A STUDY ON FACTORS AFFECTING THE RELATIONSHIP BETWEEN CONGESTION IMPACTS AND CONGESTION PERFORMANCE MEASURES IN AREA-ROAD NETWORKS

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ABSTRACT

Congestion performance measures (CPMs) are a key part of decision making. There are several aspects they have to fulfill in order to be useful tools for performance based planning. The relevance aspect corresponds to the capacity of a CPM to capture the impacts of congestion. Previous studies have identified factors that can impact the relevance of the indicators. Additionally, current congestion performance measures use the output of long term planning models. This made the indicators insensitive to the dynamics of congestion. Current improvements in traffic information and data availability have not been followed by corresponding evaluations of how congestion indicators describe the impacts of congestion. The present study is devoted to analyzing these factors with a special focus on factors influencing pollutant emissions. The car fleet composition has significant influenced when comparing areas with different car fleet compositions, hence it was not possible to identify the indicator that performed best. When the car fleet compositions between two areas are similar, the indicators that provided higher relevance were Relative Speed Reduction (Weighted Average) and Excess Delay. The percentage of heavy vehicles does not influence the capabilities of capturing the impacts of congestion. A discussion about how relevant aspects act together with other desired aspects for CPMs is presented. Recommendations for practitioners are presented at the end of the document.

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1 BACKGROUND

Congestion reduces mobility and accessibility in urban areas as well as the quality of life and the prospects for economic development (Weisbrod, Vary et al., 2001). Besides impacts in travel time, there has been increased awareness about the increases in pollutant emission caused by traffic congestion. Regional and local governments have endeavored to diminish all these congestion impacts in the congested areas. These efforts, like all the efforts made by politicians, are evaluated using measures of effectiveness. The selection of the measures of effectiveness has to be done carefully as they will direct funds of future investments. Turner et al. (1996) provide recommendations for the selection of these measures of effectiveness. For example, matching the measures of effectiveness with the goals and objectives of the study, and identifying the error levels of calculation in relation to the measured level. NCHRP Report 446 (Cambridge Systematics, 2000) introduces these measures of effectiveness as performance measures. This report points out that these performance measures have a key role in the performance based planning process as shown in Figure 1.

Sinha (2007) claims, in this general decision-making context, that these indicators have to be: i.- Appropriate (i.e. it should be an adequate reflection of at least one goal or objective of the system action), ii.- dimensionally consistent (i.e. it should fit the dimensions of the evaluated problem. The performance measure should be comparable across time periods and geographic regions), and iii.- defensible (i.e. it should be clear and concise so it can be communicated effectively to intended audiences).

FIGURE 1: ELEMENTS OF A PERFORMANCE BASED PLANNING PROCESS (CAMBRIDGE SYSTEMATICS, 2000)
1.1 CONGESTION MEASURES IN THE TRAFFIC PLANNING AND MONITORING CONTEXT

These recommendations in a general decision-making context can be further specified for the traffic planning context. SRA (1999) points out that a good congestion performance measure (CPM) should be relevant (i.e. have a monotone relationship and be as highly correlated as possible with the defined goal or impact caused by congestion). Several studies and reviews about CPMs can be found in the literature (Lomax, Turner et al., 1997; Bremmer, Cotton et al., 2004; Schrank and Lomax, 2005) but the relevant aspects have not been widely analysed or discussed in the literature.

Beside congestion impacts on delay, Litman (2007) recognizes that a good CPM is expected to be a good descriptor of the congestion impacts, i.e. delay, emissions. In this way, recent awareness of other traffic impacts provides a new dimension in which the CPMs need to be evaluated. Several efforts have recently been carried out to incorporate green indicators at different levels of aggregation (Bigazzi and Bertini, 2009; Choi and Frey, 2010). The scope of these studies has been link, intersections or metropolitan areas. However, for monitoring congestion impacts in different types of traffic installations and road networks, the capability of the area-wide indicators has not been widely studied in terms of the available enhanced data capabilities or the environmental aspects.

Besides these shortcomings, current congestion performance measures use the output of long term planning models. This made the indicators insensitive to the dynamics of congestion. Current improvements in traffic information and data availability have not been followed by corresponding evaluations of how congestion indicators describe the impacts of congestion.

The capacity of capture the effects of congestion (in traffic performance and emissions) and dynamic aspects of congestion are important and necessary for CPMs to be useful and efficient tools for policy makers and traffic engineers.

