Kapsch TrafficCom
CONDUITS-DST
Further development of the CONDUITS Key Performance Indicators

I. Kaparias
N. Eden
A. Tsakarestos
N. Zarkhin
C. Böhm

Development and application of the CONDUITS Decision Support Tool for predictive assessment of pollution impacts

1st Annual Report of the CONDUITS-DST project

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Executive summary

One year after the formal conclusion of the EC-funded CONDUITS project, which was reached with the successful real-world validation of the new traffic management and ITS evaluation framework, work on further advancing the developed KPIs continues. With the support of Kapsch TrafficCom, the framework has been taken to the next level, which features its use as a predictive decision support tool within the framework of the CONDUITS-DST project.

The present is the first report of a series to come, documenting the work and outcomes of the first phase of the CONDUITS-DST project. It first briefly reports on the main outcomes of the CONDUITS project, and then introduces the new CONDUITS_DST software and its fully-developed predictive pollution assessment module using the CONDUITS pollution reduction KPI. Finally, it presents the results of the tool's validation through its application to a case study in the city of Brussels ("alpha testing"), which demonstrate its usefulness and applicability.

1 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, 2010).

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, 2012a),

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 CONDUITS-DST project, 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 present report is the first of a series of reports to come, summarising the work and outcomes of the first phase of the CONDUITS-DST project. It deals with the development of the CONDUITS_DST software, dealing at the first instance with the pollution aspect of traffic management, in the form of greenhouse gas emissions from vehicle traffic. Within this phase, the CONDUITS KPI for pollution reduction is implemented in CONDUITS_DST and tested in a case study using a microsimulation model from the city of Brussels.

The report is structured as follows: Section 2 gives a brief summary of the background of this work, including the main contributions and results from the CONDUITS project. Section 3 then introduces the new predictive evaluation framework, as adapted from the CONDUITS KPIs, and presents the CONDUITS_DST software tool. Section 4 describes the application of CONDUITS_DST in the Brussels case study and reports on the results obtained and the analysis performed. Finally, Section 5 summarises the conclusions of the study and identifies areas of future work.

2 Background

The CONDUITS project was successfully concluded in June 2011 by achieving its primary objective, which was the definition of a new performance evaluation framework for urban traffic management and ITS. Key Performance Indicators (KPIs) were developed for four strategic themes of urban traffic management (traffic efficiency; traffic safety; pollution reduction; and social inclusion), with each theme consisting of individual sub-themes (e.g. mobility, reliability, operational efficiency and system condition as part of traffic efficiency). Operative definitions of the KPIs, along with detailed guidance on their use, were provided in a comprehensive reference document (Kaparias et al, 2011). The KPIs were subsequently validated with the help of a number of case studies in four European cities (Paris, Rome, Tel Aviv and Munich), each assessing a different aspect of urban traffic management applications (Kaparias et al, 2012b). A brief summary of the results is given here.

2.1 Case study 1: Paris

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 (Figure 1) and the construction of a new tram line (T3) on the "Boulevard des Maréchaux Sud" corridor (Figure 2). 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.

Figure 1: Paris bus lines 26, 91 and 96 (Source: RATP)

Figure 2: Paris tram line T3 (source: RATP)

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 (Table 1). Similar results were obtained for the tram scheme, with improved overall mobility being recorded (Table 2).

Table 1: Paris bus priority mobility assessment results

I_{MOB} (min/km)	Public transport			Private transport			Overall		
	Before	After	Change	Before	After	Change	Before	After	Change
Line 26	4.46	4.25	-4.82%	4.46	4.65	4.30%	4.46	4.37	-2.09%
Line 91	4.63	4.33	-6.55%	5.25	5.05	-3.89%	4.82	4.54	-5.68%
Line 96	5.03	4.67	-7.13%	2.71	3.02	11.55%	4.33	4.17	-3.63%
TOTAL	**4.71**	**4.42**	**-6.21%**	**4.21**	**4.26**	**1.14%**	**4.56**	**4.37**	**-4.17%**

Table 2: Paris tram T3 mobility assessment results

I_{MOB} (min/km)	Public transport			Private transport			Overall		
	Before	After	Change	Before	After	Change	Before	After	Change
Line T3	-	3.54	-	2.90	4.06	39.94%	-	3.70	-

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 (Table 3 and Table 4).

Table 3: Safety assessment results for Paris bus line 91

I_{ACD} (casualties/million-veh)	Weights	Deaths		Serious injuries		Slight injuries		Overall	
		Before	After	Before	After	Before	After	Before	After
Cycles	0.25	0	0	0	2	3	5	0.02	0.05
2-wheelers	0.2	0	0	3	3	71	36	0.40	0.24
4-wheelers	0.15	2	0	0	1	27	20	0.32	0.12
Pedestrians	0.4	1	1	6	11	51	51	0.42	0.50
TOTAL	**1**	**0.07**	**0.04**	**0.31**	**0.63**	**4.10**	**3.57**	**0.30**	**0.28**

Table 4: Safety assessment results for Paris tram line T3

I_{ACD} (casualties/million-veh)	Weights	Deaths		Serious injuries		Slight injuries		Overall	
		Before	After	Before	After	Before	After	Before	After
Cycles	0.25	0	0	1	0	6	7	0.09	0.15
2-wheelers	0.2	0	0	5	7	67	54	0.83	1.46
4-wheelers	0.15	0	0	1	0	67	19	0.74	0.41
Pedestrians	0.4	1	0	5	1	32	14	0.63	0.34
TOTAL	**1**	**0.09**	**0.00**	**0.73**	**0.77**	**8.12**	**9.03**	**0.55**	**0.53**

2.2 Case study 2: Rome

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 (Figure 3), a general performance assessment was carried out in terms of mobility and reliability.

The underlying conclusion of the former 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. In the case of the latter, the city of Rome was found to have a very high reliability index, with very few congestion occurrences as a whole. This, however, may be attributed to the fact that the potentially unreliable and congested peak hours were compensated by the long uncongested off-peak (night time) hours, highlighting the need for a time-based reliability performance evaluation of the transport network.

