Analyses & Evaluation Traffic Safety ,Management and ITS in crashes (Case Study: Shiraz)

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Abstract

The aim of this paper is to present and apply a new evaluation framework for traffic management and intelligent transport systems, to assist urban transport authorities in assessing relevant policies and technologies as to their performance. The principles behind performance measures and indices are outlined, along with a description of the framework development methodology. Two key performance indicators (KPIs) for the mobility and traffic accident respectively are formulated. Then, the new KPIs are applied to a case study in Shiraz, involving the introduction of a scheme granting priority to buses at signalized junctions. The results from the before-and after-analysis are reported and interpreted. It will be seen from the standpoint of the applicability of the evaluation framework.

Keywords:

Intelligent Transport Systems, Traffic Efficiency, Traffic Safety, Traffic Management

1-Introduction

Cities today share common transport problems and objectives with respect to traffic management, and put great focus on intelligent transport systems (ITS), but have different characteristics and individualities.

In the absence of a set of widely accepted performance and transferable methodology, it is very difficult to globally assess the effectiveness of urban transport policies ITS. Indeed, cities have often developed their own performance indices with the aim of evaluating the effectiveness and success of individual traffic management policies and ITS implementations. However, this have been mostly used on an ad hoc basis, and as a result, refer only to the city in question and are not able to provide objective conclusions about whether a specific policy or technology that had certain effect in one city could have similar or different effects in other ones.

As identified by a focus group consisting of representatives of 16 European cities in May 2010, the development of a set of common key performance indicators/indices (KPIs) can assist in overcoming the issue of the comparative assessment of traffic management and ITS(Zavitsas, et al,2010) by providing on innovative benchmarking process.

Four strategic themes of urban traffic management have been tackled: traffic efficiency, traffic safety, pollution reduction, and social integration and land use. The aim of this paper is to present two of developed KPIs for the themes of mobility and traffic accidents within the strategic themes of traffic efficiency and traffic safety respectively.

2- Conceptual framework of performance measurement

This section first identifies the needs from performance measurement in urban traffic management ITS, and then provides a description of the development methodology of a common evaluation framework.

2.1. Requirements of performance measurement

Performance measurement and monitoring significantly impact development, implementation and management of existing transport plans and programs, and largely contribute to the identification and assessment of alternatives. Moreover, performance measurement and monitoring enable obtaining the data necessary to compare different projects and programs in future scenarios and to evaluate the same projects and systems at different time points (before and after analysis).

Performance measures should be classified according to dimensions or market segments. Measures are related to broad goal categories, such as traffic efficiency, traffic safety, pollution reduction and social inclusion. These many dimensions make performance-Based planning more challenging in the transport field than in more narrowly focused sectors.
Performance indices, on the other hand, combine various measures into a single indicator, potentially covering multiple dimensions, or even goal categories. Performance indices are relevant to planners and decision makers that intend to reduce the complexity and volume of performance-related data that must be regularly monitored or factored in to a specific decision.
Other desired functionalities stated by the cities were that performance measurement that should:

- Promote cities' interests by reflecting both the users' satisfaction and the system operator's concerns,
- Make use of existing data, as collected by cities are ready, and should not necessitate a collection of any new data,
- Consider the individuality of cities,
- Be easy to apply and simple to convey to the public, and
- Be projectable by means of integration with existing models.

3- Definition of key performance Indices

The main advantage of KPIs is simplicity; as it is much easier to understand grasp a single number rather than a large collection of individual measures, whose meaning often requires trained inside and careful analysis. The disadvantage, nevertheless, is that and aggregate number does not provide immediate inside in to which aspects of performance are changing or why, make it difficult to distinguish the sensitivity and index to changes in its components measures. However, this ambiguity may lead to some other advantages. The index increases the opportunity for all modes and markets to be included, conveys the idea that each service is important, and elevates the discussion about how best two measure and report system performance. This operation between modes and sectors enhances awareness, broadens perspectives and leads to more comprehensive solution.