1.2 OBJECTIVES

The objective of this research is to provide better understanding about CPMs for monitoring the road system. The present study is devoted to analyzing the factors that impact the relevance of the CPMs, that is, the factors that impact their capability of capturing the impacts of congestion. A special focus is on pollutant emissions.

1.3 SCOPE

The study of the relevance requires to know the impacts (delay for example), as well as the CPMs. In practical applications, if the impacts (delay for example) are perfectly known, the congestion indicators lose their importance. However, in most practical application for monitoring the impacts are not known and the indicators are used as proxies. The present study uses data where impacts and the impact proxies (i.e. CPMs) are known in order to compare their descriptive capabilities.
1.4 STRUCTURE OF THE PAPER

The structure of the paper is as follows: the first section is the present introduction. The second section presents the literature research. The third section describes the methodology. The fourth section presents the results. The fifth section presents the conclusion and discussion. The recommendations for future research are presented at the end of the study.

2 LITERATURE STUDY

The estimation of congestion first requires a study on the definition of congestion. The first subsection is devoted to this topic as well as describing some CPMs. The second briefly describes the existing literature about emission models as well as the selection ground of the emission model in the present study.

2.1 DEFINITION OF CONGESTION

The literature presents two approaches for defining congestion that can be applied for monitoring purposes: the travel-time approach and the bottleneck approach (Morán and Bang, 2006). Earlier studies considering either of these approaches have proposed suitable CPMs. In the case of the travel-time approach, the suitable indicators are: Excess Delay (ExD), Travel Time Index (TTI), and Relative Speed Reduction (RSR). For the bottleneck approach, the suitable indicator for monitoring purposes is Standing Still Seconds (SSS).

2.1.1 EXCESS DELAY – ExD

Excess delay is defined as shown in (1) below:

\[
ExD = TR_{obs} - TR_{ref} = \frac{\sum_{i \in N} f_i \times tt_i}{\sum_{i \in N} f_i \times l_i} - \frac{\sum_{i \in N} f_i \times tt_i^{ref}}{\sum_{i \in N} f_i \times l_i} \tag{1}
\]

where, \( f_i \) is the flow on link \( i \), \( tt_i \) is the travel time on link \( i \), \( tt_i^{ref} \) is the reference travel time on link \( i \), \( l_i \) is the length of link \( i \), and \( N \) is the number of links in the network. The Travel Rate is the inverse of the Network Speed and describes the consumption of time per kilometer travelled in the network. The Excess Delay, defined in Eq. 1, is then the extra consumption per kilometer caused by congestion compared to the reference level. If information from each individual driver \( k \) is available for each link, then the indicator becomes:

\[
ExD = \frac{\sum_{i \in N} \sum_{k \in E} tt_{i,k}}{\sum_{i \in N} \sum_{k \in E} l_{i,k}} - \frac{\sum_{i \in N} \sum_{k \in E} tt_{i,k}^{ref}}{\sum_{i \in N} \sum_{k \in E} l_{i,k}} \tag{2}
\]
2.1.2 Travel Time Index - TTI

The Travel Time Index (TTI) has been used in various studies mainly in United States (Schrank and Lomax, 2005). It is defined as the ratio between the congested and non-congested or free-flow travel times. The proposed aggregation method uses VKT\(^1\). \(i\) is the Vehicle-Kilometers Travelled in link \(i\), the indicator can be expressed as:

\[
TTI = \frac{\sum_{i \in N} VKT_i \times TTI_i}{\sum_{i \in N} VKT_i} = \frac{\sum_{i \in N} VKT_i \times \frac{t_{i}}{t_{i}^{\text{ref}}}}{\sum_{i \in N} VKT_i}
\]

(3)

If information on individual trips is available, the expression above becomes:

\[
TTI = \frac{\sum_{i \in N} \sum_{k \in I} l_{i,k} \frac{t_{i,k}}{t_{i,k}^{\text{ref}}}}{\sum_{i \in N} \sum_{k \in I} l_{i,k}}
\]

(4)

2.1.3 Relative Speed Reduction - RSR

Previous studies in Sweden (SRA, 1999) used the Relative Speed Reduction (RSR) as a performance measure for a link:

\[
RSR_i = \frac{S_{i}^{\text{ref}} - S_{i}^{\text{obs}}}{S_{i}^{\text{ref}}} \times 100\%
\]