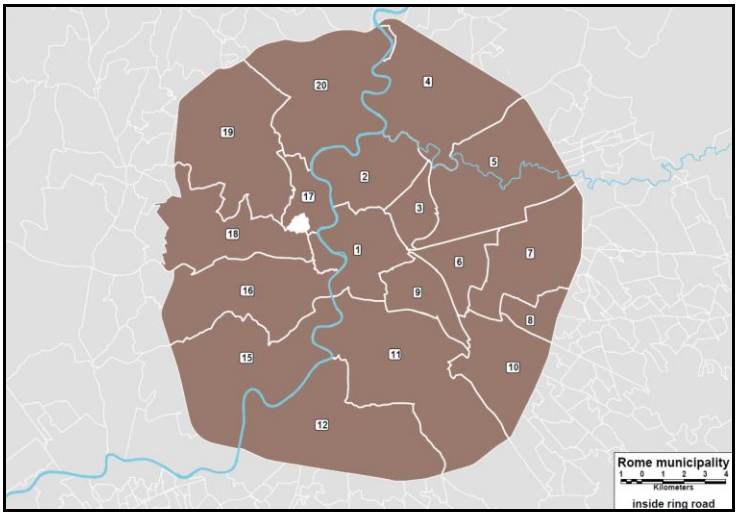

Figure 3: The 18 zones of the Rome study area (Source: Rome Mobility Agency)

2.3 Case study 3: Tel Aviv

The reliability performance of the introduction of advanced traffic signalling strategies was evaluated in the Tel Aviv case study.

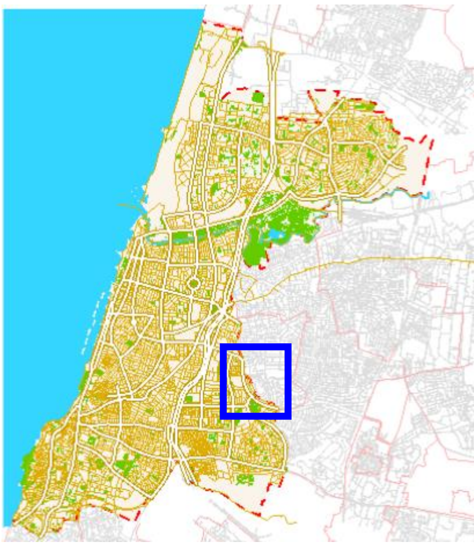

Figure 4: Tel Aviv map (Ha'shalom Arterial in the blue rectangle)

Using congestion occurrence and duration data from the Ha'Shalom arterial (Figure 4), 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 (Figure 5).

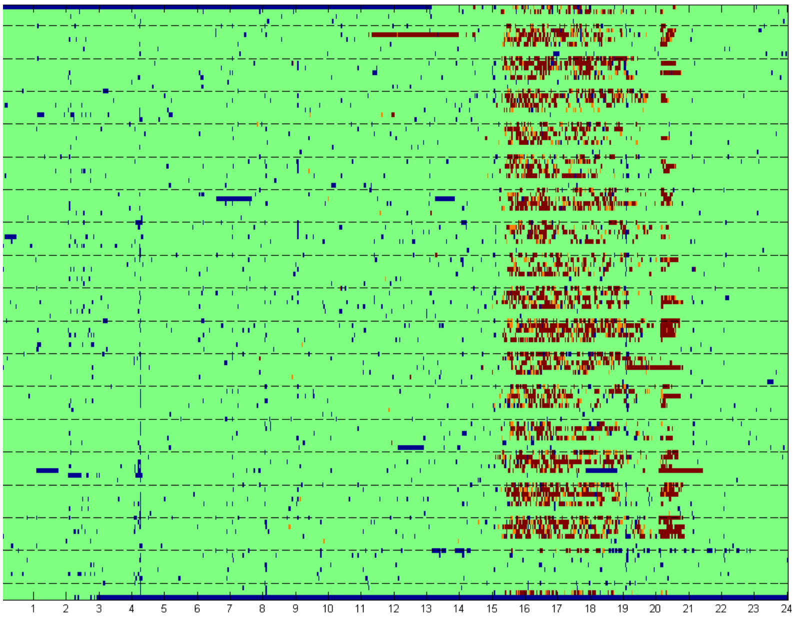

Figure 5: Congestion Analysis at Ha'shalom Arterial

2.4 Case study 4: Munich

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 (Table 5). However, the value returned to its previous level after the removal of the signs (Table 6).

Table 5: Traffic safety assessment results in Munich per link

I_{DS} (actions/veh)	Before	During	After
Paosostrasse (eastbound)	0.45	0.26	0.37
Paosostrasse (westbound)	0.73	0.48	0.70
Friedenspromenade (northbound)	0.15	0.12	0.15
Friedenspromenade (southbound)	0.29	0.18	0.30

Table 6: Traffic safety assessment results in Munich for all links

I_{DS} (actions/veh)	Before	During	After
Munich (Paosostrasse-Friedenspromenade)	0.37	0.24	0.35

2.5 Concluding remarks

The evaluation of the KPIs with the help of the five real-world case studies demonstrated the usability and accuracy of the new performance evaluation framework. The calculation output was found to generally reflect major phenomena in the traffic conditions of the respective city, as confirmed by the local transport experts used in each case study, but as opposed to previous work, the output is single values and charts rather than manifold assessments. Furthermore the validation of the KPIs demonstrated their scalability, since they were applied successfully in small parts of networks (e.g. the case studies of Paris) as well as in large caption areas (e.g. the general assessment for Rome).

The KPIs are immediately usable by local authorities, as they utilise common and available data. This instance was not only confirmed through the application with data from four different cities, but also by means of direct consultation with other local authorities through the CONDUITS City Pool. It is hence the next step of the work to implement them in a new decision-support tool, CONDUITS_DST, which enables the predictive evaluation of impacts based on microsimulation modelling.

3 The predictive evaluation framework

The use of standard and aggregated KPIs, like those developed within CONDUITS, is an effective tool for two types of processes:

- Decision making process prior to the deployment of an ITS project - Decision makers are mostly interested in evaluating the benefits to be gained from the considered ITS measure, prior to its deployment. In other words, better decision making requires reliable predictive KPIs.
- Ex-antefacto/ex-postfacto analysis of the implementation of an ITS project – After the initial deployment, decision makers are interested in quantifying the effectiveness of the implementation of an ITS project with respect to its initial goals, based on ex-antefacto and ex-postfacto data. Calculation of the KPIs provides this feature.

These two processes are based on different data sources as illustrated in Figure 6, at which the predictive KPIs are based on modelling outputs and the reality reflection KPIs, are based on measurements made by devices in the field.

