Future Requirements on Urban Traffic Control Systems

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Abstract: This paper presents some future requirements on urban traffic control systems. These include a clear definition of goals, considering all transportation modes and also impacts beyond the transportation system. Consequently, the optimization of traffic control should consider all road users, and tools for multi-modal assessment and optimization must be improved. Increasing traffic safety must stay as the goal of highest importance. A comprehensive recording and analysis of accidents is necessary. Traffic signals should be integrated in a multi-level hierarchy of signal controllers, and they should contribute to demand management strategies. The problem of aging traffic signals must be solved, and quality management procedures have to be established. Traffic data must be detected area-wide, and interfaces and components of traffic signals must be standardized. Comprehensive guidelines have to be established, and appropriate resources must be provided. Finally, urban traffic control needs good public relations management and an international exchange of experiences.

1. Introduction

In future, our cities will need mobility as they do today. Mobility is a key factor for a good economic development. The quality of life in our cities depends on the opportunities to be mobile, but at the same time it is endangered by the negative impacts of traffic. The need to find a balance between improving the mobility of the citizens and protecting their living environment makes urban traffic control a most important instrument for the future development of our cities.

There are several instruments to control traffic and to influence transport demand, such as land-use control, parking management, road pricing, ramp metering, and others. Among these instruments traffic signals play an outstanding role. They allow a safe and efficient traffic flow at single intersections, on arterials, and in networks. And they can contribute significantly to the demand management, in particular to the prioritization of public transportation vehicles and to the promotion of non-motorized traffic.

In this article, some future requirements on urban traffic control and in particular on traffic signal control are presented. Of course, there are major differences in the state of development between different countries. In some countries the one or other requirement may be fulfilled already.

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2. Twelve Requirements

1) Goals for urban traffic control must be clearly defined, considering all transportation modes and also impacts beyond the transportation system.

While in most cases traffic signals are installed to improve traffic safety and to increase capacity for motorized vehicles, we must be aware that for the operation of urban traffic control systems and traffic signals there are further goals in the area of safety, capacity, environment and economy. We should consider the goals of the road users (requirement no. 2). We should consider the goals of our society in general, e.g. environmental protection, economic welfare, and local impacts of traffic control which may be negative as well as positive. Last but not least, we have to consider the goals of the operator of the urban traffic control system who may focus on an efficient and reliable operation but should also take aspects of user acceptance into account.

The more goals we have the more goal conflicts may arise. Careful integration of all the different aspects in setting up the traffic control scheme is absolutely necessary. Therefore, the overall quality of an urban traffic control system depends very much on a successful conflict management.

2) The optimization of traffic signal control should consider all road users in an appropriate way.

It seems that in many cities traffic signals are designed for car traffic only. But our urban roads have many more users, such as public transportation vehicles, cyclists, and pedestrians. In many countries there are also many different types of motorized vehicles ("mixed traffic flow"), which needs specific consideration. Insufficient consideration of the needs of different user groups may result in severe safety problems or influence modal choice towards the use of private cars. On the other hand, for example, a clear policy of prioritization of public transportation vehicles can contribute significantly to shorter travel times of trams and busses, and thereby to an higher attractiveness and acceptance of this mode.

Despite the capacity problems for motorized traffic which exist in many situations, it must be clear that following only the one goal of increasing capacity for car traffic and neglecting all other goals (see requirement no. 1) may result in negative impacts on modal choice, on the shape of the city, and at the end on its overall attractiveness and development. There are many examples on this topic. Busses joining the queues and congestion on urban roads cannot be more attractive than using the own car. Cycle lengths of 300 s and more cause long waiting times for pedestrians and cannot be compatible with their needs. Too narrow sidewalks at heavily frequented intersections cannot invite people to walk and to shop.

The setting of priorities in each situation should follow a common strategy for a city, which has to be clearly defined. Of course the chosen strategy may vary from city to city, because the situations and the policies are different. It is of importance that in such strategy no absolute priority is given to the one or the other group of road users. Otherwise the disadvantage for other road users may not be appropriate.

For example in the City of Darmstadt (Germany) there is a clear priority ranking with pedestrians and cyclists first, then public transportation vehicles, and at the end car traffic. This strategy could successfully support a modal shift towards public transportation over the years. But the too strict use of this rule may lead to quite unacceptable situations. For example, even in the peak-hour a single pedestrian wishing to cross a major arterial may interrupt the co-ordination in a green wave and cause a lot of delay in car traffic. Although it takes some efforts, we do not need too simple and generalizing rules, but a detailed, integrated consideration of the advantages and disadvantages of measures for the different user groups in each situation.