(5)

where \(S_{i}^{\text{ref}}\) is the reference speed and \(S_{i}^{\text{obs}}\) is the observed or measured speed on link \(i\) during the peak traffic period. The above link indicator can be aggregated to measure area congestion. Different approaches can be considered for aggregating this indicator. The Weighted Average Relative Speed Reduction (RSR\(_{WA}\)) indicator is defined as:

\[
RSR_{WA} = \frac{\sum_{i \in N} \sum_{k \in I} l_{i,k} \frac{S_{i,k}^{\text{ref}} - S_{i,k}}{S_{i,k}^{\text{ref}}}}{\sum_{i \in N} \sum_{k \in I} l_{i,k}}
\]

(6)

where \(S_{i,k}^{\text{ref}}\) is the reference speed for user \(k\) on link \(i\), \(S_{i,k}\) is the observed speed for road user \(k\) on link \(i\), and \(l_{i,k}\) is the distance covered on link \(i\) by user \(k\). Another expression for the Relative Speed Reduction indicator for an area network can be derived by considering the Network Speed (defined as the total distance travelled in the network divided by the total time spent in the network, as shown below in Eq. 7).

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\(^{1}\) VKT stands for Vehicle-Kilometers Travelled. VKT for link \(i\) is defined by \(VKT_i = \sum_{i \in N} f_i \cdot l_i\), where \(f_i\) is the flow in link \(i\) and \(l_i\) is the length of link \(i\).
Network Speed \( S_{\text{NET}} = \frac{\sum_{i \in N} \sum_{k} l_{i,k}}{\sum_{i \in N} \sum_{k} t_{i,k}} \) \hspace{1cm} (7)

The network level speed reduction indicator can be derived by using the network speed, \( S_{\text{NET}} \), instead of the Link speed, \( S_{i} \), in Eq. 5.

\[
\text{RSR}_L = \frac{(S_{\text{NET}})_{\text{ref}} - (S_{\text{NET}})_{\text{OBS}}}{(S_{\text{NET}})_{\text{ref}}} = \frac{\sum_{i \in N} \sum_{k} l_{i,k}}{\sum_{i \in N} \sum_{k} t_{i,k}} \frac{\sum_{i \in N} \sum_{k} l_{i,k}}{\sum_{i \in N} \sum_{k} t_{i,k}} \hspace{1cm} (8)
\]

In empirical studies, the above indicator has been shown to have the narrowest confidence interval among the presented indicators (Morán, 2008).

2.1.4 Queue Indicator

The bottleneck approach considers, in general, design variables or apriori parameters (i.e. travel demand). Unfortunately, demand cannot be empirically observed when its value is above capacity. In this way, queue becomes suitable for empirical estimations using this approach. “Time in queue” is the usual indicator when dealing with links or single servers (for example using the Markov MM1 model). However, in road networks where vehicles circulate at speeds that vary in a continuous range, “Standing-Still-Seconds” (SSS) will be a more adequate indicator.

The literature shows some studies aggregating indicators for road networks using the critical speed for queuing as under 3 km/h with no consideration of the distance to the previous car (Amini, Shahi et al., 1998). This is a sound assumption when considering streets in the city center and it will be used this study.

2.2 Pollutant Emissions: Model Requirements and Choice.

Methods for measuring emissions at an area level are usually affected by the ruling weather conditions at the moment when the data collection takes place. On the other hand, if every single vehicle is measured, the elevated cost would make the analysis prohibitive. Microsimulation has been preferred in recent studies due to the possibilities of obtaining data in an extremely disaggregated manner (Boulter and McCrae, 2007; Chen and Yu, 2007; Zhang, Chen et al., 2009) and recent efforts have focused on implementing an integrated approach (Stevanovic, Stevanovic et al., 2009). A detailed review of the literature about simulation and emissions can be found in Smit (2008). Thus, microsimulation is used because it allows data to be collected in an extremely disaggregated manner in time and space dimensions.

Barlow et al (2007) reviewed available instantaneous models and recognized that MODEM and PHEM performed equally well at predicting light duty vehicles, despite MODEM being older than PHEM. It also recognizes its suitability over an entire route. MODEL estimates pollutants for each second based mainly on instantaneous speed and acceleration (Joumard, Jost et al., 1995). The
MODEM project was initially created by a consortium during the Drive V1053 EU Project MODEM, and is now managed by TRL-UK (Joumard, Jostb et al., 1992). A review of microsimulation and instantaneous emission modeling can be found Boulert PG and McCrae (2007).

