Using Key Performance Indicators for traffic management and Intelligent Transport Systems as a prediction tool

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Abstract

In recent research work (FP7 CONDUITS) a performance evaluation framework for traffic management and Intelligent Transport Systems was developed. The new framework consists of a set of Key Performance Indicators (KPIs) for the strategic themes of traffic efficiency, safety, pollution reduction and social inclusion, and the last stages of the project saw its validation through its application to four case studies. Following up from this work, this paper presents the extension of the framework for use as a prediction tool enabling urban transport authorities to assess the impacts of relevant policies and technologies before implementing them. Focussing on pollution reduction, a tool (CONDUITS-DST) integrating the respective KPIs with microsimulation modelling is developed. The paper describes the integration process, including the model chosen for calculating the emissions levels of a number of scenarios, presents the results of the application to a case study in the city of Brussels, and outlines future developments targeted at broadening the integration of the KPIs into decision-making.

Keywords: Performance Indicators, Intelligent Transportation Systems, Pollution Reduction, Simulation, Emissions

Introduction

Cities today share common transport problems and objectives with respect to mobility management, and put great focus on Intelligent Transport Systems (ITS). The market offers decision makers a variety of ITS solutions, from which they are required to choose the most suitable and effective ones. Making this choice is a non-trivial task, especially given that transport problems are multi-dimensional by nature. Hence, a performance evaluation framework that addresses the various dimensions of transport problems, while at the same time reflecting the perspectives and priorities of decision-makers, is required (Zavitsas et al, 2011).

Development and testing of a performance evaluation framework

An evaluation framework for urban traffic management and ITS was developed as a result of the European Commission funded CONDUITS project. Key Performance Indicators (KPIs) were formulated, taking into account a wide range of requirements, such as the need for them to be easily understandable, impartial and scalable. The development process adopted a hierarchical approach, where traffic management as a whole was decomposed into the four strategic themes of traffic efficiency, traffic safety, pollution reduction and social inclusion, and where each theme was decomposed according to its relevant dimensions (e.g. the traffic efficiency KPI aggregates performance measures relating to various transport modes, various types of routes within the network etc.) (Kaparias et al, 2011). The developed KPIs were subsequently validated through the conduct of case studies in the cities of Paris, Rome, Tel Aviv and Munich, each assessing a different aspect of urban traffic management applications (Tsakarestos et al, 2011; Kaparias et al, 2012), and a brief summary is given.

Two case studies were examined in the city of Paris: the implementation of systems granting priority to buses at signalised junctions on three bus lines and the construction of a new tram line (T3) on the “Boulevard des Maréchaux Sud” corridor. For both case studies, a before- and after-analysis was carried out in order to quantify the impacts of the two schemes in terms of mobility and traffic accidents. Using the appropriate KPIs fed by data from the city, it was found that the bus priority scheme resulted in clearly better public transport mobility for the three bus lines and in marginally lower private transport mobility on the corresponding road stretches, thus indicating an improved overall mobility on the affected network parts. Similar results were obtained for the tram scheme, with improved overall mobility being recorded. As concerns the accidents assessment, it appeared that the bus priority measures were accompanied by a clear reduction in the casualty rate of deaths and slight injuries, but by a marginal increase in the rate of serious injuries, mainly involving pedestrians and cycles. The overall accidents rate, however, appeared to remain constant. A similar trend was observed in the casualty rates of the tram scheme.

A large-scale performance evaluation of the various techniques and ITS technologies that have been implemented within the framework of the Mobility Control Centre of the city of Rome was conducted. Using travel times between representative zones throughout the city of Rome, defined as the area lying inside the “Grande Raccordo Anulare” (GRA) orbital motorway, a general performance assessment was carried out in terms of mobility. The underlying conclusion was that, as expected, private transport mobility was better than public transport mobility, with index values ranging at similar levels to the Paris case study.

The reliability performance of the introduction of advanced traffic signalling strategies was evaluated in the Tel Aviv case study. Using congestion occurrence and duration data from the Ha’Shalom arterial, it was found that the new signal programmes resulted in significantly improved reliability, additionally supported by travellers’ perceptions. Nevertheless, it was found through continuous monitoring that the index value had a decreasing tendency, becoming stable within a year following the implementation of the scheme.

