Definition of Key Performance Indicators for Energy Efficient Assessment in the Transport Sector

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Abstract: The transport sector is constantly growing as well as its complexity and energy consumption. One way to reduce the involvement and the volume of data to evaluate and monitor the energy efficiency of the sector for cities authorities is by using Key Performance Indicators (KPIs). This paper describes a set of KPIs to measure and track energy efficiency in the transport sector. The KPIs that are summarized in this paper were identified based on a literature review of mobility projects/strategies/policies that had been implemented in cities around the world. Future applications, which are presented at the end of this article, will give a better understanding of the systems and its components.

1 INTRODUCTION

City authorities, all around the world, are currently facing the increasing cost and demand of energy in which transport sector represent at least a 33% of the total consumption. At the same time, this sector is far away to be efficient. High use of private vehicles, as well as, low levels of Public Transport (PT) and ALternative Modes (ALM) use and several other factors had raised the energy requirements.

As a result, governments have been implementing policies on better use of energy through improvements in technologies (e.g. bio fuels, cleaner vehicles etc.) and changes in inhabitants Transport Choices (TC). In the meantime, these improvements are generating a wide range of benefits to the whole mobility system, as reduction of pollution, general cost improved health conditions, environmental sustainability and others (Marcucci et al., 2012)

The evaluation and monitoring of Energy Consumption (EC) is limited due to the complexity of the transportation sector. Other sectors with high complexity, like the industrial or communication domain have commonly implemented Key Performance Indicators (KPIs) to simplify the complexity and the amount of necessary data for monitoring and evaluation processes. Several Energy Efficiency (EE) indicators, have been published in literature from different sectors and types of studies as the presented in (Zhang et al., 2012), which focuses on the factory production. In the transportation sector, KPIs definition and standardization has not been performed mainly because the approach of the monitoring and evaluations processes are still performed in traditional ways based on authorities previous experiences and empirical knowledge. As a consequence, studies from some sectors like the ones presented in (Bosseboeuf and Richard, 1997; Marcucci et al., 2012; Litman, 2013, international Energy agency, 2012, etc.) are not comparable.

Actions from International Energy Agency (IEA), the organization for economic Co-operation and development (OECD), and World Energy Council (WEC) have overcome with common practices and methods for measuring EE, however today there is not a universally accepted EE definition, neither a common way to measure it.

This paper presents a literature review on these policies and proposes a set of KPIs for performing energy assessments. This set aim to provide metrics that will be used to determinate the success of policies' actions on the sector as well as the timely information that authorities need to track for evaluating the performance of the sector in order to make changes and achieve sustainable transport systems. This document is organized as follows: Section 2 describes the KPIs for transportation sector and the summary of the identified KPIs is presented in Section 3. Section 4 gives an overview of KPIs possible applications. Section 5 describes how complex system can be evaluated and monitored by measuring KPIs. Finally, section 6 gives conclusions and future work.

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2 REVIEW OF KEY PERFORMANCE INDICATORS IN THE TRANSPORTATION SECTOR

Due to the constant increase in EC by the transport sector, countries had been implementing measures to reduce its consumption. The measures can be categorized in *technological* or *cleaner vehicles strategies* and *Optimization* or *mobility management strategies*. The first one tries to promote new technologies that use less energy/more efficient, which includes establishment of limits over transport companies. Equally important, the *Optimization* or *mobility management strategies* optimize the way of energy use. This means that they change the mobility patterns by promoting public transport, connectivity between modes, a higher vehicle's occupancy and the use of alternative modes. A research conducted by Victoria transport Policy Institute from Canada found that mobility management strategies generally achieve more planning objectives than cleaner vehicle strategies, particularly if cleaner vehicle strategies have rebound effects (Bosseboeuf and Richard, 1997; Litman, 2013; Litman, 2007; Usón et al., 2011). Rebound effects, also called take back effects, refer to the increase in car use that result from increased fuel efficiency, cheaper fuels or roadway expansion that increases traffic speeds.

Although there is not a standard for measuring EE, several studies agreed that the main inefficiency comes from irrational use of private vehicles inside and outside the cities and the lack of alternative sources of energy (biofuels, electricity, etc.). In contrast, an study performed by Usón et al., 2011 found, that bus, regional train and on foot transport modes are more EE and considers several indicators, such as fuel consumption, infrastructure, time travelled and environmental cost (defined in term of cost for nature replacement).

