Abstract Master-Thesis

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Topic: Optimisation of traffic signal control considering pedestrian flows

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Traffic signals are used to control the multimodal transport, particularly in urban areas. The goal of an optimal signal control is the adaption to the traffic conditions for minimizing adverse effects, such as long delays. However, only the delay of motorized vehicles is included in the optimisation mainly. In the majority of cases, a multimodal approach to address the needs of all road users is missing. Accordingly, this master thesis deals with the development of an optimisation method in consideration of pedestrian traffic. A distinction is made between the offline optimisation based on fixed values and the online optimisation as an adaptation to current data.

The control of traffic lights can be divided into several methods. The simplest form is the fixed time program, which consists of immutable parameters and is a stationary method. Unsteady methods offer the opportunity to respond to current traffic situations. A first adjustment is possible by selecting a signal program based on the current flow of traffic or an operating schedule. Using the signal program modification, the green traffic light duration or the phase sequence can be adapted to the traffic conditions. Apart from a few safety aspects, all elements are mutable if new signal controls are created. The implementation of stationary methods can be done in a rule/ measured based or a model-based / an adaptive way. Rule/ measured based methods run through a flow logic every second with logical and temporal conditions for adapting situational parameters. The quality of the signal control depends on the engineer, who designs it. An optimisation does not take place. Model-based or adaptive control methods work with different models. Traffic models are designed to measure the traffic and to determine additional parameters such as delays. The optimisation model computes the optimal signal program by considering a predetermined objective function as well as the variation of the signal control parameters.

The goal of the offline optimisation is the creation of optimal fixed time programs based on traffic surveys for daytime-dependent signal program selection. The online optimisation can be carried out due to the adaptive control method. The development of this method is the outcome of the selection of a right method for the determination of parameters, as well as the creation of a new objective function and the selection of a suitable optimisation method.

The parameters determining the offline optimisation are done computationally. The HBS (2015)[1] sets up the requirements for calculating the delays of motorized and pedestrian traffic. The input variables consist of the evaluated traffic loads during the peak hours, which has been recorded by a traffic survey. The determination of the parameters, which are used in the online optimisation, is based on models. The travel pattern models describe the current traffic data and its prognosis. Traffic flow models carry out the simulation of traffic flow. Traffic impact models derive traffic-related effects, including delays.

The objective function is, based on the valuation method by Hunter et al. (2011)[2], the average delay of all road users, weighted by the number of participants. In terms of the offline optimisation, these are the respective highest average delay in vehicle traffic and the highest maximum delay in pedestrian traffic, calculated by using the HBS (2015)[1]. Furthermore, various weighting factors, which weigh up the current

delays, are introduced. A consideration between pedestrians and vehicles serves as the basis. Motorized vehicles offer a high comfort and the possibility of individual locomotion with short travel times. High delays lead to increased emissions in form of exhaust fumes and noise. Due to their greater space requirements compared to the limited space, which is provided in the intersection area, congestions are possible within the junction at high delays, which can in turn affect the entire road network. Pedestrian traffic is considered particularly environmentally friendly and the costs for building the infrastructure are low. Pedestrians are, due to their lack of save surroundings, exposed to environmental influences without protection. Although, accidents are relatively rare, injuries are usually far more serious. Pedestrians are particularly vulnerable to high delays, which can result in jaywalking. Taking these attitudes and behaviours into account weighting options are introduced into the offline optimisation. The location factor was added, which takes the characteristics of the surrounding area into account, such as noise-sensitive or vulnerable facilities. The importance of the route is another criterion. This factor integrates the relevance of the junction for all road user groups, such as its connection function. Small available areas, both for the motorized and pedestrian traffic will be considered by the factor of the junction shape. The historical factor, which takes environmental and accident data into the consideration, is also used for weighing the delays. Within the online optimisation two additional factors are introduced. The weather-dependent factor takes the vulnerability of the pedestrian during bad weather into account. Exceedances of emission limit values are to be avoided by weighing the delay of vehicles using the environmentally -dependent factor.

