Controlling user groups in traffic

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Abstract
On the basis of policy-based target groups, we developed a prioritization strategy for traffic streams and applied it with the adaptive urban traffic control (UTC) ImFlow. Our main aim was to gain understanding of the possibilities of a policy driven prioritization in an urban context. We conclude that traffic light control can become more rational, effective and efficient from a policy viewpoint. However, situational and operational constraints pose a limit.

Introduction
There is a growing awareness that traffic management and transport policy in general should deal with target groups instead of general traffic volumes. Moreover, traffic light control can be a tool for achieving transport policy goals beyond overall delay minimization. Once a system is installed, common practice is to fine-tune control parameters in order to keep delays minimal for all traffic at individual junctions. This implies a kind of prioritization with an unclear outcome for society that may even lead to contradictions in priority on a network scale. With a target group approach, policy making can presumably become more rational, effective and efficient. Optimizing traffic light control by prioritizing target groups on a network scale can lead to better performance for high-ranked groups, in line with policy objectives. However, at the same time it might lead to local traffic problems that can be rated as unacceptable. Furthermore, control constraints related to traffic safety (e.g. clearance times) and equity (e.g. maximum waiting time) might implicate a limited ability to adjust weights in traffic light control plans. This paper discusses the development of a target group strategy and its application with ImFlow for a case of two intersections in the city of Helmond in the Netherlands. The aim of our research was to answer the question whether policy objectives can be pursued by applying weights for different user groups? Secondly, we examined whether this approach is easy to implement and if it leads to acceptable local situations that together are more in line with overall policy objectives.

Adaptive network control
The last decades, traffic network control systems have emerged that coordinate traffic lights at multiple signalized intersections in a network to arrive to optimum values for certain user defined criteria. One of these systems so-called adaptive urban control systems (UTC) is ImFlow, which is comparable to SCOOT and UTOPIA. On the basis of target groups, we developed a prioritization strategy for traffic streams and applied it in an ImFlow configuration for a simulation study on two intersections of the city of Helmond. ImFlow provides the option to optimize a given situation for user defined policies and constraints for different traffic streams based on chosen criteria reflected by a set of control variables [also see 1]. Control variables cover different levels (i.e. area, route and intersection) and multiple control objectives (e.g. delay, stops, queue, public transport and vulnerable road users). See Figure 1. This offers the possibility to link the system objectives to overall policy objectives and to close the plan-do-check-act loop, i.e. to evaluate the objectives and to refine them.

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Traffic streams
The first question is how to set up a prioritization strategy that matches a policy and how to effectuate this prioritization with a system like ImFlow, SCOOT or UTOPIA? We start off by defining an overall objective for network management. In many cities in the Netherlands the main objective is to arrive to optimal accessibility in terms of travel times, within constraints regarding livability and traffic safety. We took a more integral objective, namely the development of a sustainable transport system that contributes to local welfare and well-being in the most optimal way. It follows that: (1) sustainability and the contribution to welfare and well-being need to be defined; (2) accessibility and traffic livability in urban environments need to be assessed simultaneously, and (3) local transport policy needs to acknowledge mobility aspects for different societal groups.
A major deviation from the approach applied in the last decades is the acknowledgement that local transport policy can be more effective and efficient if tailored to the desires and needs of different social groups with different spatial and temporal activity patterns. New policies like accessibility planning are in line with this approach. The focus on network activity relations instead of traditional network performance and traffic volumes might well lead to different solutions which can be considered more sustainable. With traffic light control as with other measures in the realm of transport policy, certain groups can be defined, e.g. on the basis of their origin and their travel and activity pattern (see Figure 2). For the case of Helmond we used 6 different target groups on a city level: (1) daily commuters, (2) through traffic, (3) freight traffic, (4) internal traffic, (5) visitors, and (6) shoppers/recreationists. Their origins and destinations may be different with combination out of the following: (1) city center, (2) residential areas/city boroughs, (3) industrial areas/rural areas, and (4) outside municipality. Based on these 6 target groups and their origins and destinations we defined 9 traffic streams which were used in the case study (see Table 1).

Case study
Two major signalized intersections in the center of Helmond, The Netherlands were selected. See Figure 3. For data collection purposes a prerequisite was that ImFlow is operational at the selected intersections in real-life. The intersections are situated on the main corridor through Helmond.