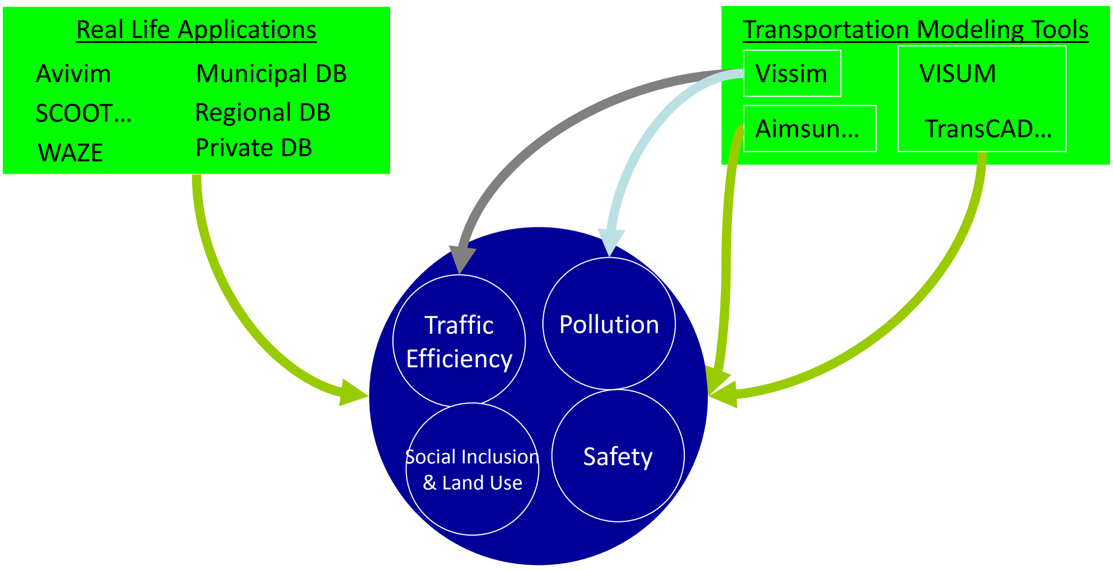

Figure 6: The CONDUITS-DST development framework

The overall predictive Decision Support System (DSS) based on the CONDUITS KPIs, is also presented in Figure 6, as it describes the modelling tools that will be implemented in the CONDUITS DST in the years to come.

3.1 Theoretical framework

One of the most common methods in pre-deployment analysis in transport is microsimulation modelling. Microsimulation is an efficient tool offering a detailed reflection of the implementation of an ITS measure on the mobility patterns in the transport network. The output of a microsimulation model can be segregated and aggregated, with mobility-related data on different aspects of the network (nodes/links/routes) and different transport modes being available. This data is the basis for the generation of the two most important transport systems descriptive indicators as highlighted by the cities: pollution reduction and traffic efficiency.

KPIs for pollution reduction and traffic efficiency have been developed and validated within the framework of the EC-funded CONDUITS project. It is the objective of this project, hence, to further develop them in an innovative decision-support tool, so as to use them in a predictive manner based on microsimulation. The development work, hence, takes place in two stages, with the first stage focussing on the CONDUITS pollution reduction KPI, and the CONDUITS traffic efficiency KPIs being developed in a second one.

Recalling the definition of the CONDUITS performance evaluation framework, the pollution KPI is formulated as

$$KPI = \frac{\sum_{VT} \sum_{ET} w_{VT} w_{ET} Q_{VT,ET}}{\sum_{VT} \sum_{ET} w_{VT} w_{ET}} \tag{1}$$

where:

KPI	the pollution reduction KPI
w_{VT}	vehicle type weighting factor
w_{ET}	emission type weighting factor
$Q_{VT,ET}$	the variable expressing the quantity a certain emission type from a certain vehicle type

When using the pollution KPI in conjunction with a microsimulation model, its value is calculated based on aggregated results from several seeds of the same scenario. This ensures that the result obtained is statistically significant and reflects the broad trends of the phenomena observed, rather than being biased by specific occurrences and outliers.

3.2 The CONDUITS_DST software

The procedure of coupling microsimulation modelling with performance evaluation is integrated in the CONDUITS_DST software. This essentially allows for the calculation of the KPIs based on the results estimated by microsimulation and included in so-called "vehicle records", i.e. files containing the simulation results per individual vehicle included in the model. Valuable simulation results are based on aggregation of many simulation runs with different seeds. Thus the tool is based on the possibility that more than a single mutation (seed) is used to generate the emissions and calculate KPIs. The results generated by the tool enable easy comparison between different simulation runs and scenarios.

The CONDUITS_DST software starts with a main menu, which has been configured to allow the user to call the appropriate performance evaluation module for his/her desired task (Figure 7). The main menu also allows the user to open previously computed results, to find additional information on the software's settings, and to access further general information about the CONDUITS_DST development.

Figure 7: CONDUITS_DST main menu

The specific CONDUITS_DST module of pollution, which is the only one that has been fully developed so far, consists of the following components:

- Emissions estimation (Figure 8) – this component evaluates the emissions of the vehicles registered in the vehicle records using the well-established AIRE (Analysis of Instantaneous Road Emissions) tool, provided free of charge by SiAS transport planners, on behalf of Transport Scotland. It should be noted, though, that the use of this component is optional, as emissions may be calculated by other tools/modules (e.g. the emissions module of PTV VISSIM) and stored in the vehicle data file, and then used by CONDUITS_DST for the pollution KPI calculation;
- Aggregation of the emissions by vehicle type along all defined mutations (Figure 9);
- KPI calculation which encompasses different mutations, vehicle types and emissions (Figure 10).

