Guiding toward optimal route and parking choice of urban traffic

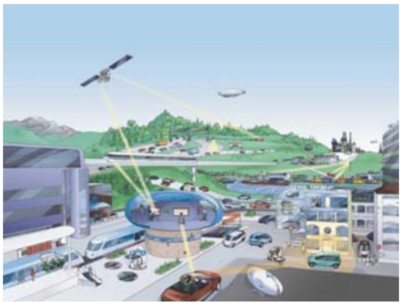
Development of an optimization model based on a trade-off between interests of specific stakeholders

Anke Rouwette

Graduation Date:
27 June 2008

Graduation committee:
Martin van Maarseveen
Kasper v. Zuilekom
Hurink en Boucherie (TW)
Korving en Goemans (W+Bos)

Organisation:
Witteveen & Bos



The amount of traffic all over the world is growing, together with its negative side effects. Especially in cities, problems caused by traffic growth are increasing rapidly. In the end, the only real solution to the traffic problems can be found in modal split changes and trip reduction. However, this is not a solution, which can be realized on the short term. Fortunately, with advanced guidance of road users, considerable changes in the traffic situation are possible.

Current route and parking guidance systems inform individual road users, but do not guide the complete traffic process. Therefore, these systems are not able to realize significant changes in the traffic situation. There is need for a central guidance system, which guides the complete traffic process, based on a trade-off between the interests of the stakeholders. With advanced guidance many interests can be served. The guidance can be used to spread road users over the parking stock, to relieve the most polluted parts of a city or to minimize congestion.

However, not all interests can be served equally. Therefore, in each situation a trade-off is necessary, between wishes and demands. There is no easy rule telling which guidance results in the optimal situation. Therefore, the objective of this study is to develop a generic model for the optimization of dynamic route and parking guidance, based on a trade-off between interests of specific stakeholders. The model is developed in four steps: conceptual model, theoretical model, implementation and testing. The following vision describes the future guidance:

The local government decides on the objective and constraints for the guidance, based on a trade-off between interests. For example, it is decided to minimize the emissions within the city center, but the maximum detour for road users is constrained to 10%. For every period of five minutes, the guidance model computes the optimal spread of traffic over the network. Based on this optimal spread, an individual route and parking advice is sent to each road user that enters the network. The road user receives the advice on his in car navigation.

The conceptual model
The conceptual model defines the traffic process, with guidance, based on the role, influence and interests of four specific stakeholders: the road user, the parking holders, air quality and the local government. The road user ‘creates’ the traffic process through route choice, parking choice and compliance with the guidance. The main interest of the road user is minimization of individual travel time. Furthermore, road users do not accept large detours or large walking distances from parking to destination.

The local government (LG) is the provider of the road network and regulations and manager of the guidance system. The LG is the stakeholder with the largest influence on the traffic process, through management tools and regulations. The LG establishes the guidance objective and constraints, based on a trade-off between the interests of all stakeholders. The parking holders provide the parking stock, but have limited influence on the traffic process. However, a fair competition between different parking holders is a constraint for the guidance optimization. An interest of the parking holder is reduction in queuing and searching at parking locations. This is possible by spreading the traffic over available locations.

The last stakeholder, air quality, is an output of the traffic process. The importance of and awareness on air quality are increasing all over the world. Air quality is one of the main triggers for efficiency improvements in the traffic process. Emission minimization is the main air quality interest.

The theoretical model

The conceptual model is translated to a theoretical (mathematical) model. This model consists of two levels. On the upper level the guidance settings are chosen. The guidance consists of a split of the traffic, per Origin-Destination (OD) relation and time period, over a set of available routes. The lower level comprises a model for the traffic assignment and propagation. Two traffic streams are distinguished: a stream of traffic that complies with the guidance and a stream of traffic that ignores the guidance. Furthermore, the traffic is split per parking type: public or private parking.

Three time steps are used to model the traffic process. The OD matrix (demand) varies per large time step (15 minutes). In every medium step (5 minutes) the route inflows of both guided and non-guided traffic are calculated, respectively based on the guidance settings and individual cost minimization. These inflows are distributed, per OD relation, over a set of available routes. In the smallest time step (20 seconds) the link inflows, outflows, occupancies and travel times are updated; the traffic is propagated through the network. For each medium period network performance measures are computed.

The optimization loop is run every medium period. In each iteration new guidance settings are fixed on the upper level; the traffic assignment and propagation are performed at the lower level. The guidance solution is valued, based on the network performance measures. A simulated annealing algorithm (mathematical search algorithm) is used to choose new guidance settings in every iteration and to search for the best guidance settings.

The implementation

The theoretical model is implemented in Matlab. For each model component a separate syntax (program) is written. The components are linked to perform all steps in the guidance optimization. The complete implementation uses link data, node data and a dynamic OD matrix as input. The outputs are guidance settings for every medium time period and network performance measures, such as link flows, travel times and occupancies. The objectives and constraints for the guidance optimization can be changed easily in the program, as well as the parameters.

Model testing

The guidance model is verified, calibrated and applied to a case study. In the verification, several tests are performed to check if the model works as it is intended to do and improvements are introduced. The tests show that the model functions correctly. The calibration is very limited, due to a lack of data. Therefore, it is mainly used to obtain plausible results. The traffic assignment is calibrated with results of the RBV (a Dutch traffic simulation model). For the guidance component, the calibration is used to find the parameter settings that lead to the best optimization, within the computational limitations.

The guidance model is applied to the city of Rotterdam (The Netherlands). Scenarios are studied to explore the possibilities of the guidance model and to study the effects of the guidance. The influence of different objectives, constraints and parameters, such as the compliance percentage, is studied. Furthermore, the model is applied to scenarios with demand varying from light to heavy and to the situation with a large demand peak for an event.

The case study gives a first indication of the possibilities of the guidance model and the effect of the guidance. The results are promising, especially for the parking guidance. However, it is not possible to conclude on the guidance effect with this case study. A small number of iterations is used in the optimization, because of computation time limitations. Since the solution is space is very large, the guidance model is not able to find good solutions for every period. Furthermore, it is difficult to conclude on the effect of changes in parameters and scenario settings, due to the large variability in the results. An extended calibration and optimization are necessary to be able conclude on the effects of guidance.

Discussion

The final product of this study is a flexible guidance optimization model. The current implementation can generate guidance related to four objectives: user equilibrium (with and without guidance), minimization of the average link travel time (weighted per user), minimization of average IC ratio (weighted per link or per user) and minimization of differences in parking occupancy. Furthermore, the model facilitates constraints related to maximum IC ratio, parking occupancy, walking distance and detours.

The main strengths of the guidance model are its flexibility and clear structure. The model components can easily be changed and extended. Furthermore, the model can be applied to every city and time period, without changes. The model is the first in its kind to generate guidance for a whole traffic process, based on objectives and constraints, which can be varied by the model user. The model fulfills in the need for central guidance of road users. The main model weakness is the large computational requirement. To enable a good calibration and online implementation, the model has to be translated to a faster programming language.

In the current version the guidance model is a very useful tool for analysis of the traffic process with and without guidance. When the model is translated to a fast program, the impact of guidance with different objectives, constraints and settings can be studied. This research is a start in the guidance model development and brings along many interesting follow-up studies.