3 METHODOLOGY

The first section describes methodologies in previous for studies on the relevance of the indicators. The second section describes the experiment design used in the present study.

3.1 RELEVANCE ANALYSIS

The relevance analysis is divided in three sections: simulation platform, data processing, and regression analysis.

3.1.1 SIMULATION PLATFORMS

Previous studies on relevance considered simulation platforms of two areas of dense urban areas in Stockholm corresponding for Sankt Eriksplan and Valhallavägen (Moran, 2011). This study recognizes “groupings” in data for each the simulated networks (see Figure 2 ) and identifies that the factors that could have affected the results are the differences between the considered sites.

Those differences were car fleet, the percentage of heavy vehicles, and the topology of the network. These factors can have created groupings in the scatter graph considered in the analysis. The characteristics of the selected zones are: interrupted flow, mixture between residential and commercial areas, reduced parking and two or more road hierarchy types of the road network. The simulations were carried out in VISSIM (PTV, 2009). This study also recognizes that when comparing indicators across several areas, CPMs with smaller variation around the mean value shows poor capabilities for capturing the impacts of congestion. This pointed out that these two aspects of a congestion performance measure can act in an opposed manner.

If the variation around the mean value is smaller, then a smaller sample sizes is required to shown statistical significant difference.
3.1.2 DATA PROCESSING

Data was collected every second for every vehicle in the network. The impacts (delay and emissions) were later aggregated in five-minute intervals. The impacts of congestion are expressed in total area-wide values divided by the vehicle-kilometers travelled during each five-minute interval. Dividing the total impacts by the vehicle-kilometers provides a better comparison between the two areas of different sizes. The first three five-minute intervals (i.e. the first 15 minutes) are part of the warming up of the network and are excluded from the analysis. Ten random seeds for generating the flow were applied.

The impacts are:

- Delay [seconds/veh-km]
- Carbon Monoxide emissions CO [mg/veh-km]
- Hydrocarbon emissions HC [mg/veh-km]
- Carbon Dioxide emissions CO2 [mg/veh-km]
- Fuel consumption [mg/veh-km]

The congestion performance measures were estimated using the formulas above. These congestion performance measures are:

- "Excess Delay;" ExD [min/km]
- "Travel Time Index;" TTI [%]
- "Relative Speed Reduction – Weighted Average;" RSR_WA [%]
- "Relative Speed Reduction – networks as a Link;" RSR_L [%]
- “Standing Still Seconds”; SSS [seconds]

3.1.3 REGRESSION ANALYSIS

Scatter plots can be generated for each impact-indicator pair (congestion impact on the y-axis and the CPMs on the x-axis). Each point in the scatter plot corresponds to five-minute interval observation of the congestion performance measure on the horizontal axis, and congestion impact on the vertical axis. The analysis considers visual inspection as well as numerical estimation of the regression.

3.2 EXPERIMENT DESIGN

The present study is devoted to analyze the factors that affect the correlation between CPMs and congestion impacts. Two experiments are considered:

- The first experiment focuses the car fleet composition.
- The second experiment focuses on the percentage of heavy vehicles.

3.2.1 CAR FLEET COMPOSITION

The analysis considering the car fleet composition considered that all the car vehicles belong to the same vehicle class. The classes of vehicle considered were European Gasoil cars 1 to 4 (i.e. G1, G2, G3, G4) and European diesel cars (D4). The car type is an important factor for emissions as it
causes variations in the emissions. The present analysis reviews if this variation affects the
capabilities of the indicators to describe congestion. The hypothesis is that if the car fleet
composition is a significant factor, it will influence the correlation between indicators and
emissions. In other words, a CPM will be strongly correlated when one engine type is considered
but poorly correlated when another engine type is considered.

3.2.2 Percentage of Heavy Vehicles
The analysis referring to the variation in percentage of heavy vehicles considered constant flow
level. For each of the simulated areas, four scenarios were considered: 1/4, 1/2, 3/4 and the
original of the percentage of heavy vehicles. So if the original percentage of heavy vehicle was
8%, the experiment considered 2%, 4%, 6% and 8% of heavy vehicles. The hypothesis is that if
the percentage of heavy vehicles is a significant factor, the differences or “groupings” between the
two sites should decrease as the percentage of heavy vehicles decreases and gets closer to zero.