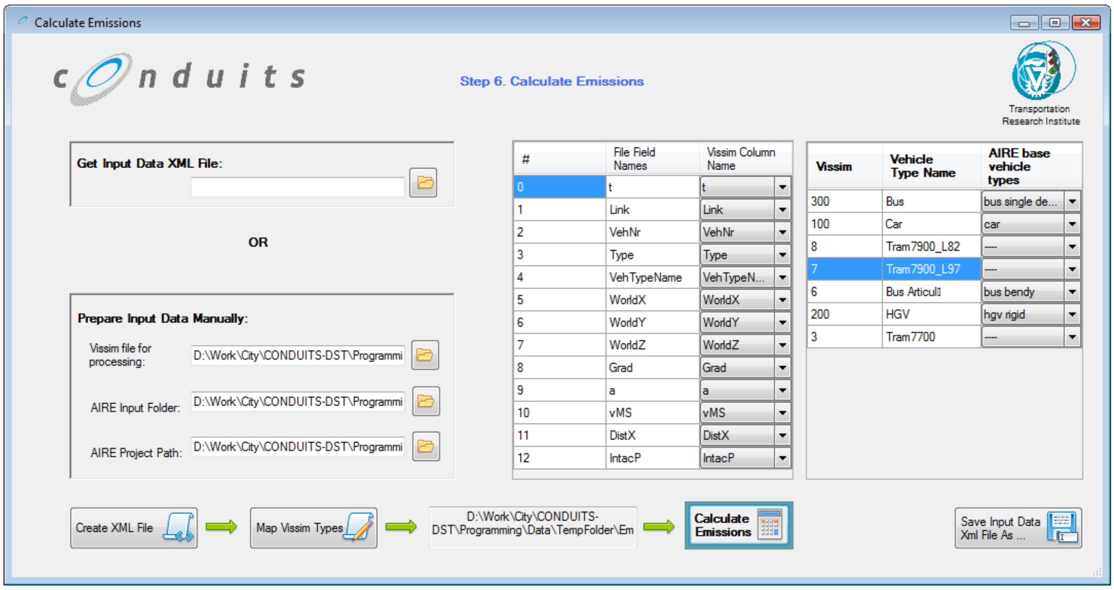

Figure 8: Emissions calculation component interface of CONDUITS_DST

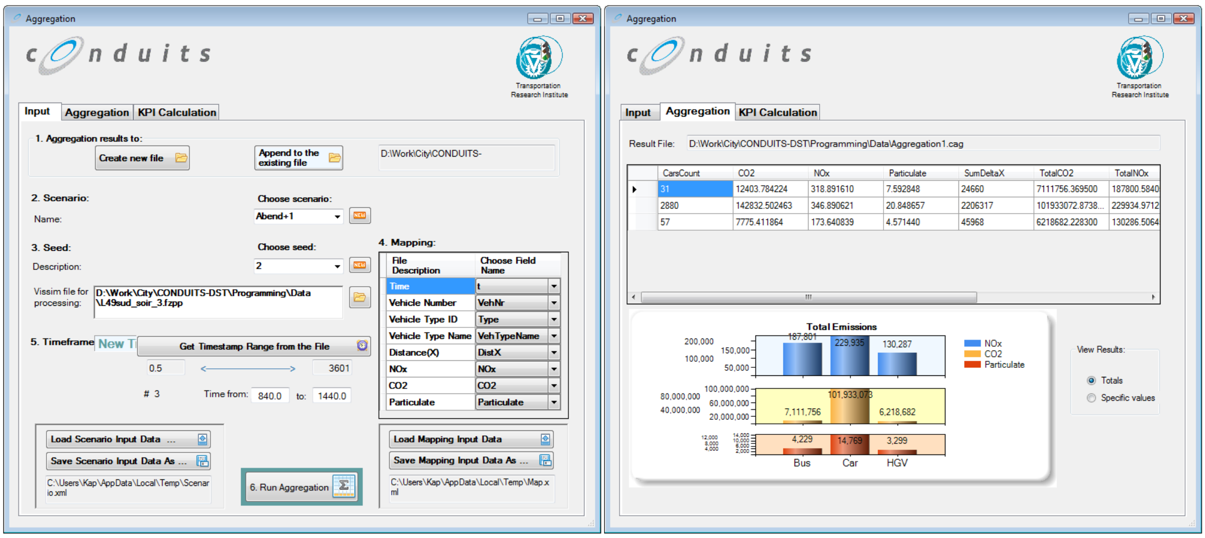

Figure 9: Emissions aggregation component interface of CONDUITS_DST

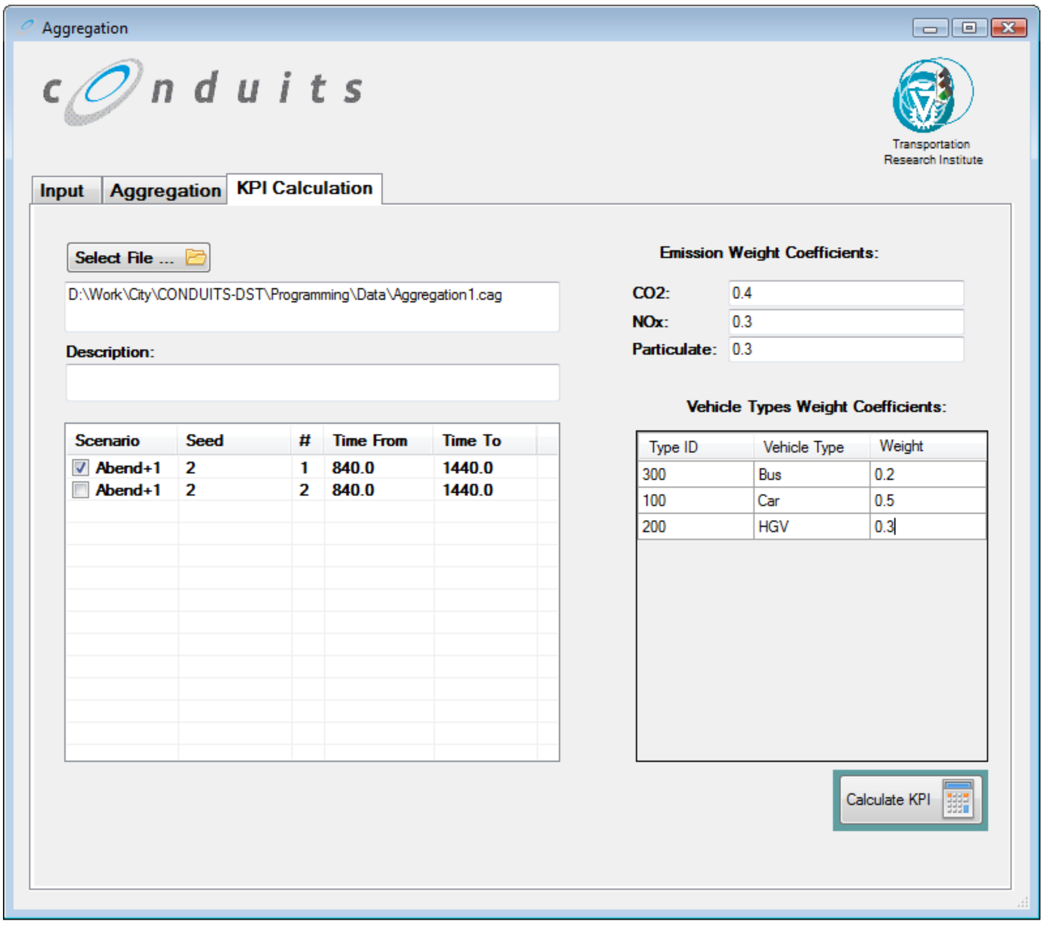

Figure 10: KPI calculation component user interface of CONDUITS_DST

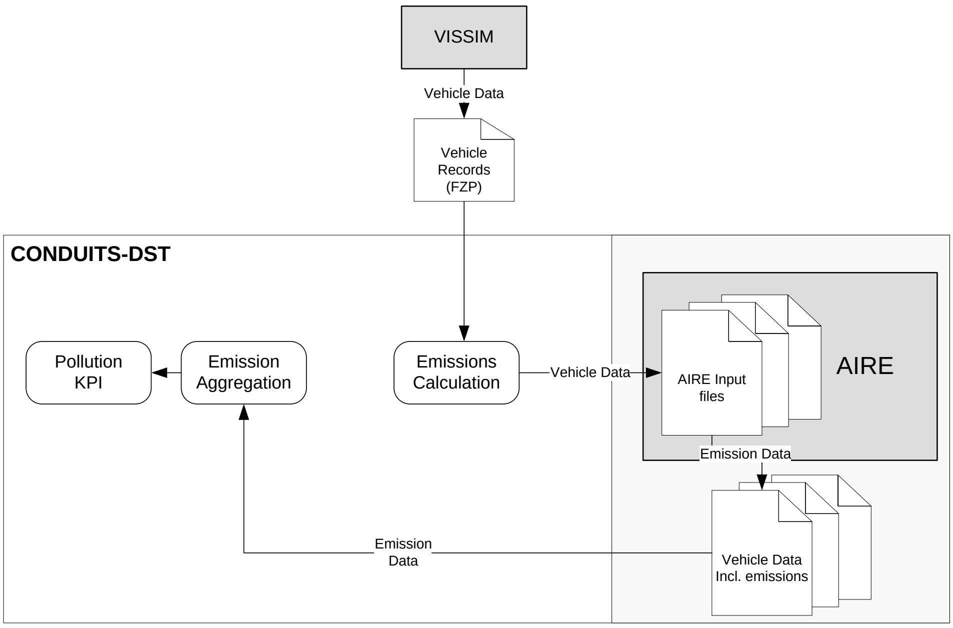

Figure 11: CONDUITS-DST architecture

The CONDUITS-DST architecture is illustrated in Figure 11. The right rectangle in the chart represents the optional calculation of emissions, whereas the shaded elements represent third party applications, which need to be installed.

CONDUITS_DST assumes that the fundamental data was generated using the PTV VISSIM microsimulation tool. Nevertheless, an important feature to note here is its transferability, as this is not bound to any particular microsimulation platform and can work equally well with available modelling tools providing vehicle logs, such as PARAMICS, provided the fields presented in Table 7 are available.

Table 7: VISSIM fields required in CONDUITS_DST

Field	Description
[t]	Simulation second
[Link]	Link number
[VehNr]	Vehicle ID
[Type]	Vehicle type ID
[VehTypeName]	Vehicle type name
[WorldX]	Simulation network X coordinate
[WorldY]	Simulation network Y coordinate
[WorldZ]	Simulation network Z coordinate
[Grad]	Road gradient
[a]	Acceleration [m/sec^2]
[vMS]	Velocity [m/sec]
[DistX]	Distance travelled by car
[IntacP]	If the car breaks, this row must contain a "BREAKEAX" note

As concerns the output, CONDUITS_DST generates the following files:

1. Updated vehicle log file with the emission calculated by AIRE;
