Methodology for Energy Efficiency Assessment in the Transport Sector for Smart Cities

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Abstract: To measure the impact of transport projects in smart cities can be expensive and time-consuming. One challenge in measuring the effect of these projects is that impacts are poorly quantified or are not always immediately tangible. Due to transport projects nature, it is often difficult to show results in short term because much of the effort is invested in changing attitudes and behaviour on the mobility choices of city inhabitants. This paper presents a methodology that was developed to evaluate and define city transport projects for increasing energy efficiency. The main objective of this methodology is to help city authorities to improve the energy efficiency of the city by defining strategies and taking actions in the transportation domain. In order to define it, a review of current methodologies for measuring the impact of energy efficiency projects was performed. The defined energy efficiency methodology provides standard structure to the evaluation process, making sure that each project is being evaluated against its own goals and as detailed as it is required to the level of investment. An implementation in a smart city of the first step of this methodology is included in order to evaluate the implementation phase of the defined process.

1 INTRODUCTION

Cities are the places where most of the produced energy is used. By 2012 urban mobility was 40% of all CO_2 emissions, in which road transport represent 32,6% of the total energy consumption in Europe, being private cars one of the principal emitters. Therefore, reducing car use and promoting public transport (PT) are both essential to reduce the energy consumption/CO_2 emissions in cities (International Energy agency, 2012).

This paper presents a methodology that provides guidelines for measuring the impact of transport projects in energy efficiency/carbon emissions and to perform evaluations all through the mobility project processes. The developed methodology engaged authorities from different cities to make a conscious and schematic procedure for early projects stages, so this will facilitate analysis and evaluation. The process is divided into eight steps, starting from the goals and objectives settlement until the final evaluation, which encourage cities to make a consistent process that will suit specific city applications, local conditions and target groups. The methodology compromises the following steps: definition of goals, identification of target groups, identification of variables, energy evaluation, set targets, implementation, analysis and strategy evaluation. The results from the evaluation process can be used to refine transport projects and achieve the city objectives. The energy efficiency methodology will be implemented in three smart cities and this paper will present the implementation in one of them. A smart city is understood as a city who use technology to enhance interoperability between its components, to reduce consumption of resources, especially in this case, energy, and to improve the life of their inhabitants.

This paper is organized as follows: section II gives an overview of transport projects evaluation issues. Section III introduces the most relevant methodologies for mobility project evaluation. Section IV describes the defined energy efficiency methodology. Section V presents the application of the methodology in a smart city and finally section VI gives the conclusion and future work.

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2 EVALUTION ISSUES IN TRANSPORT PROJECTS

Results of the evaluation process of projects can provide the sensation of achievement in the sense of remuneration for what was invested (e.g. money and time), which is fundamental for the motivation in transport projects and specifically from the energy efficiency point of view. This process allows cities to demonstrate that they have achieved the results or identify if they need to make improvements or corrections in the taken actions. Unfortunately, there is not a methodology that is commonly accepted and worldwide applied, which forces cities to create and implement energy projects by their own. In consequence, they become isolated entities and the knowledge coming from their transport projects is lost or can't be understood by others, which makes impossible to make further comparisons with similar approaches.

Additionally to the issue of the missing process definition, it is commonly known that some transport projects are not being evaluated or monitored. The core of this problem is on the time nature of the projects. Transport projects on energy efficiency or/and CO2 emissions reductions are based on changing inhabitants attitudes, which is a process that takes time. In consequence, to measure short-term changes do not reflect the whole impact of the projects.

3 METHODS FOR ENERGY EFFICIENCY ASSESSMENT

As mentioned before, there are several methodologies and standards for energy mobility evaluation. In this section, the ones in which this methodology is based are presented. It includes two European frameworks for mobility management projects: European Union's MOST MET program (Finke, 2001), Sweden's SUMO program (Rosqvist et al., 2004)), and the international standard ISO 50001 ("ISO 50001 - Energy management - ISO,").

MOST MET (MM) is the toolkit for Mobility Managements from the European Union MOST program, which combines monitoring and analysis processes for mobility management measurements to assess the impact of transport projects. SUMO is a method for systematic planning to standardize evaluations. It focuses on evaluating soft parameters, like communication initiatives. ISO 50001 is an international standard that works as a tool for organizations to establish systematic procedures to improve the energy performance of systems. The norm is known worldwide as the plan-do-check-act cycle which forces organizations to go for changes and constant improvement.

4 METHODOLOGY FOR ENERGY EFFICIENCY

The defined methodology was created to support smart cities to make energy assessments and provide a basis for comparing their performance and improvements (see Figure 1). The methodology starts by defining the project scope and goals. Next steps define the target groups and the relevant variables that show how the energy use is affected. Step 4 describes the energy evaluation that has as output, a list of performance indicators and baselines that on the next step are used to define targets. The step 4 values are going to be monitoring during the implementation step, as well as in connection with monitoring and evaluation. Feedback from several steps is proposed in order to make improvements in projects already in progress or in the initial steps. A more detail description of each step is provided in the following sub-sections.

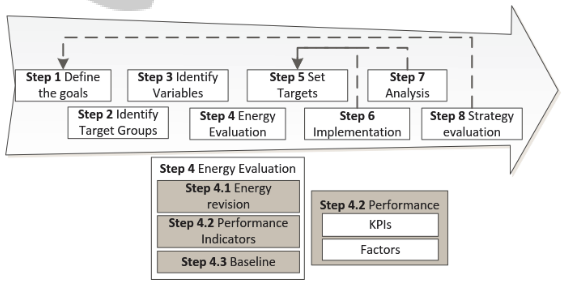

Figure 1: MoveUs methodology for energy efficiency assessment.