3.1. Traffic efficiency- Mobility

The vast majority of urban traffic management policies and solutions, including those involving ITS, have the improvement of traffic efficiency as their objective. While the implementation of a specific policy or technology

may have several objectives across the spectrum of urban traffic management, traffic efficiency usually figures high among them. This makes the quantification of the performance in terms of traffic efficiency very important. As an essential component of traffic efficiency, mobility is defined as the ability of transport system to provide access to jobs, to recreation, shopping, intermodal transfer points on the other land users, which is one of its primary proposes. It expresses the ease or difficulty of performing trips at either the application specific level, i.e. on certain defined routes connecting specific origin and destination vacations, or at the network-wide level, i.e. between a large number of origin and destination zones across the city, and may refer to the private or public transport networks on their own, or to the entire system.
The primary constituent performance measure of mobility is the average travel time. Hence, the mobility performance KPI defined here essentially compasses the average travel time to different destinations in the highways and public transport networks expressed in time unites, normalized by the distance to the destinations, and weighted by importance according to the goals and objectives of the application under consideration. The mobility KPIs, I_{mob} , expressing the average travel rate (defined as travel time per unit length) in minutes per kilometer, is thus formulated as follows:

$$I_{MOB} = w_{PV} \cdot \sum_{r \in R_{PV}}^{|R_{PV}|} w_r \frac{ATT_{PV}^r}{D_r} + w_{PT} \cdot \sum_{r \in R_{PT}}^{|R_{PT}|} w_r \frac{ATT_{PT}^r}{D_r} \qquad (1)$$

Where:

r	a rout (specific OD pair) among a set of selected R_{pv} and R_{pt} on the road and public transport network respectively,
ATT^r_{PV}	Average travel time in minutes for route r on the road network
ATT^r_{PT}	Average travel time in minutes for route r on the public transport network
D_r	Length in kilometers of route r
w_r	Represents the weight of route r
W_{PV}	Represents the weight of the travel time on the road network
W_{PT}	Denotes the weight of the travel time in public transport

Within the average travel time assessment the route weights W_r have to be determined with values from 0 to 1, with the target sum set to 1. The special concern of the analysis influences this section of routes (origins and destinations), as national and regional authorities are likely to have different needs than local authorities. In general, locations of public services relevant to the examined special concern, the main road network junction according to the road hierarchy of the examined area, and the public transport terminals at the desired level of debt, should all be considered. It should be noted that the dimensionless weights W_{PV} and W_{PT} are to be determined to an expert-based technique, such as the Delphi method (Linstone &Tourof, 1975; Nijkamp et al, 1998)

3.2. Traffic safety- Accidents

Despite considerable improvement in recent years, safety is still a key issue within transport planning, as many people are involved in road accidents every day, often suffering injury or death. A variety of measures aiming at reducing traffic accidents have been introduced throughout the last decades, with ITS increasingly playing a prominent rule (e.g. collision control, variable speed warning signs, etc.) as is expected, the improvement of traffic safety as a priority for city authorities and the quantification of a city' s performance is that aspect is essential.

The safety level of transport infra structure is defined by number of accidents on one hand, and by the impact of the accidents on the other. Accident numbers are fairly straight forward to obtain and analyze; however, the quantification of the impact is more complex and is mostly measured as the number of people injured or killed. (Elvik et al,2009). The main factors influencing road injuries are: exposure (the amount of travel), accident rate (the risk of accident per unit of exposure), and accidents severity (the outcome of accidents concerning injuries).

Based on these considerations, a KPI for traffic accidents is defined, taking into account the fact that each city has its own traffic and accident characteristics by introducing weighting factors to specific accident type and severity categories. The accidents KPI are thus formulated as follows:

$$I_{ACD} = \sum_{l \in L}^{|L|} \left\{ w_l \cdot \sum_{se \in SE}^{|SE|} \left[w_{se} \cdot \sum_{m \in M}^{|M|} \left(w_m \cdot \frac{ACD_{l,se,m}}{DTV_l} \right) \right] \right\} \qquad (2)$$

Where:

w_{se}	Weight representing the importance of reducing the number of casualties in accidents with a specific severity *se* from the set of possible severity levels *SE* (uninjured, slightly injured, seriously injured or killed)
w_m	Weight representing the importance of reducing the number of casualties in accidents involving a specific traffic mode *m* from the set of possible traffic modes *M* (car, truck, bus, motorcycle, bicycle, pedestrian)
w_l	Weight representing the importance of link *l*, among the set of links *L* of the network, in terms of safety
$ACD_{l,se,m}$	Number of casualties of severity users of mode *m* on link *l* on an average day
DTV_l	Daily traffic volume on link *l* in million vehicles

The values of w_{se} , w_m and w_l can be varied between 0 and 1, but it should be ensured that the values of each importance item sum up to 1. Similarly to the mobility KPI, their values can be determined through an expert-based technique, such as Delphi method.
It should be noted that the index defined by equation (2) considers that accidents occur on links.
Nevertheless, due to the fact that traffic management and ITS applications have different impact areas, it is often more appropriate to differentiate between accidents at links and junctions. In that case, an identical accidents index for junctions can be defined, whereby for each junction *j* among the set of junctions considered *J* a weight value w_j will apply. The indices of links and junctions can be then added to deduce the total accident index; in has to be ensured, however, that the sum all w_l and w_j values is 1.

