3. Here the average delay and average number of stops of the probe vehicles at each stop line along the whole arterial have been evaluated. These averages have been added over all stop lines along the arterial to get the \(\mu\)-values in TABLE 1. In a similar way the standard deviations \(\sigma\) (variability between probe vehicles regarding delays and no. of stops on the whole length of the arterial) have been estimated.

We see that in both steps of development an improvement of traffic quality could be achieved. In the AFTER-I period, however, for the northbound direction also a deterioration was observed. For the AFTER-II period all indicators turned into positive values; i.e. a reduction of delays and of number of stops could be detected in each case. The reduction of delays by the ASTC averaged up to more then 40 % which indicates quite a substantial improvement of traffic quality.

Similar improvements were also observed when different routes of the probe vehicles were analysed.
FIGURE 2  Comparisons of the average delays (left) and of the average number of stops (right side) between BEFORE and AFTER I

FIGURE 3  Comparisons of the average delay (left) and of the number of stops (right side) between BEFORE and AFTER II

FIGURE 4  Standard deviation of travel times for probe vehicles as a comparison between “BEFORE”, “AFTER-I”, and “AFTER-II”. 
TABLE 3 Differences for the sum of all delays and the total number of stops in the coordinated direction for a trip through the whole length of the Albersloher Weg (averages for each measurement campaign).

<table>
<thead>
<tr>
<th>direction</th>
<th>time</th>
<th># of stops [-]</th>
<th>delays [s]</th>
<th># of stops [-]</th>
<th>delays [s]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>μ</td>
<td>σ</td>
<td>μ</td>
<td>σ</td>
</tr>
<tr>
<td>South</td>
<td>7:00-9:00</td>
<td>6.2</td>
<td>2</td>
<td>5.4</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>281</td>
<td>66</td>
<td>206</td>
<td>71.5</td>
</tr>
<tr>
<td></td>
<td>16:00-18:00</td>
<td>9.5</td>
<td>2.5</td>
<td>6.2</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>405</td>
<td>89</td>
<td>264</td>
<td>87.5</td>
</tr>
<tr>
<td>North</td>
<td>7:00-9:00</td>
<td>6.1</td>
<td>2.3</td>
<td>7</td>
<td>3.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>296</td>
<td>86</td>
<td>301</td>
<td>104</td>
</tr>
<tr>
<td></td>
<td>16:00-18:00</td>
<td>5</td>
<td>2.1</td>
<td>5.6</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>255</td>
<td>90</td>
<td>242</td>
<td>82.6</td>
</tr>
</tbody>
</table>

The same effect is also illustrated in FIGURE 5. Here we see the sequence of travel times of the probe vehicles in the afternoon periods of all measurements in the order of their departure time. We see rather constant travel times in the order of 8 to 10 minutes for the ASTC conditions (AFTER-II) whereas the travel times in the BEFORE-period as well as in the AFTER-I-period are higher and they show a larger variability.

FIGURE 5 Travel time of probe vehicles for traffic departing from the city centre to the south in the afternoon period as a comparison between “BEFORE”, “AFTER-I”, and “AFTER-II”.
5.2 Consequences for transit busses
Transit busses had a remarkable benefit from the improved signal control. They could reduce their travel time by 3 – 4 minutes (TABLE 4). What was even more important is, that the reliability of operation was rather improved which can be obtained from the sharp reduction in deviations from the schedule. These effects are mainly due to a qualified prioritisation of busses at signals by RBTA techniques which were already implemented in the AFTER-I-period. ASCT could only contribute further minor improvements.

TABLE 4 Results for transit busses: averages for each measurement campaign.

<table>
<thead>
<tr>
<th>Time Averages for</th>
<th>7:00-9:00 a.m.</th>
<th>4:00-6:00 p.m.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Travel time t [min]</td>
<td>Deviation from schedule [s]</td>
</tr>
<tr>
<td>Northbound</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BEFORE</td>
<td>15,0</td>
<td>291</td>
</tr>
<tr>
<td>AFTER-I</td>
<td>11,6</td>
<td>85</td>
</tr>
<tr>
<td>AFTER-II</td>
<td>11,1</td>
<td>58</td>
</tr>
<tr>
<td>Southbound</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BEFORE</td>
<td>13,8</td>
<td>196</td>
</tr>
<tr>
<td>AFTER-I</td>
<td>10,6</td>
<td>2</td>
</tr>
<tr>
<td>AFTER-II</td>
<td>10,8</td>
<td>19</td>
</tr>
</tbody>
</table>

5.3 Performance Index Evaluation
For the probe vehicle operation (plus busses) also performance indices \( P_l \) (see eq. 2) were evaluated. Results are given in TABLE 5. Here it should again be emphasized that a low value indicates better performance. As one remark it should also be mentioned that the Albersloher Weg, in a section of 600 m length has received a substantial structural improvement by widening the street during the time of the experiment. This section has been omitted from the PI-evaluation to avoid bias due to these improvements of the street layout. If these aspects would be neglected then the positive effects would be even larger.

From TABLE 5 we see that the performance of traffic along the arterial has been improved to some degree already in the AFTER-I-period. The \( P_l \) was reduced by 13 % in the afternoon whereas a slight increase (3 %) was obtained in the morning. This means that the RBTA control could only slightly improve traffic operation over the length of the whole arterial, which was quite a disappointment because the renewal of the signal system consumed quite a significant amount of funds. The ASCT, however, initiated a further significant improvement up to 37 % (compared to the BEFORE-period). This is a strong indication for the high performance of the ASCT by MOTION.