2. The averaged emissions per vehicle type and per simulation seed and time frame;
3. The CONDUITS Pollution KPI for the defined scenarios, time frame and seeds.

To ensure compatibility with and transferability to other third-party applications, the last two files are XML type.

CONDUITS_DST also has a reporting interface, allowing for the presentation-friendly display of the pollution KPI calculation results (Figure 12). This can be also called independently from the main menu in order to display previously calculated results.

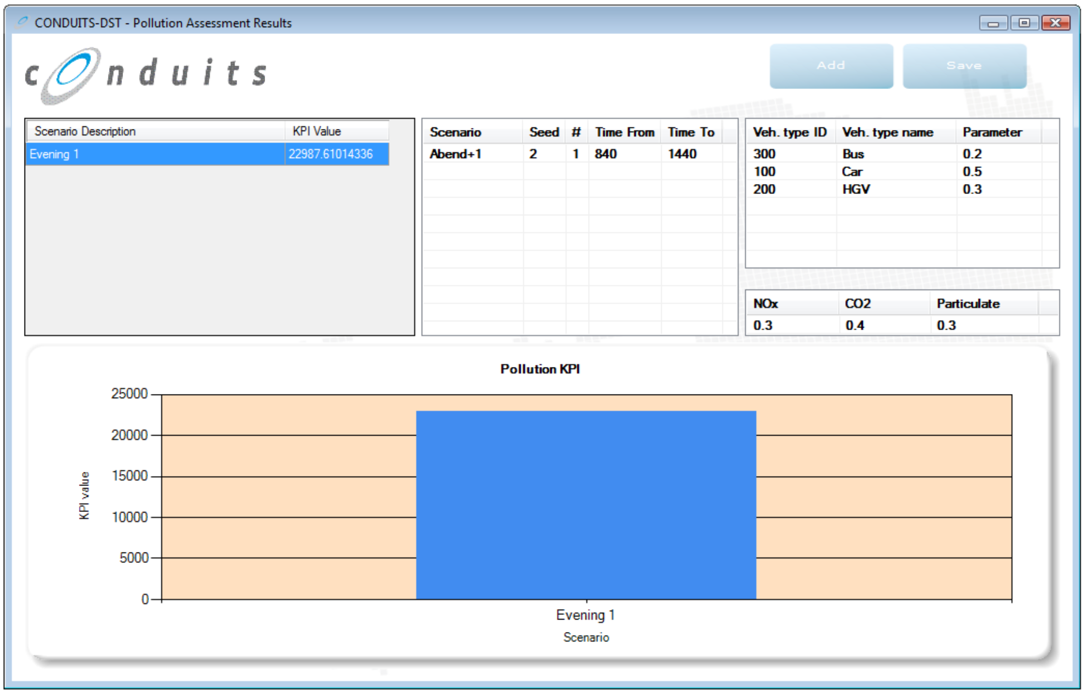

Figure 12: Pollution reporting interface of CONDUITS_DST

4 Application and validation

The KPIs framework for traffic management and ITS developed in CONDUITS was validated based on surveyed data from real life operations that were provided by public authorities (Section 2). This demonstrated the applicability of the KPIs for assessing improvements through ITS and the availability of the necessary input data within the public authorities. A similar validation process is undertaken for the predictive evaluation using the CONDUITS_DST software. The basic requirements that had to be met are:

- Applicability for realistic case studies using simulation
- Usability by the means of a public authority
- Generation of plausible results verified by the case study

For the application and validation of CONDUITS_DST a two-step approach is chosen. In an initial step, an “alpha testing”-city is to provide a concrete case study to be used by the scientific team for testing and validating the tool. In a second step, once the usability of the tool is verified, “beta-testing” cities will receive the tool in order to undertake calculations independently.