4 RESULTS

4.1.1 Car Fleet Composition Results
Figure 3 shows examples of the scatter plots having, on the vertical axis, CO1 (first row in graphs
a, b, c, and d), CO2 (second row in graphs e, f, g, h) and HC (third row in graphs i, j k and l). The
horizontal axis corresponds to ExD (first column), RSRWA (second column), RSRL (third
column) and SSS (fourth column). For example, each point in Figure 3a) represents the CO1
emissions during a five-minute interval divided by the VKT (y-axis) and the value of the ExD for
the same time period. Simulations for Sankt Eriksplan are shown in red (G1), blue (G2), green
(G3), yellow (G4). The only simulation for Valhallavägen is shown in black indicating G1 with
circles and D4 with “+”. The original “grouping” in previous studies considered the G1 engines
for Valhallavägen corresponding to black circles. Original grouping in Sankt Eriksplan considered
engines G2, G3 and G4 (see Figure 2) and cannot be directly observed in Figure 3.
For visualization purposes, Figure 3 shows G1, G2, G3 G4 and D4 for Sankt Eriksplan in the color
described above, and D4 in black “+”. Only 5 random seeds are shown in the figure.
It can be observed that if only European Gasoil 1 engines only are considered (i.e. G1 with black
circles and red squares), the results of the correlation analysis will show the poorest correlation
(i.e. lowest R2 values) for RSR_L. When European only Diesel 1 engines are considered (i.e. D1
with black pluses and cyan dots) the results of the correlation analysis will also show for the
poorest correlation for RSR_L. This points out that the type of engine considered does not affect
which indicator is more relevant. This confirms previous studies results that CPMs with smaller
variation show low relevance.
FIGURE 3: SCATTER PLOTS. CO1, CO2 & HC(x-axis) vs. EXD, RSRWA, RSRL, SSS (y-axis).

From the figure it can also be deduced that if two areas with different types of engines are to be compared (for example one area with a mix of G1, G2 and other area with all the engine types) the possibilities of using CPMs to capture the emission impacts are strongly restricted. It can be risky to make comparisons between areas in different countries, climates and levels of economical development. However, if the areas belong to the same metropolis (i.e. neighborhoods in cities like Bronx, Manhattan and Brooklyn in New York) in which the car fleet can be considered constant, the capabilities of capturing the impacts of congestion on emissions will not vary significantly. In this last case, it will then be preferred to consider RSRWA or ExD.

4.1.2 PERCENTAGE OF HEAVY VEHICLES RESULTS

Figure 4 shows examples of the scatter plots having on the vertical axis Delay impact (first row in graphs a, b, c), and CO1 emissions (second row in graphs d, e, f). Each one of the points in Figure 4a) represents the delay during five-minute interval (y-axis) and the value of the TTI calculated for the same period. For example, simulations with 25% of the original heavy vehicles are shown in red, using a square for S. Eriksplan and a circle for Valhallavägen.
FIGURE 4: SCATTER PLOTS: DELAY AND CO1 VS. CONGESTION PERFORMANCE MEASURES (TTI, RSRWA, RSRL)

Clear groupings can be observed with Valhallavägen being the upper grouping. Additionally, it can be observed that higher congestion levels are observed for the yellow series (100% of the original heavy vehicles) while lower levels tend to be observed for the red series. However the difference between both sites does not significantly reduce the groupings. Furthermore, the linear regression for each site provides similar values for each site. It can be concluded that the percentage of heavy vehicles does not have an impact in the descriptive capabilities of the indicators.

5 CONCLUSIONS AND DISCUSSION

The importance of measuring congestion and the problematic estimation of CPMs has been described. CPMs are key indicators for decision making and they should fulfill certain characteristics. The present study focuses on the capabilities of capturing the impacts of congestion, i.e. relevance. A framework for the analysis of the capability of CPMs for describing the traffic and environmental impacts of congestion has been presented. Two approaches for defining congestion have been considered and suitable congestion performance indicators have been described. These indicators have been further developed to enable an analysis using microsimulation that is time dependent and, thus, more sensitive to the dynamics of congestion than previous studies.
The study focused first on the car fleet composition and reviewed if it affected the relevance of the indicators. The results showed that even when the emissions varied, the indicators that were poor in relevance continued to be poor. However, attention has to be considered when applying the CPMs in areas or cities where the car fleet varies considerably (for example a city with only gasoil vehicles and others with a certain percentage of diesel vehicles). The study focused later on the percentage of heavy vehicles. It was observed that, for the range of variation considered, this parameter did not affect the relevance of the CPMs.