A safety performance evaluation was, finally, conducted in a case study in the city of Munich, where the so-called direct safety impact of the installation of speed feedback dynamic message signs for a certain test period was measured through an appropriate KPI. It was found that the introduction of the signs resulted in a reduced speed warnings per vehicle value compared to before, indicating an improvement in safety during the test period. However, the value returned to its previous level after the removal of the signs.

Through the conduct of the case studies, it was concluded that the KPIs are easy to apply and require already available data, thus forming a very useful evaluation tool for assisting decision makers in the field of urban traffic management and ITS, and to some extent for identifying best practice applications in other cities, that can be adopted in the near future.

Yet the necessity for extending the framework from its current state of a tool for evaluating existing systems to a tool for evaluating future systems becomes apparent, given the current economic climate and the increasing need of making as informed decisions as possible. The present study, therefore, sponsored by Kapsch TrafficCom, concentrates on integrating the KPIs with microsimulation modelling in order to create a prediction tool for traffic management and ITS, so as to leverage the ability of city transport authorities to practically use the developed KPIs for future projects. The pollution aspect of traffic management is considered here, in the form of greenhouse gas emissions from vehicle traffic.

Predictive evaluation framework

The procedure followed for predicting the potential impact of new traffic management and ITS applications combines real life measurements on one hand, and the simulation of alternative scenarios on the other. One of the most common transport modelling tools used for pre-deployment analysis is the PTV VISSIM micro-simulator. This tool has the ability to estimate the likely impacts of ITS measures on mobility patterns and, as a consequence, the traffic-generated emissions. The emissions related to the different vehicle types are a fundamental component of the predictive pollution reduction KPI.

The research described aims at the development of the CONDUITS decision support tool (CONDUITS-DST), which is a specialised tool working as an additional module to microsimulation software packages, such as VISSIM. The tool combines output data from simulation models and the output of an external emissions model (AIRE), and calculates the KPI for pollution reduction according to different scenarios set up by the planners.

The pollution KPI itself is based on requirements specified in earlier stages of the CONDUITS project (Kaparias et al, 2011), and is thus defined as the weighted sum of all distance-averaged emissions per vehicle and per vehicle type existing in the network.

$$KPI_{Pollution} = \frac{\sum_{VT}\sum_{ET} W_{ET} W_{VT} Q_{VT,ET}}{\sum_{VT}\sum_{ET} W_{VT} W_{ET}}$$

Where:
VT – Vehicle type
ET – Emission type
WVT – Vehicle type weighting factor
WET – Emission type weighting factor
Q (VT,ET)– The average ET quantity by travel distance and number of cars per VT

The individual components of CONDUITS-DST and the flow of information between these components are shown in Figure 1. An important feature to note here is the transferability of CONDUITS-DST, as this is not bound to any particular microsimulation platform and can work equally well with available modelling tools providing vehicle logs, such as VISSIM, PARAMICS, etc.