Another specific user group to be mentioned here are the handicapped persons. A society taking care of her citizens will consider the specific needs of handicapped persons also in signal control. But here many goal conflicts come up, as well. Lowered curbs to allow the use of wheelchairs may cause problems with the rain water drainage. Acoustical signals make it easier for the blind and partially sighted persons to find the crossing and to notice the green period but may cause unacceptable noise for people living around the intersection. Consideration of the lower walking speed of handicapped persons when designing the green period for pedestrians and the following intergreen period decrease the capacity for motorized vehicles. Traffic engineers have to weight the different goals against each other in an appropriate way or to find technical solutions which overcome the goal conflicts.

3) Tools for multi-modal assessment and optimization of control strategies and traffic signal programs must be improved.

Optimization of urban traffic control needs appropriate tools. Those tools available today focus very much on the optimization of car traffic only. Also quite much research is spent on complex mathematical algorithms which provide the perfect solution for motorized vehicles which move in an artificial grid network without any environment, without parking, without pedestrians waiting to cross the road, without public transportation vehicles that should be prioritized. But we need a full consideration of all goals and all road users (compare requirements no. 1 and 2), which makes the optimization procedure very complex and hardly to be solved with a set of linear equations only. New tools have to be developed which may use such mathematical procedures for parts of the solution process, but go much further in supporting the engineers in an open step-by-step optimization process with the assessment of all relevant aspects. Recent efforts in micro-simulation promise quite realistic results and may be extended to consider all road users and environmental effects. But further development of these tools is needed, e.g. for many countries to consider mixed traffic flow without lane discipline.

Future simulation tools may be able to run on-line as well, supporting the on-line optimization, the completion of detected data, the detection of incidents in the network, and the set-up of traffic situation reports.

Another concern according the assessment of urban traffic control is the consideration of the users´ viewpoint. No industrial producer or service operator would optimize his product by technical criteria only, such as traffic engineers mostly do with measures such as average delay or total number of stops in a network. But which urban road authority really thinks of the road users as being their customers? If responsible politicians and traffic engineers like to make the maximum for the citizens with the limited resources, criteria should be used which are more relevant for the road users, e.g. travel time, and the road users´ opinion about the traffic situation should be included. Introducing a management of complains is a valuable but passive solution. In addition, their could be a more active integration of the users´ assessment in the optimization process by questionnaires.

4) Improving traffic safety must stay as the goal of highest importance. As prerequisites to improve traffic safety and to eliminate accident blackspots a comprehensive recording and thorough analysis of accidents has to be conducted.

Unfortunately, in our real world even the efforts to save lives depend on economical restraints. But there is no doubt that traffic safety is of highest importance among the different goals for urban traffic control, today as well as in future. Traffic safety is not only one of the major reasons for the installation of traffic signals but also for further measures to change intersection design and traffic signal programs. For example, there is a clear tendency towards more stages and especially towards separate stages for left-turn movements, increasing traffic safety even in cases where capacity is not sufficient for this measure.

The design of intergreen periods has major influence on traffic safety and should be done with special care. Since absolute safety cannot be gained, also here compromises are necessary to bring safety issues and capacity issues together. For more details on designing intergreen intervals for signal-time settings see Arasan and Boltze[1].

It is an important principle of intersection design and signal-time settings to consider human behaviour even where it is not compatible with the current traffic regulations. So-called latent dangers exist for example when the waiting times for pedestrians are too long, and pedestrians tend to cross the road against the red light. Another example is the unprotected left-turn movement of cars where drivers partly need to pay more attention than they are able to pay in observing not only the car traffic from the adjacent approach but also parallel public transportation vehicles on separate lanes, cyclists, and pedestrians. Or pedestrians who have noticed that the main stream on one approach has got a red signal and start crossing the road before the green for the pedestrians is shown, while a turning movement on the same approach still has a green signal. Of course, we cannot avoid all these latent dangers completely. But considering what the behavior of the road users could be and where the latent dangers are is an important task for traffic engineers (major contributions to this topic were given by Haeckelmann[3]).

Any measure to increase traffic safety should be taken, but of course some accidents will happen. It is our duty to learn from these accidents. A detailed standardized report on each accident, mapping all accidents over 1 year, 3 years and even longer periods, and a thorough analysis of those accidents help us to find out accident blackspots and to take appropriate countermeasures. The process of accident reporting and analysis should be well organized and normative. For this purpose, a good co-operation between police, traffic engineers, transportation planners, and all other relevant parties must be established. An electronic data processing should be used. All experiences show that the efforts for this accident analysis are more than justified by the overall economic benefits which arise from avoiding accidents.

5) Each traffic signal should be integrated in a multi-level hierarchy of signal controllers to allow co-ordination and an integration in local and regional traffic management strategies.

Future urban traffic control should be intelligent and communicative. The need for this begins with the simple co-ordination of two adjacent signalized intersections and ends up in the support of large-scale regional traffic management strategies by traffic signal control.