The application process and development of the tool are overlapping processes, such that the initial calculation runs – still providing statistically uncertain results – are used to gain valuable experience with running the software in different technical environments and in countries with different metric systems. This insight is then immediately used to improve the tool and to make it more robust for its dissemination to any public authority interested in its use.

The actual application upon the case study has been undertaken by two different persons – one researcher and one student – independently from each other. This also ensures the user-friendliness for a person not in immediate contact with the developing team.

4.1 Description of the case study

A case study for the “alpha-testing” is provided by the Brussels Capital Region, where a large-scale public transport priority programme is being planned and implemented. The major goal of the programme is the reduction of travel times by increasing the operational speed and by reducing delays around signalised junctions using priority signals for public transport vehicles.

The concrete case study focusses on the priority measures in the southern part of bus line 49 (Figure 13), which connects the Metro station of Bockstael with the Midi railway station (Gare du Midi) and services the south-western part of the city's centre. The line segment under observation is roughly 8 km long and contains eleven signalised junctions. The settlement structure serviced by this bus line includes manifold land use patterns from residential and mixed areas to industrial areas and large public transport hubs. Both line 49 itself and the road network it uses show high levels of commuter traffic in all modes.

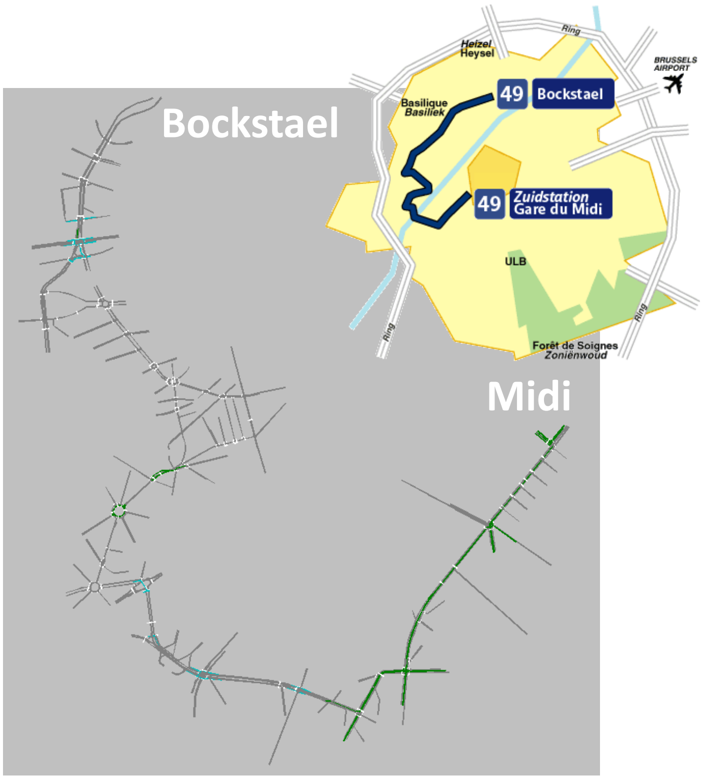

Figure 13: Line 49 and simulation Network for the Brussels case study

For the priority at signalised junctions the MS12 system has been implemented. For each phase a minimum green time has been defined, representing the legally required minimum, which in most cases, however, does not meet the actual demand. Beyond that, a standard green time has been defined, pre-adjusted to satisfy about 2/3 of the actual demand. On this basis, according to the current traffic conditions and the priority requirements of the public transport vehicles, two extensions of the green time can be applied: the first to meet the remaining 1/3 of the demand and the second to service public transport vehicles.

In this modular system, the extension of the green time can be applied according to the current situation, an instance that increases effectiveness. However these extensions have a green time reduction of competing phases as an inevitable consequence.

During the planning of the system the anticipated improvements of this measure, reflecting goals of public transport service quality, have been verified by the means of microsimulation. The applied simulation scenarios are available to the scientific team and can be used for the purposes of the present study. They consist of four scenarios concerning the southern part of line 49 in the PTV VISSIM traffic simulator. The scenarios are the following:

morning peak hour	→ before the implementation
	→ after the implementation
evening peak hour	→ before the implementation
	→ after the implementation

The demand levels are the same in all four scenarios, an instance that indicates a short-term consideration of the system's impacts. Since the focus of the original study has been to assess changes in the number of stops and delay times of public transport, this time frame has been sufficient. However, it is likely that at least in a short-term consideration, these measures will have an undesired side-effect of increased pollution levels from private traffic. This side-effect is, hence, now to be evaluated using CONDUITS_DST.

4.2 Application of CONDUITS_DST

The data to be extracted from the simulation consist of detailed protocols delivering speed, acceleration, and breaking activity for a distinct group of vehicles at each pre-defined time step. For the purposes of this calculation the simulation step is 0.5 sec. This data can be easily obtained from the microsimulation output files for the entire network. For measures already implemented, however, a sample of realistic floating car data provided by a test fleet can deliver a similar calculation basis. The simulation data are subsequently processed by CONDUITS_DST to an external emissions module (AIRE) that calculates the momentary emissions of each vehicle at each time step and adds three additional items to the data set: NO_x, CO_2 and Particulate emissions (Figure 14) and thus delivers the necessary input for the pollution KPI calculation.