The best possible result under given conditions can be achieved through optimisation. Mathematical considered, it is the optimal solution of a function in the form of a minimum or maximum. A local optimum is limited to a part of the solution space, whereas the global optimum applies to the minimum or maximum of the entire space. The optimisation criterion defines the objective function value, which often involves the minimum delay in the optimisation of traffic signals. The optimisation parameters are used to solve the optimisation problem and in this case include all variable components of the signal program as the phase split and sequence or the green times of the signal groups. The methods for solving optimisation problems can be divided into four groups. The exact methods lead to a safe solution of the problem through a finite number of steps. Examples of this include the full enumeration or analytical methods. Approximation methods only converge to the searched optimum. Statements about the quality of the identified solution can be made. The approximation method produces systematic arbitrary solutions whereby information about the quality of the solution can not be provided. Heuristics are used to find the best possible solution in a short time. This is mainly used in areas where other methods access their limits due to the high computation times, like solving NP-hard problems. A distinction is made between design heuristics for finding a first good solution and the improvement heuristics for further improvements. Metaheuristics are used to systematically overcome local optima. Often used to optimise traffic light controls are population-based heuristics, such as the genetic algorithm. Based on the theory of evolution and heredity by Darwin and Mendel the algorithm differs between a gene, a chromosome and a population. A gene corresponds to a part of the solution, the chromosome to a possible total solution of the optimisation problem and the population to a set of chromosomes. Over several generations new populations of potential solutions are produced by recombination and mutation. Depending on their fitness value, which is determined by the objective function, bad solutions go extinct. The best possible solution is found after achieving the predetermined termination criterion.

Based on these facts, the developed optimisation method is divided into computational or model-like characteristics determination, the determination of the weighting factors and the final optimisation of the objective function in the form of the multimodal total delay using a genetic algorithm. The application and review of the method is based on the offline optimisation of a cross junction in Darmstadt city centre.

The offline optimisation of the case study was divided into several sub-problems. A traffic survey was carried out to collect input variables for the determination of the parameters and the traffic-dependent weighting. The definition of the phase split and number was based on the consideration of qualitative and safety aspects as well as taking the relevant traffic volumes into account. The optimal phase sequence is determined by calculating the critical sums of inter-stage times of different variants. Subsequently the junction was evaluated based on the situation-dependent weight factors. The optimisation was performed using a genetic algorithm of the computer program MATLAB. The variation of the weighting factors showed the following results. A first influence of pedestrian delays within the objective function was found in a 4-fold or 2 -fold weighting of the number of pedestrians. While the maximum pedestrian delay was reduced by several seconds, it barley increased for the motorized traffic. 8 - and 25 –folding the weight in the evening rush hour, carried out a further improvement of pedestrian delays. Due to reaching the minimum phase duration of a single phase, the delays of motorized vehicles of the other flows increased sharply, while further raising the weight on pedestrian delays. With a weighting factor of "38" or "46" the delay of motorized vehicle traffic exceeded the pedestrian delay. The average delay, based on the number of travellers of each group, increased due to the low number of pedestrians constantly.

To verify the developed optimisation method the simulation of the case study was implemented by the microscopic traffic flow model VISSIM. Due to a lack of records to verify the simulated network, only qualitative statements could be made. The simulation was based on the previously determined optimal signal programs, the result of differently weighted objective functions. The results of the simulation corresponded to the optimisation findings. With increasing weight on pedestrian delays, their travel time decreased, while the loss of time of vehicle traffic increased progressively.

By applying the optimisation method and evaluating the junction using the situation-dependent weighting factors, the effects have to be examined precisely. A high weight on pedestrian delays increases the comfort and makes the walking traffic conceivably more attractive. Security risks such as jaywalking or the vulnerability of children can be reduced by shortening the delays. However, low pedestrian waiting times normally increase the delay of vehicle traffic and vice versa. Consequences are high travel time losses and possible congestions into nearby junctions. The increased emissions of exhaust fumes or noise effects the surrounding area and thus also the waiting pedestrians. A first proposal to compensate the loss of comfort of the unprotected pedestrian is a standard weighting of pedestrian delays by the factor of "3". A further influence by the planner is possible by using the situation-dependent weight factors.

Missing traffic participants, such as cyclists and the public transport sector, still have to be included into the optimisation method in following studies. Larger field studies to verify the weight factors and the implementation of this method as an adaptive signal control are the aim of future studies.

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References

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[2] Hunter, B.; Wolfermann, A.; Boltze, M. (2011): Multimodal assessment of signalized intersections considering the number of travellers. In: 90th Annual Meeting of the Transportation Research Board. Washington, D.C.