![Figure 3 – Overview of the two signalized intersections](image)

To come to weights on a signal group level we used the following approach. First we defined a selected cordon origin-destination (OD) matrix relevant to the two intersections. See Figure 3 (left). We then transferred the city level traffic streams with their different OD patterns to the OD’s of the selected cordon (see Figure 4). For this a so-called gravity approach [2] and all-or-nothing assignment was used. It goes beyond the scope of this paper to discuss the details of this procedure. The outcome of this process was an OD-matrix for five periods of the work day with a total traffic flow that consists of the sum of the flows of 9 traffic streams. With another all-or-nothing assignment we finally determined a fraction for each traffic stream for each direction at the intersections (i.e. signal group), which could be weighted based on their respective priority.
For further quantitative analysis VISSIM was used for a traffic simulation study. From the traffic stream fractions and the average vehicle delays in case of common practice control, we could assess the implicit prioritization of traffic streams of common practice traffic light control. It is important to note that although this prioritizing may satisfice local demands (e.g. delay and volumes) it may not be desired from a policy perspective. For the policy-based priority we defined as an example a strategy that favors travel movements with explicit economic value for the city of Helmond. Most notable differences between explicit priorities based on policy and resulting priorities based on common practice are for traffic to/from the city center (e.g. work, shopping, etc.) and through traffic. For these two traffic stream both strategies are opposed: the former favors traffic to/from the city center and the latter favors through traffic. A closer look at the priorities teaches that the common practice clearly prioritizes high traffic volumes and minimum local delay. Finally, from the fractions and an explicit policy-based priority for each traffic stream we derived the control weights per direction. As such, signal groups received weights from 1 = least important to 10 = more important. These weights served as direct input for the ImFlow configuration.

Table 1 – Resulting actual versus policy based prioritization

<table>
<thead>
<tr>
<th>Traffic stream</th>
<th>Flow (veh/h)</th>
<th>Delay-based (before)</th>
<th>Policy-based (after)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2 Centre-Residential area v.v.</td>
<td>780</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>1-3 Centre-Industrial area v.v.</td>
<td>280</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>1-4 Centre-Outside municipality v.v.</td>
<td>340</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>2-2 Between or inside residential areas</td>
<td>1140</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>2-3 Residential area-Industrial area v.v.</td>
<td>1430</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>2-4 Residential area-Outside municipality v.v.</td>
<td>3580</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>3-3 Between or inside industrial areas</td>
<td>260</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>3-4 Industrial area-Outside municipality v.v.</td>
<td>890</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>4-4 Through traffic</td>
<td>980</td>
<td>1</td>
<td>9</td>
</tr>
</tbody>
</table>
In terms of average delay per vehicle per traffic stream there are clear differences based on the new weights. See Figure 5. These differences have the expected sign: when the priority increased, the average delay decreased and vice versa. For example the average delay time of through traffic (4-4) increased significantly, which is in line with the much lower priority. Similarly, the traffic streams into and out of the city center were rated more important and their average delay time reduced accordingly. However, the magnitude of the differences is less than expected for which there are three possible explanations. Firstly, standard control constraints related to traffic safety (e.g. clearance time and minimum green) and equity (e.g. maximum waiting time and phase sequence) must still be obeyed and limit the flexibility of the control optimization. Secondly, at these two intersections the main route is heavily loaded and therefore has a dominant influence and poses another limit to the flexibility of the optimization process. Finally, several signal groups receive a balanced mix of traffic stream. As a result, changes in priority are cancelled out and diminish the overall effect.

![Figure 5 – Average delay per traffic stream by approach](image)

**Conclusion**

For traffic streams, new priorities based on policy differ significantly from resulting implicit (and perhaps non-intended) priority of common practice traffic light control. In a case study, control weights have been altered substantially within the configuration of the adaptive urban control system ImFlow. Effects on the average delay of traffic streams were substantial although less than expected, but in the same direction as the weight had changed. Results show a more equal treatment of traffic streams in pursuit of the policy based strategy, despite limiting situational and control constraints. Due to resulting local inefficiencies the overall delay increased by 9%, which could lead to considerable opposition in society. Nonetheless, we conclude that there is potential for a policy-based traffic management approach that links adaptive urban traffic control to overall policy objectives. Minimally it leads to a clearer and consistent contribution of the transport system to society as a whole.

**References**