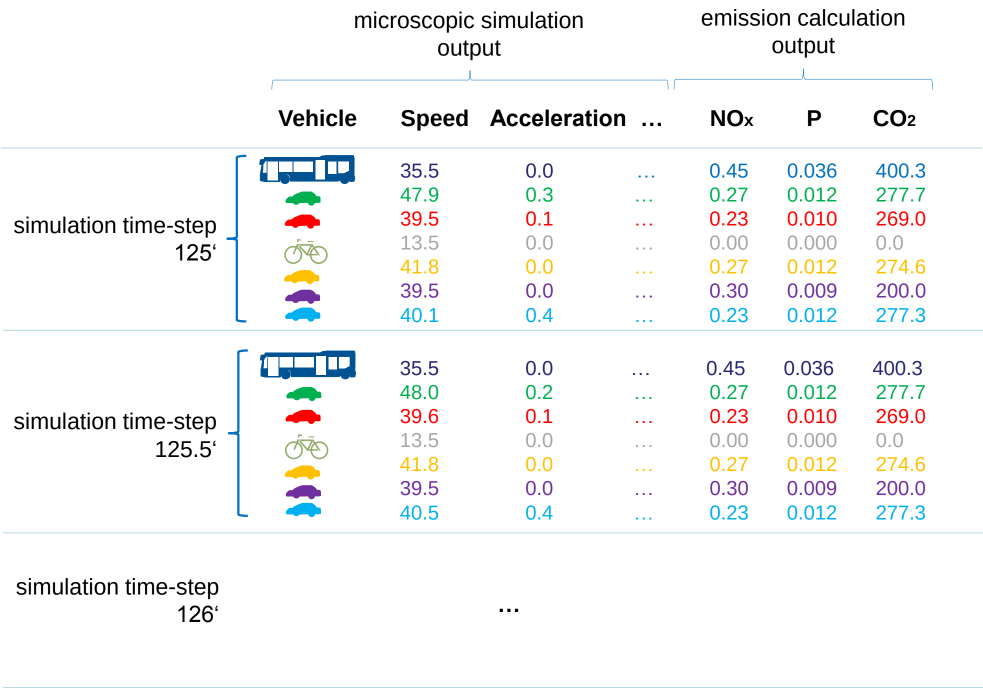

Figure 14: Structure of an AIRE-result file

CONDUITS_DST aggregates the single values of the AIRE output files, first to a total sum for each pollutant over the whole assessment period and finally to a KPI value using adjustable weights for each pollutant. These weights take the goals of the local transport policy in to account. For the current study an equal weighting of 1 is used.

At an organisational level the tool's application can be undertaken both within the planning process of ITS systems and during the operation of the systems. Public authorities will be able to apply the tool independently, since it can be used for continuous monitoring of impacts. In the predictive phase, however, the work is often conducted by external private planning companies, which may be based outside the periphery of the authority. CONDUITS_DST is suitable for these cases of task sharing, and since it does not require additional commercial software and draws data from open databases, it is portable for different users.

4.3 Results of the case study

Figure 15 shows the results of the pollution KPI calculation in the four scenarios of the Brussels case study as calculated by two independent users. The differences in the KPI values are a result of the stochastic uncertainty simulated in VISSIM by the use of random start variables; this can be compared to the difference between two samples on different assessment days. It is evident from the results that the values for the two after-scenarios in the case study are higher than in the before-scenarios. The increase is approximately 3% to 7% in the morning and 6% to 7,5% in the evening peak period.

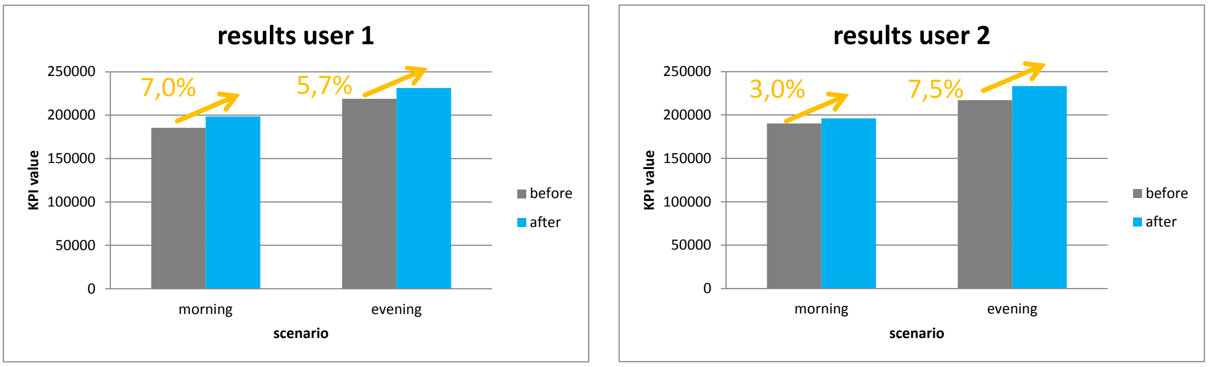

Figure 15: KPI calculation with CONDUITS_DST in the Brussels case study

A more detailed analysis of single performance indicators, drawn from the simulation, suggests that private transport flows directed along the bus line show an improvement in terms of the number of stops and travel time. However, the flows perpendicular to the bus line demonstrate an increase in lost time at the signalised junctions, which reverses the average KPI value over the entire network part examined. The evaluation of the indicators for public transport verifies the results of the previous study, showing a 20% to 60% decrease in the number of stops and a 3% to 6% reduction in travel time. This confirms that the results of the simulation are plausible.

This concrete application has however some constraints. Due to the higher lost time at single junctions, the complete demand cannot be incorporated in the simulation. This influences the final results, since they are weighted by the number of vehicles. In addition to that, the simulation is not combined with a macro model to assess the changes in the route and modal choice of the drivers. The additional modelling required to take these phenomena into account, however, is beyond the scope of the current study.

This overall result reflects the side-effect on pollution mentioned above that is expected by the experts. If such results were to be presented in the planning phase of an ITS system, they would prompt a debate about whether the system should be applied in reality or not. Thus, the question that emerges from city authorities is how can CONDUITS_DST support stakeholders in their decision process; a sensitivity analysis is conducted for the case study for that purpose.

4.4 Sensitivity analysis

The application of public transport priority introduces a range of side effects on traffic patterns. As a mid-term effect, it is expected that drivers subsequently shift to alternative routes. The effects of increased travel times are thus expected to spread in a wider part of the network, and the peak encountered along the route of line 49 will even out. If the improved travel times for buses remain competitive to the new car travel times, then a modal shift from private transport to bus and soft modes can occur in the longer-term. The prediction of such effects requires detailed macroscopic modelling, which is in most cases too costly to be conducted alongside ITS planning.

For the sensitivity analysis a more simple and pragmatic methodology is chosen. The given demand levels of the relevant flows are progressively reduced in increments of 1% and the KPI values are recalculated for each new situation. This procedure continues until the KPI value for a reduced demand level meets the KPI value calculated for the before-scenario. This will show the level of shift in demand that would be necessary to counterbalance the negative side-effects of the system. Although the value is a result of a hypothesis and not of a prediction model, experts are able to assess if it can be reached by any means available to a public authority.

The following figures show the results of the sensitivity analysis. In the morning peak hours (Figure 16) a reduction of demand of approximately 1.5% would reduce the pollution KPI back to the level it had before the implementation of the priority. In the evening peak (Figure 17) the reduction has to reach approximately 3.5%.