The developments of the recent years show that a flexible, multi-level hierarchy of controllers fits the needs of future urban traffic control best. It can be quite easily adapted to different organizational structures and distributions of responsibilities. A communication network should allow to send data on the current traffic situation and on the status of the signal controllers at one intersection bottom-up to an area traffic controller. Aggregated data are sent from there to a traffic management center which may be part of a regional communication network. On the way top-down, control strategies are communicated through the different levels. How far the intelligence of such traffic control system has to be allocated at the different levels of this hierarchy is a question that can be answered in different ways, depending on specific local situation, technological development, communication costs, and strategy needs.

6) Traffic signals should contribute to demand management strategies.

With increasing demand on our roads we should be aware that traffic signals can not only control traffic flow at intersections, but they can also contribute significantly to the demand management in an urban transportation system. There are many examples for this. Traffic signals are already frequently used as metering signals for network access. By varying the quality of co-ordination, traffic streams can be shifted to more compatible routes. And by consequent measures of giving priority to public transportation vehicles a modal shift can be gained. Or the traffic quality for cyclists and pedestrians effects the modal choice, and it may even influence the overall atmosphere of a city.

Of course successful demand management strategies usually are made up not by measures in traffic signal control alone but also by measures in other areas of traffic management such as parking management and public transportation pricing. It is important that traffic control measures which have significant impact on demand do not decrease but increase the positive effects of other management strategies set in a city.

7) The problem of aging traffic signal programs must be solved.

The problem of aging traffic signal programs is well known since many years. Changing traffic volumes make it necessary to review the situation at each traffic light in a not too long period, especially if it is fixed-time controlled.

Nowadays, in most cities this cannot be done often enough because of lack of resources. Many controllers run over many years without anybody taking notice of potentials for improvements or even malfunctions. There is only some reaction if road users complain or - in the worst case - if accidents happen. It seems to be absolutely necessary that a review plan for all intersections is set up and that reviews are conducted systematically.

It is obvious that traffic adaptive control reduces the need for an adaptation of the traffic signal programs, but the limits of flexibility within the adaptive control algorithms will also set limits to the adaptability. This and the higher probability of malfunctions of detectors and other devices make reviews of intersections with adaptive control also necessary, but the period may be longer than for fixed-time control.

Future developments should focus on intelligent self-learning controllers which may be able to develop the adaptive control programs on their own, taking every change in traffic volumes into account.

8) Quality management procedures for traffic signals have to be established.

In our society, in many areas of production and services quality management procedures are already well established. They became important elements of a successful business management. In traffic and transportation such approaches to quality management came up quite late with increasing privatization and market-orientation. To ensure and to improve the quality of our traffic and transportation systems in general it will be necessary to discuss the matter of quality management comprehensively and to apply adapted concepts of quality management to the various areas of traffic and transportation. There are sufficient reasons to include urban traffic control into this development.

As an important operational instrument, traffic signal control substantially contributes to safety and efficiency of the road traffic. Since the requirements are subject to constant changes, and since various technical defects can occur during operation, a systematical, comprehensive quality management for traffic signals should be applied. The mentioned accident analysis (requirement no. 4) and the systematical review of aging signal programs (requirement no. 7) can be integrated in this quality management.

The degree of formalization of the quality management procedures will be different from country to country. Some user-oriented assessment, a comparison of traffic signal control in different cities, and a benchmarking would be valuable first steps in this direction. In the case of Germany, we will discuss if an integration into the safety audit process or even a formal procedure following the international standard for quality management DIN EN ISO 9000:2000 is appropriate.

On this conference, Achim Reusswig will report on the development of a standardized, expenditure-optimized procedure and the associated computer-aided tools for such quality management. The modularly structured procedure consists of evaluations of accident data, process data and operational data as well as on-site observations. With the acquired information and by the use of an extensive knowledge base, adequate measures for the quality improvement are identified.

From the accidents and delays that are avoided by the quality management measures, a reasonable economical benefit can be expected. Furthermore, if the quality inspection is conducted by an independent expert, the result may also be used to certify the technical quality of the traffic signal control to the public.

By the comprehensive discussion of this topic which just started we hope to improve the awareness of quality aspects and to gain better orientation of measures on the quality of signal control.

9) The traffic situation must be detected area-wide.

Data detection is an essential prerequisite for adaptive traffic control. Detected data should not be used only locally but should be aggregated to gain information on the complete network. These aggregated data should be used to detect traffic problems in the network, to activate and deactivate predefined traffic management strategies for the network, and to provide a comprehensive traffic situation report to travel information service providers.

Data should be stored to support the planning process (e.g. transportation planning, planning of traffic management strategies, planning of traffic signal programs) and the forecast of the traffic situation. Data detection is also necessary to measure the quality of traffic flow within a quality management scheme (requirement no. 8).