This study confirms previous studies’ results regarding two aspects that a good CPM has to fulfil. It was shown that these aspects seem to act in an opposed manner. This means that indicators like \( RSR_L \), that show statistical significance even with small sample sizes, can be poorly correlated with some of the congestion impacts. On the other hand, indicators like \( RSR_{WA} \) and \( ExD \), that capture the impacts of congestion, might require larger sample sizes to have statistical significance.

\section*{5.1 OVERALL GENERAL RECOMMENDATION}

The difficulties of measuring congestion in urban areas have been presented. Several aspects to take into account have been described, for example: time dependent aspects of the phenomena, methods for taking in to consideration the preferences of the users, capabilities of capturing other environmental impacts, statistical efficiency of the indicator in terms of required sample size, correlations between the input parameters required for the calculation of the congestion performance measures, etc. Given the diversity of the aspects analysed, it is likely that one indicator will best perform in one aspect, and another indicator in another aspect. In order to provide a recommendation about the most suitable indicator, it will be necessary to know some of those characteristics.

However, in order to provide an overall general recommendation that considers a balance between all the aspect, a decision framework is necessary. Resnik (1987) refers to the \textit{Maximin rule} in the framework for a decision under ignorance. This rule will compare the minimum utilities (i.e. disadvantages) provided by the selection of each indicator and will choose the indicator whose minimum is the maximum for all the minimums. Applying this framework requires answering the following questions:

\begin{itemize}
\item[a.] What are the disadvantages of using a very reliable indicator, if it has low relevance?
\item[b.] What are the disadvantages of using a very relevant indicator, if it has low reliability?
\end{itemize}

Given that the purpose of the CPMs is to provide information to decision makers or road users, then the disadvantages of using a very reliable indicator that has low relevance appear to be larger than in the other case. This means that the minimum \textit{minimum-utility} occurs when choosing a reliable indicator with low relevance. In the same way, the maximum \textit{minimum-utility} occurs when choosing a relevant indicator with low reliability. Furthermore, the \textit{Maximin rule} is applied to the preferences or disadvantages at a single moment in time. Considering the latest improvements in
data infrastructure and developments in traffic data collection methods, the availability and quality of data has dramatically increased in recent years. This trend is expected to continue. Thus, it is expected that the disadvantages of considering a less reliable indicator will diminish over time.

For readers interested in having a unique answer to a problem that has no unique answer, it can be concluded that the Relative Speed reduction aggregated using vehicles kilometres as weight (i.e. $R_{WA}$) is the preferred indicator.

### 6 Future Research

All data collection methods inherently consider an aggregation method. The presented analysis used disaggregated data collection, meaning that the obtained results were “not affected” by an inherent aggregation method. Further research needs to focus on the impacts caused by each specific data collection method. Special emphasis needs to be placed on the upcoming mobile data collection methods and ubiquitous detector technology currently under development for traffic monitoring. The emergence of GPS and other ubiquitous technologies is improving the possibilities of modelling congestion in dense urban areas as well as for empirical estimations of the congestion situation. An important issue in this regard is the privacy aspects associated with these methods of data collection.

The relevance aspects covered in the present study were connected to the emissions caused by vehicles that suffer congestion. A holistic view of the transportation system should also consider the impacts that congestion has on other road users. For example, studying how residents perceive congestion in their neighbourhoods. It might be expected that, in this situation, queue indicators will be a better understood measure of the congestion impacts than travel-time-based indicators. Another example can be to consider other sustainability aspects, i.e. including the efficiency that other transport modes have together with cars. This will provide a better descriptor of the performance of the transport system. Further research should be focused on efforts to integrate these aspects.

It was argued above that congestion performance measures have to be defensible. This becomes important when communicating the concept to non-experts. The acceptance of a congestion performance measure by the politician, for example, is important. Furthermore, studies of the information in the form of congestion performance measures that travellers can use need to be undertaken.

### 7 References