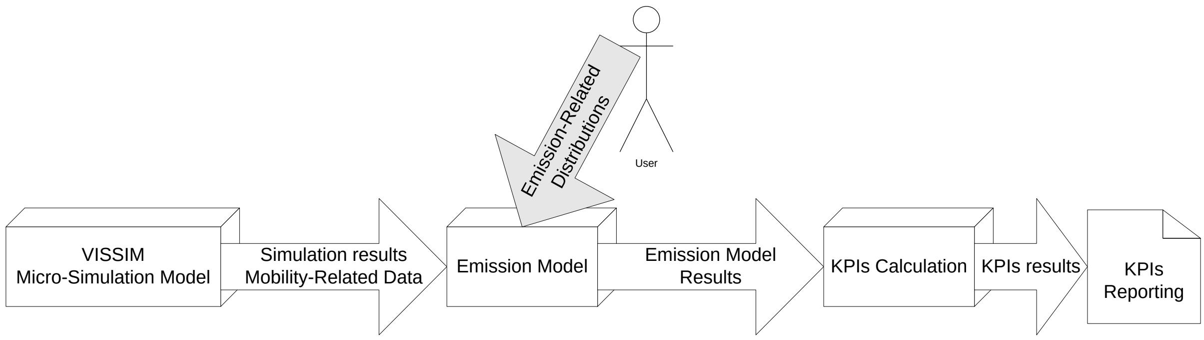

Figure 1: Structure of CONDUITS-DST

Application and validation

The research described has been carried out in close cooperation with city authorities, with CONDUITS-DST being validated through an existing case study in the city of Brussels. Following the EU directive and the high interest of the Brussels-Capital Region to provide a better quality of life to its citizens, the city authority has been constantly seeking for ways to deliver a more efficient transport system on one hand, but a less polluting one on the other. One of the measures pursued involves increasing the share of public transport in the modal split, which requires making it more competitive compared to motorised private transport. With an already dense public transport network (70 public transport lines with a total length of more than 700 km), though, any improvements must be based on the existing system.

One of the means to introduce a more competitive public transport system is by reducing travel times. To achieve that, the Brussels-Capital Region has introduced a programme aiming at increasing the operational speed of most of its public transport lines. The programme focuses on reducing delays around signalised junctions by giving priority to public transport vehicles over private transport. This strategy promotes the attractiveness of public transport, both in the short- and the long-term, by offering lower travel times; however, it is also likely to have an undesired side-effect of increased pollution levels from traffic, especially in the short-term, due to increased waiting (idle) times and more stops and accelerations by private transport vehicles.

Brussels is used as a case study for the purposes of validation of CONDUITS-DST, and more specifically, the prospective pollution impact of the introduction of priority signals along bus line no. 49, is analysed. The study consists of four scenarios, representing the states before and after the implementation of the system in the morning and evening peak hours, respectively. From the planning phase of the signal control a calibrated VISSIM simulation network has been developed for all four scenarios (Figure 2).

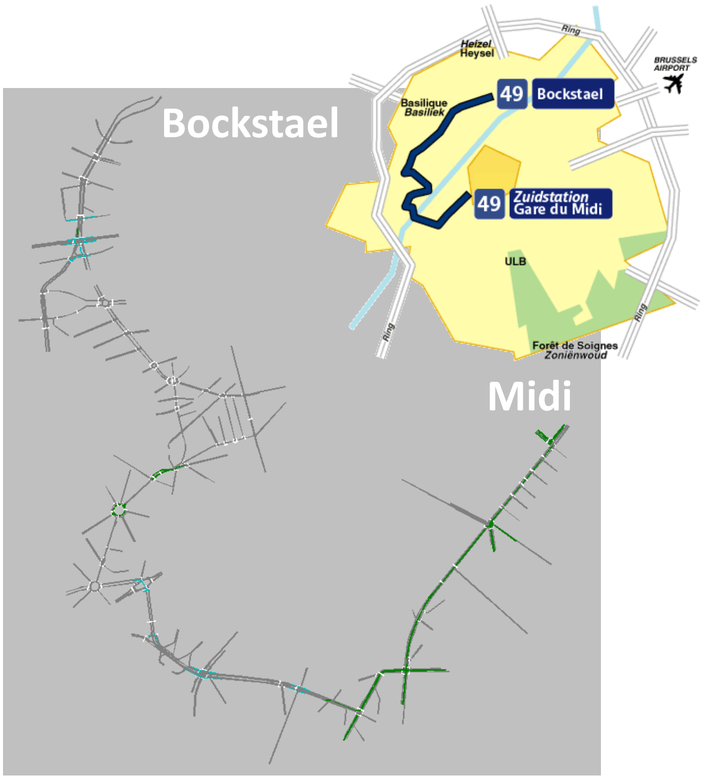

Figure 2: Simulation network for the Brussels case-study

For the validation, several simulation runs are used, extracting the necessary data for the KPI calculation. The evaluation period is a span of three hours in the respective peak time.

