Evaluation of a Traffic Signal Coordination for Bicycles in a Mixed Motor Vehicle and Public Transport Urban Network

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Introduction

Present-day traffic signal control strategies mainly consider the operational needs of motor vehicle and public transport traffic. However, as the share of bicycle traffic increases, city authorities are making efforts to consider bicycle traffic in the development of traffic control strategies. In cities such as Copenhagen [1], Amsterdam [2], Rotterdam [3], Vienna [4] and Bern [5], the signal coordination has been adapted to the needs of bicycle traffic. However, such measures might have negative effects on the operation and traffic efficiency of other transport modes. Especially public transport operation along a corridor can be negatively affected by the application of a bicycle signal coordination due to the reduction of the progression speed of the new signal coordination, which can increase the number of stops and the waiting time at signalised intersections. Waiting time at signalized intersections comprises a large portion of public transport travel time in urban areas, especially in city centres, and is the main reason for degradation of public transport service [6]. For this reason, city authorities often implement various traffic control strategies to support and improve the public transport operation. Public transport prioritization at traffic signals is often implemented and can decrease passenger travel time and improve its reliability and attractiveness at a lower cost [7]–[11]. However, it is unclear what effects a bicycle coordination can have on the performance of public transport prioritization as well as how public transport prioritization limits the effectiveness of a signal coordination designed for bicycle traffic.

In this context, the City of Munich carried out a pilot study to assess the operation of a traffic signal coordination for bicycle traffic combined with public transport prioritization along an urban corridor in a district in the centre of Munich. The new signal coordination is deployed at five consecutive signalised intersections along Schellingstraße, Munich. Before the deployment of the new signal coordination, a motorized traffic signal coordination with public transport prioritization at all signalized intersections was in operation. The goal of the coordinated traffic signalisation is to decrease the travel time and number of stops of bicyclists and to increase the overall attractiveness and comfort of bicycling. The new signal coordination has the potential to increase traffic efficiency for bicyclists, through the design of a new traffic signal coordination with a progression speed of 20 km/h. At the same time, the traffic situation for other road users may be altered due to the adjustment of the traffic control plan to cater to the requirements of bicycle traffic. The main objective of this paper is to examine the effects of the new coordination strategy on bicycle traffic as well as on the motor vehicle traffic and on public transport operation.

Related Research

In cities with high bicycle traffic share such as Copenhagen [1], Amsterdam [2], Rotterdam [3], Vienna [4] and Bern [5], the signal coordination has been adapted to the needs of bicycle traffic. One of the biggest challenges in designing a signal coordination for bicyclists is the strong deviation in the bicyclist velocity profiles which result in not every bicyclist being able to comply with the design speed of the signal coordination. Differences of up to 10 km/h between the average rates of progression for different bicycle user groups were measured in [4]. Bicyclist progression speeds between 15 and 22 km/h were measured at four intersections in Munich.

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[12]. For this reason, several applications and solutions have been developed to assist bicycle traffic at signalised intersections either through the prioritization of bicyclists at the signalised approach [13] or through communicating the signal state to the bicyclist [14], [15]. However, such solutions require additional investment for new infrastructure and might not be applicable in the case where bicycle traffic is not routed on dedicated bicycle infrastructure. Also, the effectiveness of solutions relying on smartphone applications are more elaborate but are linked to the penetration rate in the bicyclist population. The adaptation of the signal coordination to the needs of bicycle traffic remains the most easily applicable, simple and cost-effective solution.

Study Area

A 1.9 km section of the Schellingstraße corridor in Maxvorstadt, Munich is selected for the pilot study. The section is comprised of five signalized intersections with one narrow traffic lane in each direction of travel. Schellingstraße does not have any bicycle specific infrastructure, yet it is an important corridor for bicycle traffic accessing two universities in the area as well as the Englischer Garten, a large park. At the same time, two bus lines operate along Schellingstraße, each with a 10-minute headway in both directions of travel. Two tramlines operate along Barer Straße, a road that crosses Schellingstraße, each with a 10-minute headway in both directions of travel. Public transport vehicles are prioritized locally at each intersection with an advanced request prioritization system. Specifically, all the intersections are controlled with a fixed time signal plan. Upon arrival at an intersection approach the public transport vehicle requests for priority to cross the intersection without stopping. The traffic signal controller at the intersection switches to or extends the green time for the public transport vehicle, while retaining the same cycle time as in coordination mode.

Methodology

The evaluation of the traffic efficiency of the signal control strategy for bicycle traffic is based on specific traffic efficiency indicators. Because the progression speed is adjusted to bicycle traffic, it is important to determine the number of stops for bicycle at each intersection approach. According to the RiLSA [16], the number of stops along road sections with coordinated intersections is the decisive indicator for assessing the quality of the signal coordination. By reducing the number of stops, the convenience and comfort for bicyclists using the corridor is increased. In addition, the travel times for bicyclists may be reduced through the reduction of the waiting times and stops at traffic lights. Also, it is important to consider the effects on public transport operation. As public transport is prioritized along the route, it is important to assess the effect the new signal coordination will have on public transport operation. At the same time, the prioritization of public transport vehicles will be disrupting the normal operation of signal
coordination along the route. Thus, it is important to assess the effect of this disruption on bicycle and motor vehicle traffic. The following scenarios are tested on three different days:

- Study case 0 MTC + PTP: Signal coordination for motorized traffic (MTC) with public transport prioritization (PTP) (22. June 2017) (Base Scenario)
- Study case 1 BTC + PTP: Signal coordination for bicycle traffic (BTC) with public transport prioritization (PTP) (20. June 2017)
- Study case 2 BTC: Signal coordination for bicycle traffic (BTC) without public transport prioritization (PTP) (27. June 2017)

The corresponding traffic control strategy is deployed on these dates during the morning peak hour (8:00-10:00) and the afternoon peak hour (15:00-19:00). The distance between different intersections ranges from 174 to 217 meters. Due to the almost equivalent distribution of distances between most intersections and at the same time progression speed and signal cycle times corresponding with these distances, the signal coordination may operate efficiently in both travel directions (Figure 1). The signal coordination is however optimized for the travel direction east to west. The necessary traffic data for the motorized traffic are collected using six mobile ANPR (Automatic Number Plate Recognition) cameras positioned at the start, middle and end of the study road section in order to capture all incoming motorized traffic. The bicycle traffic data are collected by study participants, who rode with their bicycles along the test section during the afternoon test periods using tracking smartphone applications. A similar methodology has also been implemented in [13].

**Results**

The results for the motorized traffic, public transport operation and bicycle traffic with respect to the measured travel time and number of stops for bicycle traffic are depicted in the following figures:

![Figure 2: Results of the field studies for the bicycle traffic](image1)

![Figure 3: Results of the field studies for the motor vehicle traffic and public transport](image2)
For the bicycle traffic there is an overall reduction in both average travel times and average number of stops per study participant through the implementation of the new coordination. In comparison to the base scenario, the travel time is reduced in total by -14% in BTC + PTP (-19% for the optimized and -9% for the not optimized travel direction) and by -27% in BTC (-30% for the optimized and -25% for the not optimized travel direction). At the same time, the average number of stops per bicyclist is reduced by -48% for BTC + PTP and by -72% for BTC along the entire network. The highest reduction is observed in the optimized travel direction (-57% in BTC + PTP and -81% in BTC). The results for the bicycle traffic show that both examined control strategies improve the traffic efficiency for bicycle traffic. However, the disruption of the coordination due to public transport prioritization limits the improvement of the selected traffic indicators for BTC + PTP.

For the motorized traffic, reductions in the average travel time are also observed. The travel time is reduced by -11% for BTC + PTP and by -14% for BTC. The travel time reductions were observed in both directions of travel. Again, as with bicycle traffic, results improve for no public transport prioritization indicating that the disruption of the coordination due to public transport operation result in longer waiting times. The improved results for motor vehicle traffic can also be attributed to the high bicycle volumes travelling along the corridor which reduced the speed of motor vehicles. Under mixed traffic conditions, motor vehicles were observed during the field studies to drive with comparable speeds to the bicyclists as overtaking was difficult due the dense traffic.

For the public transport operation, results suggest a slight overall increase of 0.8% for BTC + PTP and an increase of 17% for the BTC for the average travel time in both directions of travel. Thus, public transport performs slightly better in the MTC + PTP study case. However, it is important to assess the results of the analysis in order to determine if the differences among different study cases are statistically significant.

To evaluate the statistical significance of the differences between the study cases, the Tukey-Kramer Test [17], [18] is used. The assessment of the statistical significance suggests that the reductions in travel times for bicycle traffic in the entire network are statistically significant; the reduction in average travel time for the private vehicle traffic is statistically significant for BTC in both directions of travel and for BTC + PTP only in the not optimized direction of travel. For the public transport traffic, the change in travel time is assessed as statistically insignificant in BTC + PTP and statistically significant in BTC for the not optimized travel direction.

**Conclusion and Future Work**

The evaluation results show that the most optimal traffic control strategy from the ones tested for all road user groups is BTC + PTP, as the travel times for public transport vehicles significantly deteriorate in the case of BTC. The scenario BTC + PTP was found to significantly reduce travel times for both private motor vehicles and bicycle traffic. BTC further improved the traffic efficiency indicators for motor vehicle traffic and bicycle traffic in comparison to BTC + PTP. Thus, the disruption of the coordination due to public transport operation limits the improvements on traffic efficiency for bicycle traffic and motor vehicle traffic through the operation of the bicycle friendly coordination. Yet BTC + PTP improved the traffic indicators for motor vehicle traffic and bicycle traffic while conserving the same traffic efficiency for public transport operation. This highlights the importance of the consideration of public transport operation along urban corridors, where signal coordination for bicycle traffic is implemented. Additionally, results show that a combination of public transport control strategies along a coordination for bicycle traffic can potentially improve traffic efficiency for all road users. However, the results cannot be easily generalized, as in the study road network factors, such as the equivalent distances between intersections and the bicycles forcing motor traffic into lower speeds as a result of the narrow traffic lanes, contribute to the improved efficiency for the
bicycle traffic signal coordination. Finally, the development of a traffic control algorithm that considers the current traffic state of bicycle and public transport traffic along the network and conditionally prioritizes public transport vehicles and adapts the signal coordination on the current traffic state has the potential to further optimize the traffic quality for bicycle traffic.

References