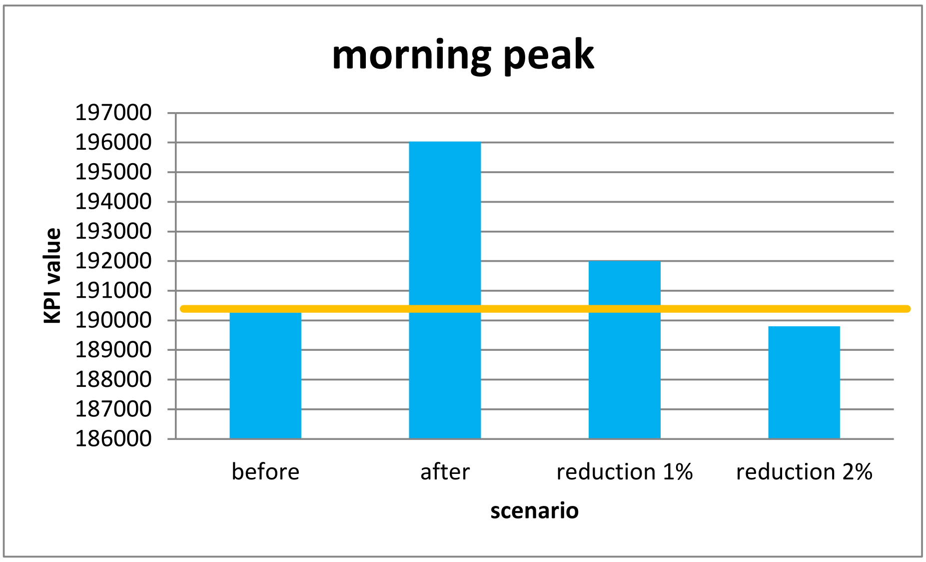

Figure 16: KPI values in the morning peak for different demand levels

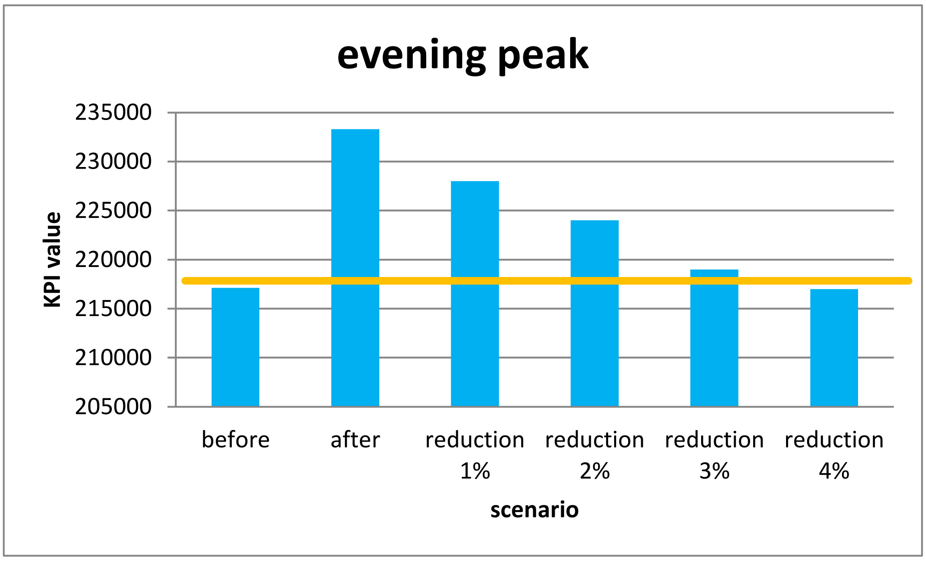

Figure 17: KPI values in the evening peak for different demand levels

Whether this reduction can be achieved solely through the application of public transport priority is questionable. In most cities with similar applications more measures are applied to encourage or to force modal shift. However, within an integrated strategy for demand management this decrease is feasible, but the decision upon the exact measures is an issue of local transport policy and strategy.

Nevertheless, it should be pointed out that the level of the KPI value is not only a result of a calculation, but is also significantly influenced by the weighting of the pollutants. A more detailed analysis of simulation outputs shows that reducing the levels of pollutants back to the conditions before the implementation is highly diverse. Table 8 shows the demand reduction that is necessary to even out the increase of each individual pollutant and of the KPI value for the two peak hours.

Table 8: Sensitivity analysis of the single pollutants

Pollutant	Morning	Evening
CO_2	1,5%	4,0%
NOx	3,5%	6,0%
PM_{10}	0,5%	3,0%
KPI	1,5%	3,5%

It is evident that NO_x requires a higher reduction in demand than PM_{10}. A different weighting of single pollutants would thus have a significant effect on the values of the KPI.

5 Conclusions and further work

The implementation of the KPI for pollution reduction in the new purpose-developed software (CONDUITS_DST), coupled with the AIRE emissions model and the VISSIM microsimulation package, has been the first step in the direction of predictive performance evaluation, and its pilot application (“alpha testing”) to a case study in the city of Brussels has delivered very promising results. The results 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.

With the expressed intention of Kapsch to continue supporting the development of CONDUITS-DST for another two years, a number of further tasks to be undertaken have been planned. As a first step, and following the successful implementation of the pollution reduction KPI, the tool will be expanded to accommodate more KPIs, starting with the ones for traffic efficiency. In particular the mobility and reliability indices will be implemented, which, in a similar way to the pollution index, will build upon the outputs of traffic simulation to predict the performance and impacts of specific traffic management and ITS schemes. The implementation will be complemented by the parallel continuous development of the tool’s user interface to accommodate the addition of the new module, and will be followed by the conduct of a pilot case study in the city of Brussels for initial validation purposes.

A further step to be undertaken is an investigation for expanding CONDUITS-DST to include a road safety prediction module, based on the developed CONDUITS KPIs (accident numbers, direct safety impacts, indirect safety impacts). Conversely, however, to pollution reduction and traffic efficiency, whose prediction is relatively straightforward on the basis of simulation, the development of a predictive framework for safety is a much more complex problem and requires the consideration of a wide range of factors. Namely, it is widely acknowledged that the causes of accidents, and safety hazards in general, are only partly captured by the principles underlying traffic simulation, with a large part being attributed to individual driving behaviour. It is, therefore, likely that the development of the safety KPI module of CONDUITS-DST will require looking at and considering models from the field of traffic psychology. As with the other modules, a pilot case study will be conducted for validation purposes in a city to be determined when the module development has been completed.

Aside from the development and "alpha-testing" of new modules, the next steps of the project will also concentrate on the further validation of CONDUITS-DST through the conduct of additional case studies in different cities ("beta-testing"), featuring the combined use of all developed modules. This will enable more complete predictive assessment for urban traffic management and ITS schemes, as it will allow for the identification and quantification of potential "side-effects", which are of great importance to city authorities. It is planned to conduct three case studies, with cities having already expressed interest including Zurich, Stuttgart and Perugia.

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