Under those circumstances, the use of private vehicles should be tracked (measure) and one of the ways to do it is by looking the availability of them. Indicators such as the number of vehicles per 1000 inhabitants, reflect not only the availability but also the potential to implement politics to reduce the use of cars. Eurostat, the statistical office of the European Union, calculates that if users of vehicles, which have not being manufactured could cover their needs by using PT, the efficiency would improve by 80%, because the number of vehicles per 1000 inhabitants will drastically decrease from 411 to 250 vehicles (Usón et al., 2011; International Energy Agency, 2014).

Indirect measurements such as the average income can reflect the number of vehicles per 1000 inhabitants. Statistics from ADEME (2012) show that countries with low average income, such as Romania and countries mostly from Central and Easter Europe, own less than 500 cars per 1000 inhabitants, with use below 5000 km/year. In contrast, countries like Finland, Slovenia, France, UK, Sweden, Germany and Norway, consider as higher income countries, have a higher average or equal to 700 cars per 1000 inhabitants with a use between 12000 and 16000 km/year (Lipscy and Schipper, 2013).

Furthermore, it is required to know the composition of the vehicles fleet, such as the age distribution, type of engines, average travelled distance, etc., to calculate their contribution to the final EC. As an illustration, Sweden has the higher consumption per vehicle compare with Italy, which is caused by powerful cars and lower share of diesel engines. On the contrary, Italy has least powerful cars with a high percentage of diesel engines. Consequently, the average car size, horsepower and the percentage share of diesel are important factors on the EE calculation (International Energy Agency, 2014; Kaparias and Bell, 2011).

Energy Consumption (EC) not only happens during the travelled time, in fact, there is an energy cost on manufacture, maintenance, recycling and the city infrastructure (roads and parking places etc.) (Usón et al., 2011; Ministry of ecology and sustainable Development and energy, 2014). Thus, the EC/carbon footprint (CFP) of vehicles should be calculated having into account its life cycle as well as its performance on the road.

As it was mentioned before, energy saving can be achieved by increasing the efficiency on the technical performance of the vehicle (*technological* or *cleaner vehicles strategies*). Similarly, decreasing the car size and/or horsepower, increasing the average vehicle occupancy, or transforming driving behaviour can also lead to savings in different proportions. However, vehicles that are more efficient, are connected with regressions in driving behaviour, by a growth in the number of vehicles and the travelled kilometres; therefore, overall consumption tends to rise (Bosseboeuf and Richard, 1997). To demonstrate this issue, Japan has one of the most efficient transport systems, besides, it has a high amount of mini-cars with average occupancy of one, and the average fuel use per passenger-km is similar to US, Japanese cars uses about 15% less fuel/km than US cars. In addition, Japanese cars are considerably smaller and less powerful. Therefore, the main reason why those levels are similar is congestion (Lipscy and Schipper, 2013).

At the present time, other factors like the increasing population along with the expanding urbanization rate, the growing health and environmental concern and rising fuel prices point to reduce the private vehicle use, which results in the increase of demand for other transport modes (Litman, 2013; Frank et al., 2010). In average, cars require four times more energy to transport one passenger per km than PT (rail transport and buses), and five times more energy than rail transport alone (trains, metros and tramways) (International Energy agency, 2012). Additionally transport's specific consumption for a lorry is around 15 times higher than using a railway(Usón et al., 2011).

Examples from Italy and France illustrate how behaviour changes achieve energy savings by implementing rewards on PT and/or ALM use (Litman, 2005; Metz, 2013). Although car travel will not disappear completely, many would prefer to drive less and rely more on alternatives modes like walking or cycling if they perceive that there are enough facilities to make that mode change (Litman, 2013).

Other actions in Belgium and Germany had been bringing multiple economic and environmental benefits. In Belgium employees receive 21 cents/km compensation and in Germany prizes awarded in a lottery to the employees that satisfy a certain quota of miles biked to work per year. Not to mention well known actions for stimulating modal shift such as: building an attractive environment for pedestrian traffic, introducing traffic calming measures for motor vehicles, improving the quality of cycling routes and adding the missing route links, as well as, ensuring its proper maintenance (Ministry of ecology and sustainable Development and energy, 2014; *National Action Plan for Walking and Cycling 2020*, 2012).