Figure 3 shows the results of the KPI calculation for pollution in the four scenarios. It is obvious that the values for the two after-scenarios are higher as in the before-scenarios. The increase is approximately 7% and 6% in the morning and evening peak periods, respectively. A brief comparison of other indicators of the simulation, such as number of stops and delay times, both for private and public transport, confirm this outcome. The results, hence, show that, while public transport observes a decrease of 20 to 60% in the number of stops and an increase of the average speed of 3 to 6%, private cars experience an increase of their journey time, along with an increase in the pollution levels.

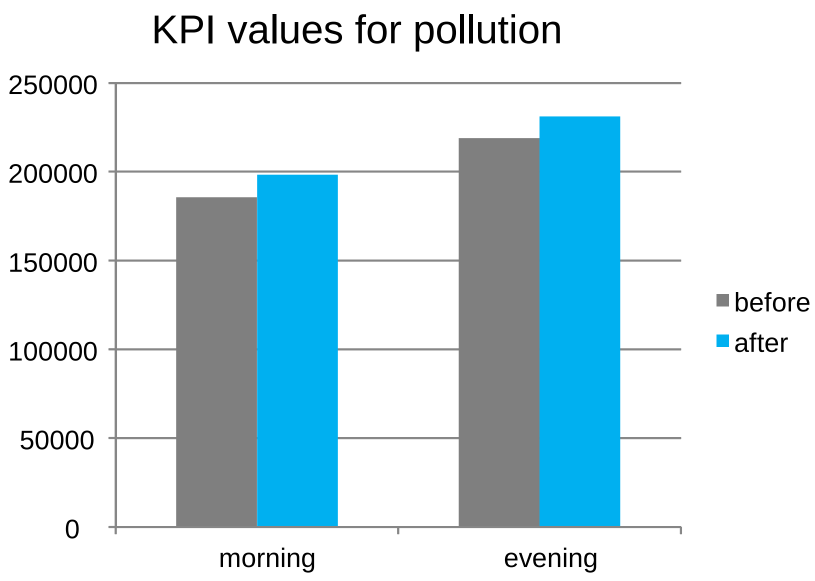

Figure 3: Results of the pollution KPI calculation

The results of this simulation run reflect a short-term impact of the bus priority strategy, as it occurs almost immediately after its implementation. Subsequently, however, gradual changes in the traffic and mobility patterns are expected to take place, as due to the increases in travel time drivers will alter their route choice and eventually distribute delay times equally over a larger part of the network. In a second step, the increase in public transport reliability and the reduction of the delays can work as a “pull-factor” and encourage to some extent a modal shift from private to public transport, which can counterbalance the short-term pollution increase in the long-term.

These effects can be also monitored and evaluated using CONDUITS-DST. Ongoing research currently involves a sensitivity analysis of the demand-pollution interrelation by gradually altering the traffic demand levels and re-calculating the KPI values, so as to experimentally reach a “break even” point, where the demand changes will be high enough to fully neutralise the negative effects on pollution. This will give the authorities the possibility to assess if such a demand shift is feasible and deliver an additional decision-making basis for the implementation of the system.

Impact

The reasonable results from the Brussels case study suggest that CONDUITS-DST can assist the prediction of the short-term effects of public transport priority on pollution in a comprehensive way, and thus support city transport authorities in political decision-making, as well as in the promotion of similar projects. Naturally, after the implementation of a particular system, the city can still use the respective KPI for “conventionally” monitoring long-term developments, utilising data from regular traffic measurements.

Aside from the city of Brussels, the research work described is additionally closely monitored by two further European city authorities (Rotterdam and Zurich), giving detailed feedback on CONDUITS-DST’s features and steering the development process alongside Brussels. Hence, it is planned that after the successful demonstration of the functionalities of CONDUITS-DST, the two additional cities will function as “beta-testers”, using the tool on case studies of their own.

With the case studies undertaken by the three reference cities, the usability of CONDUITS-DST and its applicability in different municipalities based on the same methodology is verified. The current version of the tool includes all its core functionalities, and the immediate next step involves the addition of new reporting capabilities to allow for an easier interpretation of the results by the cities themselves. By adopting the pollution KPIs developed in CONDUITS, CONDUITS-DST allows authorities to impartially evaluate the contribution of ITS to the quality of life in their cities, as well as to benchmark their own performance.

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