To be efficient, the locations of detectors in the network should be optimized.. Advanced methods for data fusion and data completion should be considered. The quality of all detected data should be controlled frequently. For the incident detection in urban road networks, new algorithms should be developed, making use of new simulation tools and even of additional information from an on-line origin-destination-matrix.

Because detectors and namely inductive loop detectors still seem to be too costly, research on new detection technologies should focus on economical aspects more than on new functions for detectors. The reliability of detectors should be improved.

10) Interfaces and components of traffic signals must be standardized.

A standardization of interfaces and components of traffic signals allows better compatibility of different products. As in other markets, standardization has positive economical effects, because it allows a free market with competition.

In 1999 in Germany, the initiative "OCIT© - Open Communication Interface for Road Traffic Control Systems" was founded. This initiative also involves partners from Austria and Switzerland. Partners from the traffic signal industry are organized in the "ODG - OCIT Developer Group". The cities as the customers for those products founded "OCA - Open Traffic Systems City Association", supported by the association of traffic engineering consultancies VIV. And the industry for traffic control components came together in "OTEC - OCIT Traffic Engineering Components". Supported by the German Federal Ministry of Transportation and the Federal Road Authority (BASt) this quite complex organization now develops and realizes the OCIT standards, and builds demonstrators to test them.

OCIT focuses on a) OCIT-Instations: Interfaces between central devices/systems and the central data bank/data distribution; b) OCIT-Outstations: Interfaces between control center and outstations such as traffic signal controllers, traffic detection stations, information display stations; c) OCIT-Control: Interfaces between internal components of outstations. Further information is shown in the internet (www.ocit.org).

11) Comprehensive guidelines for traffic signals have to be established.

Problems in traffic signal control can be very specific, and the range of possible solutions is very wide. While a lot of valuable experience is made with these different solutions in the cities of all our countries, too much of this experience is not made available to other experts. So it seems to be most useful to establish proper guidelines which include all those experiences and allow others to benefit from that.

Some regulations in such guidelines have to be normative, others may have the character of advice and recommendation. It is important to find the right balance between normative regulations, which help to avoid failures and ensure certain standards, and keeping the necessary flexibility to allow efficient traffic signal applications in specific situations. How good such guidelines ever are, the full responsibility of traffic engineers for their local solutions will always be needed.

As an example, the German Guidelines for Traffic Signals (RiLSA) may be mentioned. They are published by FGSV - Forschungsgesellschaft für Strassen- und Verkehrswesen (German Road and Transportion Research Association) and formally introduced by the German Federal Ministry of Transportation. Recently, these guidelines have been completely translated into an English version[2]. They express the full experience in traffic signals that has been collected in a German national committee over the past decades. Currently, this committee is chaired by the author and joined by 35 experts from city and state authorities, consultancies, industry and universities.

12) Appropriate resources must be provided for urban traffic control.

One of the major reasons for lacks in the quality of urban traffic control systems are insufficient resources. Because of this, a too large gap is already existing between the state of research and the state of application., especially in developing countries but even in developed countries. Also in future it seems to be one of the difficult tasks for our society to provide sufficient resources to gain an adequate quality of traffic control in our cities. It is important for us as traffic engineers to create awareness of the overall economical benefits of good urban traffic control which come from avoiding accidents, avoiding costly delays, and providing of a performing transportation infrastructure which supports economic development. Solutions must be found for the general problem in our societies that the benefits do not always occur in the same budgets than the costs.

Appropriate resources for urban traffic control include necessary new investments, but also with increasing importance reinvestments. We have too many old controllers which cannot fulfill today´s requirements (e.g. in German cities approximately 25 percent of controllers are more than 30 years old). Furthermore, a sufficient number of engineers and other staff is needed to maintain, improve, and extend an urban traffic control system. Of course, this staff should be well educated and trained, including further education when on the job.

With respect to the financial problems, which obviously hinder further development in many cities, researchers should be encouraged to pay attention to the economical needs in practice. The gap between research and application may become a little smaller if we find solutions which allow a return of investment. One positive example was the invention of LED signals which improve the quality and at the same time can reduce the costs of operation and maintenance significantly.

3. Final remarks

Of course, the mentioned requirements are not complete, but they may show some major developments which we should promote to improve the future quality of our urban traffic control systems.

Because of its importance for our society, urban traffic control has always been in the center of public interest. Since there are so many goal conflicts to be solved, not every party will always be satisfied with the quality of traffic control. It will be necessary, to have a good public relations management to explain what we traffic engineers are doing and why our solutions should be accepted. This orientation to the public may also support the public awareness for our profession, which seems to be most useful.

Finally, I like to highlight the importance of an international exchange of experiences with urban traffic control. It is absolutely useful to learn from each other. Therefore, the organizers of this conference and all speakers earn our full appreciation for their efforts.

References

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