4. Application and results

To demonstrate the operation and applicability of the performance evaluation framework, the KPIs defined above are applied to a case study in the city of Shiraz, so as to conduct a before- and after- assessment of the performance of three bus lines following the implementation of priority measures.

4.1. Case study: in Shiraz

In 2015 the Shiraz transport authority investigated the potential application of a system granting priority to buses at traffic signals, which resulted in the compilation of a set of technical specification to traffic managers. The investigation was followed up by a pilot experiment, during which bus priority was implemented at four intersections in Shiraz, the encouraging results of which led to the decision of deploying the system on several bus lines. Installation work on lines 10, 70 and 148, the location of which within the inner city of Shiraz is shown in figure 1, began in 2015. The system employed was one of dynamic (on-demand) priority, whose concept of operation relies on radio transmissions at 5-second intervals, through which the bus communicates to the signal controller its current position and anticipated time of approach. Approximately 60 signalized junctions were affected, involving a total cost of installation in excess of 1.2 million. It was anticipated that the application of the system on the three lines would result in an average travel time saving of the order of 30 seconds per passenger. Given an average volume of 8 million passengers per year on each of the lines, the anticipated saving would correspond to a saving of one vehicle on each line for the bus operating company.

Fig. 1. Shiraz bus lines 10, 70 and 148

4.2. Mobility assessment

For the assessment of the mobility of travelers as a result of the introduction of the priority measures each of the three bus lines has been broken up into four route segments of given length per direction, resulting in seven route segments per line and 21 route segments in total. Average peak-time bus travel times for each of the route segments have been measured over periods before and after the implementation of the priority, in order to identify travel time gains. Furthermore, a number of route segments of given length have been identified on the private transport network as being affected by the priority scheme (one for line 10, three for line 70and one for line148, resulting of 5), for which average vehicle traffic travel times were measured for the same periods before and after the implementation. The mobility KPI, as expressed by Equation (1), is used to perform an assessment of the overall impact of the scheme in terms of mobility on each of the lines, for public and private transport separately, taking equal weights for each of the route segments.

The results of the mobility assessment are shown in Table 1. As can be seen, the priority measures appear to have resulted in a reduction of the public transport travel rate values (and hence in improved public transport mobility) for all three lines. Consequently, an overall decrease from 3.83 min/km to 3.22min/km for public transport is recorded across the three lines, corresponding to an improvement (reduction) of 18.94% in public transport mobility. On the other hand, the priority measures seem to have negatively affected private transport mobility on lines 10 and 70, resulting in increased average travel rates, but not on line 70, for which slightly improved private transport mobility is recorded. Consequently, the

Overall private transport mobility has seen a marginal deterioration of 23.15%, expressed as a slight increase in the average travel rate from 3.25 to 2.64min/km.

In order to determine the overall change in mobility, the weights w_{PV}=0.3 and w_{PV}=0.7 have been set, following consultation with a group of experts from the municipality of Shiraz. As such, the overall mobility index is evaluated for the three lines separately, as well as for the three lines together, and the results are included in Table 1. As can be seen, an improvement (reduction) in the total mobility index on all the lines is found, corresponding to an average travel rate saving of 0.16min/km, i.e. 21.05%.

Table1. Mobility assessment result

I_{MOB} (min/km)	Public transport Before	After	Change	Private transport Before	After	Change	Overall Before	After	Change
Line 10	4.12	3.6	-14.44%	1.55	1.24	-25%	2.83	2.42	-19.72%
Line 70	5.27	4.21	-25.18%	6.33	5.27	-20%	5.80	4.74	-22.59%
Line 148	2.11	1.87	-12.83%	1.88	1.41	-33.33%	1.99	1.64	-23.08%
Total	**3.83**	**3.22**	**-18.94%**	**3.25**	**2.64**	**-23.15%**	**3.54**	**2.93**	**-21.05%**

4.3. Accidents assessment

In the evaluation of the bus priority scheme in terms of accidents, only data from line 70 has been available, split in four segments per direction (i.e. a total of eight segments). Namely, the numbers of casualties due to road traffic accidents over four –year periods before and after implementation of the priority scheme have been supplied, categorized according to severity (death, serious injury, slight injury) and road user type (pedestrian, cycle, 2-wheeler, 4-wheeler). In addition, average daily vehicle traffic flows have been obtained for the respective segments and periods. The accidents KPI, as expressed by Equation (2), are used to perform a safety assessment of the priority system on line 70, for the different severity categories separately, taking equal weights for each of the route segments. Following a consultation with a group of experts from the municipality of Shiraz, the weights for casualties of the different road user group have been set to w_{cyc}=0.25, w_{2w}= 0.2, w_{4w}=0.15, and w_{ped}= 0.4 for cycles, 2-wheelers, 4-wheelers and pedestrians respectively.