3 IDENTIFIED AND PROPOSED KPIS FOR THE TRANSPORTATION DOMAIN

The present section defines a common evaluation framework for the energy/emissions performance of smart cities in the form of a set of KPIs, which can be use in one or more transport modes. They might be an efficient baseline to compare multiple mobility projects on their individual impact in the cities' transport system.

The KPIs that are summarized in this section can play a key role in the construction of Intelligent Transport Systems (ITS) towards the improvement of energy consumption/ carbon emissions of cities. Table 1 presents the KPIs that where identified from the aims of the mobility policies/projects (that affect the EC) that were briefly described in the previous section.

Table 1: Identified KPIS in the transport sector by mode.

ID	Name	Mode		
		ALM	PT	PV
KP1	Performance of freight transport			■
KP2	Fuel consume by freight transport			■
KP3	Unitary gross annual energy savings		■	
KP4	Density of passenger transport		■	
KP5	Number of passenger transported by fuel unit		■	
KP6	Number of fuel units per passenger		■	
KP7	Offer volume in public transport		■	
KP8	Total CO_2 emissions for travel (multiple modes) passengers		■	■
KP9	Total CO_2 emissions for travel (multiple modes) freight		■	■
KP10	Private vehicles density rate			■
KP11	Average vehicle power			■
KP12	Share of diesel engine in total vehicles		■	
KP13	Share of public transport in total passenger traffic			■
KP14	Share of heavy trucks in total freight traffic			■
KP15	Share of new units in vehicles fleet		■	■
KP16	Presence of alternative fuels vehicles		■	■
KP17	Presence of alternative fuels vehicles offering	■		
KP18	Traffic-free (TF) and on-road (OR) routes	■		
KP19	Annual usage estimation in alternative modes	■		
KP20	Facilities density in alternative modes	■		
KP21	Density of links in multimodal [multimodal=more than one transport mode]	■	■	■
KP22	Link's Length in multimodal	■	■	■
KP23	KPI's change per time unit			
KP24	KPI's percentage of change			

4 KPIS FOR EVALUATION AND MONITORING OF COMPLEX SYSTEMS

It is well know that manufacturing systems share with cities transport sector the great complexity of their systems as they are composed mainly by several information sources and a great flow of data. However, in contrast with the transport systems of cities, industry uses KPIs for the monitoring and evaluation processes. Several applications and studies have described the process of implementing those KPIs. In (Florea et al., 2012), presents how the performance evaluation of several components in the manufacturing flow can be simplified by applying a division compose by layers, where KPIs are used for monitoring and evaluating all their aspects.

Others applications go further with same idea of dividing the system in layer, but with other filters, for example, who can access the information, in other words, which information is relevant for whom (Hossain, 2014).

5 POTENTIAL APPLICATIONS

Global studies have shown that the mobility model that we have today, will not work tomorrow ("CivitasInitiative | Clean and Better Transport in Cities," n.d.; OECD, 2009; Arriaga et al., 2007). The increasing population and the growing number of cars in cities compromise all the citizens' life aspects (health, destination, time, etc.). Multiples solutions had been proposed from authorities across the world, and all have in common "*smart*". Cities need to integrate systems that use real time data that can optimize personal mobility and as a consequence, optimize the EC of the whole system. The integrated systems can also serve as a platform for monitoring and evaluation for city authorities, in this case, a simplification of data (set of KPIs) proposed in this paper can effectively be applied. A methodology described in (Mantilla R. et al., n.d.) presents an option for monitoring and evaluating energy efficient mobility projects in smart cities with the use of the KPIs explained in this document.

6 CONCLUSIONS

Energy in the transport sector has become a general issue. In order to decrease its consumption, energy management should be applied. In this paper KPIs were proposed, towards an overview of all the aspects in cities transport energy. In addition, potential use of these KPIs can be done in applications that nudge people to make EE transport choices as well as provide awareness about their choices consequences inside the system.

Finally, future work will be in the application side by applying these KPIs in smart cities around Europe that have substantial differences in their transport systems, so it will be possible to measure the impact of the different identified factors.

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