There was, however, also one negative result: the cyclists and pedestrians crossing the arterial suffered slightly longer delays both in the AFTER I and AFTER II period. This was a consequence of the
modified safety philosophy for pedestrian control, which did not longer allow different signals at crosswalks in one sequence (green was only allowed when all signals controlling crosswalks at one approach could display the green signal). This principle was not applied in the before period, which had enabled longer green times for non-motorized traffic. This partial result, however, did not show the whole picture since pedestrian delay on the central median was not taken into account by the city who did these observations.

### TABLE 5 Performance Index $P_{18}$ compared between different measurement periods

<table>
<thead>
<tr>
<th>Type of vehicle</th>
<th>BEFORE [-]</th>
<th>AFTER-I [-]</th>
<th>Diff - %</th>
<th>AFTER-II [-]</th>
<th>Diff - %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pass. car</td>
<td>27</td>
<td>30</td>
<td>11</td>
<td>20</td>
<td>-26</td>
</tr>
<tr>
<td>Public transit</td>
<td>49</td>
<td>33</td>
<td>-33</td>
<td>32</td>
<td>-35</td>
</tr>
<tr>
<td>pedestrians</td>
<td>20</td>
<td>32</td>
<td>60</td>
<td>31</td>
<td>55</td>
</tr>
<tr>
<td>cyclists</td>
<td>22</td>
<td>30</td>
<td>36</td>
<td>31</td>
<td>41</td>
</tr>
<tr>
<td>total</td>
<td>29</td>
<td>30</td>
<td>3</td>
<td>21</td>
<td>-28</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of vehicle</th>
<th>BEFORE [-]</th>
<th>AFTER-I [-]</th>
<th>Diff - %</th>
<th>AFTER-II [-]</th>
<th>Diff - %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pass. car</td>
<td>30</td>
<td>28</td>
<td>-7</td>
<td>21</td>
<td>-30</td>
</tr>
<tr>
<td>Public transit</td>
<td>48</td>
<td>22</td>
<td>-54</td>
<td>28</td>
<td>-42</td>
</tr>
<tr>
<td>pedestrians</td>
<td>27</td>
<td>34</td>
<td>26</td>
<td>37</td>
<td>37</td>
</tr>
<tr>
<td>cyclists</td>
<td>25</td>
<td>32</td>
<td>28</td>
<td>33</td>
<td>32</td>
</tr>
<tr>
<td>total</td>
<td>31</td>
<td>27</td>
<td>-13</td>
<td>22</td>
<td>-29</td>
</tr>
</tbody>
</table>

6 ADDITIONAL ASPECTS

Even if the message of the project is quite positive, there are also some critical aspects. The first point was that it took quite a while to taylor the system according to the specific needs in the city of Muenster. As the ASCT is a closed system, all improvements have to be installed by the vendor and it is not possible to commission another service provider. That means that the customer depends on one specific service provider.

Another problem of the ASCT arises in connection with the switching of framework programs as it is initiated by the control system every 15 minutes. The way how this is performed, leads to short periods of temporary stand-still at some intersections and to the consequence of unsatisfactory coordination at these times. Since the total travel time is nearly as large as the actuation period of 15 min, many drivers have the chance to experience switching of framework plans. This is a reason why several complaints by the public arrived at the city offices causing not a too good reputation for this kind of signal control. Furthermore after the measurements described in this paper some intersections and their local control systems were redesigned and even speed limits were changed.
These modifications led to a reduction of overall traffic quality. As a consequence the ASCT was switched off by the city and now the stage-I solution (cf. Table 1) is in operation. Thus there is a strong need to adjust the ASCT-system to these new conditions and to solve the switching problem by an improved algorithm for switching the system from one to the successive optimized signal plan.

Meanwhile one further arterial in Muenster has been equipped with the ASCT-system. Here the problem of switching signals became even worse due to technical problems in the controllers of a second vendor. The deterioration was also a consequence of more heavy traffic demand (compared to the Albersloher Weg) combined with a rather close separation of the important intersections. Unfortunately, detailed results from this experiment cannot be included into the same report due to different project contractors.

These further experiences do, however, underline that good results applying ASCT can only be achieved by careful planning. Here also micro-simulation turned out to be rather helpful. This, however, is problematic since the algorithms of the ASCT are not open to public. Thus, neither the consumer (city offices) nor independent consultants are able to simulate ASCT without assistance by the vendor. In any case one consequence of these experiences is that an independent consultant for traffic performance monitoring is rather important to guarantee useful results implementing ASCT.

7 CONCLUSION

In the city of Muenster/Germany the stepwise implementation of adaptive signal control at a 6 km long arterial was accompanied by an independent research institute. Empirical studies based on probe car analysis were performed to evaluate the effects of the new control technique. In conjunction the operation of transit busses was captured from transit control system data.

Overall the introduction of the MOTION-system revealed an unexpectedly large positive effect. The overall traffic quality, indicated by the performance index PL, was improved by around 30%. Especially the transit busses benefitted from prioritization at signals. Thus, from the point of view of traffic flow performance the introduction of ASCT was a success. It is also expected that positive effects extend to ecological aspects. However, to make the system even more acceptable to the road users the problems arising with switching of optimized signal timing plans should be solved in the near future.

Further realisations in conjunction with research projects revealed that the positive effects will not be attained automatically by ASCT. It is required that each project is evaluated separately. Especially, assistance by an independent consultant is recommended together with the implementation of ASCT.

Moreover, it would be desirable that ASCT systems and their algorithms should be open to the public to enable customers, like city administrations, to comprehend the effects of systems which they acquire.

8 REFERENCES


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