Table2. Safety assessment result for bus line 91

I_{MOB} (min/km)	weights	Deaths		Serious injuries		Slight injuries		overall	
		Before	After	Before	After	Before	After	Before	After
Cycles	0.25	0	0	0	0	0	0	0.00	0.00
2-wheelers	0.2	2	1	38	3	0	36	0.20	0.20
4-wheelers	0.15	6	5	54	1	34	20	0.50	0.10
pedestrians	0.4	2	1	6	11	68	68	0.30	0.42
Total	**1**	**0.21**	**0.13**	**1.81**	**0.51**	**3.74**	**1.04**	**0.50**	**0.36**

The results of the accidents assessment are shown in Table 2. As can be seen, the priority measures on bus line 70 appear to have resulted in marginally improved casualty rates for deaths, and in notably improved slight injuries rates; corresponding occurrence per million vehicles seem to have dropped from 0.21 to 0.13 and from 3.74 to 1.04, respectively. However, it can also be seen that these findings are accompanied by a worse serious injuries rate, with the increased number of pedestrian and cycle serious injuries including a rise of the corresponding index value from 1.81 to 0.51 occurrences per million vehicles. Compiling the three partial indices to determine the overall change in casualty levels (with the help of the experts the weights for the severity levels have been set to w_{death}= 0.85, w_{ser}=0.1 and w_{sli}=0.05 for deaths, serious injuries and slight injuries respectively) per road user category and overall, it can be seen that the accidents rates for cycles and pedestrians have risen, while the ones of 2-wheelers and 4-wheelers have dropped. As a result, the total accidents index has risen marginally, from 0.50 to 0.36 casualties per million vehicles.

4.4. Discussion

Given that introduction of bus priority is a measure primarily aimed at improving public transport mobility, the results obtained from the mobility assessment are in line with that would be expected, i. e. better mobility for public transport without deterioration of private transport mobility, and consequently better overall mobility on all three bus lines. Accidents, on the other hand, appear to have stayed at fairly constant levels as a whole, with the increased index values of serious injuries and pedestrians being largely attributed to the fact that the smaller casually occurrence numbers of those categories are weighted more heavily than the higher occurrence numbers of slight injuries. It should be noted that the priority measure have also resulted in a drop in vehicle traffic volume along line 70, which may have further contributed to increase in accident index values. Nevertheless, the study highlights a potential “collateral damage” of the bus priority scheme, and it may be worth further investigating the circumstances of the pedestrian casualties in question.

From the point of view of assessing the evaluation framework itself, the results show that the developed KPIs seem to be able to reflect major phenomena while offering an impartial evaluation. It is worthy to note that, in a purely mobility-oriented case study; the new performance evaluation framework not only captures the intended and expected improvement of overall mobility, but also identifies the subtle impact in term of safety, which potentially requires attention. This demonstrates the applicability and usefulness of the KPIs, thus forming the first step of their validation process.

5. Conclusion

While urban traffic management and ITS are charged with the task of dealing with today’s transport problems in cities, the absence of common evaluation measure prevents objectively assessing the performance of individual policies and technologies, in order to make use of past experience and lessons learnt in the field. Recent European Commission funded research (CONDUITS) has taken a step in this direction and has defined a new performance evaluation framework. This paper has presented two of the developed KPIs for the themes of mobility and traffic accidents, along with their application to a case study the city of Shiraz, the result of which have demonstrated their relevance the applicability.

Nevertheless, it is recognized that the implementation of the KPIs requires the consideration of several dimension in order to become an effective tool of decision-making in the field of traffic management and ITS, and therefore work in this direction continues. The next steps will thus concentrate on applying the KPIs to more case studies of different characteristics, so as to continue their validation and parameter fine-tuning. Further work will also focus on the testing and validation of KPIs for pollution and social inclusion, as well as on the development of new measure and indices.

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