4.1 Step 1. Define the Goals

The first step for an evaluation process is to set a clear goal, supported by objectives. The objectives should be in a SMART structure (**S**pecific, **M**easurable, **A**chievable, **R**elevant and **T**ime framed) (Doran, G.T., 1981). To set a *specific* objective it is required to answer the five "Wh" questions: 1) who is involved? 2) What does the city wants to accomplish? 3) Where? Identify a location, if it is local impact. 4) When? Establish a time frame. 5) Why? *Specific* reasons or benefits of accomplishing the goal.

Measurable is a concreate criteria for the further measurement process. *Achievable* is related with how the objectives are going to be achieving, and if they are realistic with the current state of the system. *Relevant* objectives represent believes of what the authorities want to achieve and the use of the local resources. Finally, *Time frame* helps to prioritize the objectives, resources and work. Having clear objectives allows a proper implementation of the methodology and project evaluation process.

4.2 Step 2. Identify Target Groups

In order to measure the effects of mobility projects in an effective way (in this case, less use of resources), the early identification of the target group is a good start. Target groups are defined as the group of people that have similar needs and travel patterns but often different ways to approach the information. The identification consists in a careful description that includes the location, common characteristics, and if possible, how they can be approached.

4.3 Step 3. Identify Variables

The primary goal of step three is to identify the variables that describe the objectives of the project. These variables should be well-documented and easily-obtainable, so they will reflect the energy use/carbon emission levels changes. As an illustration, if one of the objectives is to increase the use of PT, one variable can be the average number of passengers per bus.

A way to start is by determining all energy resources: electricity, biofuels such as ethanol, biodiesel and biogas, hydrogen, and conventional fuels like gasoline, diesel and natural gas, by having in mind the objectives previously describe on step 1. By identifying the energy sources, the tracking of the transport system components that consume more energy is easier and the variables will describe them.

4.4 Step 4. Energy Evaluation

After having the list of variables that are relevant for measuring energy use /carbon emission levels and the energy resources of the transport system, the next step is to use all the information from previous steps to perform the energy evaluation. This evaluation consists of three steps: Energy Revision, Performance Indicators and Baseline.

4.4.1 Energy Revision

The energy revision has three stages: 1) *current usage and energy consumption* of the system including its past and present, and all the energy sources from step 3. With this information it is possible to 2) *identify points with high energy consumption*, which can be reduced by changing the habits of the target groups. As a consequence, this step will give to authorities the potential 3) *improvements* in the energy consumption performance of the transport system. The potential improvements could be prioritizing based on the characteristics of each city.

4.4.2 Performance Indicators

Using the system information and the knowledge acquired in the energy revision and previous steps, authorities can choose a group of indicators that reflect the energy efficiency levels. These indicators includes Key Performance Indicators (KPIs) and Affecting Parameters. The KPIs should be associated with the objectives and target groups of the mobility project. The affecting parameters reflect the environment in which the project will be materialized. The way they affect the system is by increasing or decreasing the energy consumption/carbon footprint values. A set of KPIs and affecting parameters for energy efficiency assessment in transport sector were describe for this methodology through a literature review (M. Fernanda Mantilla R. et al., n.d.); Mantilla R. et al., n.d). Cities can consult these documents or stablish their own parameters.

4.4.3 Baseline

The second output of the energy evaluation is the baseline. The baseline predicts the behaviour of the KPIs based on the historical information, so it is a quantitative reference of the objectives. In the implementation step, KPIs must be checked regularly and compared to the baseline that is calculated here. The Baseline period is used for obtaining the equation that shows how the system behaves and the next stage is the expected behaviour. In this stage the baseline value is compared with the measured value during the implementation to keep in track the energy savings.

4.5 Step 5. Set Targets

Based on the overall mobility project objectives, detail target values should be stablished. These target values not only contain the desirable value, but also the time when the system is going to be at that state. At this point the project should include schedules, resources and responsibilities for achieving the targets, so they can be used as an input for the implementation step.

Target values should be practical and achievable, as well as flexible to reflect changes in the objectives. One way to make sure that target values are achievable is by observing the baseline value. The baseline shows the existing energy pattern, so any target value to far from that patter is closer to be unachievable.

4.6 Step 6. Implementation

In the implementation step, authorities should have always in mind target values and their time frames, as well as all the control operations. Those operations make sure that entities in charge of the implementation round will apply actions to take the transport system to the desired stage. Additionally this step gives feedback to the step 5 in the sense that if the target value exceeds city capacity, the set target must be redefined.

4.7 Step 7. Analysis

When the objectives time frame comes, authorities should be prepared to perform an analysis. In this step the data acquired during the implementation process is used, not only for face target values, but also to recognize what are the factors or actions behind the system current behaviour. Thus a careful control procedure performed on the previous step would be the core of the analysis and a clue for the next step.

4.8 Step 8. Strategy Evaluation

In this step the cities will evaluate the whole mobility project process. The evaluation determinates the effectiveness of the projects in fulfilling the objectives defined on the first step, to identify the nonconformities and opportunities for improving the energy efficiency projects.

If authorities face nonconformity, the necessary corrective and preventing actions must be initiated and implemented. That is why this step must be used as a feedback to the methodology step 1, so the cycle of the methodology starts again. Time aspects in analysis and evaluation are important. Changing peoples' attitudes and behaviours takes time, so it often takes one or several years before the last two steps can be measured.

5 METHODOLOGY INSTALLATION IN SMART CITY (TAMPERE, FINLAND)

In order to test the methodology, it was implemented in a smart city that is presented in this section.

5.1 Main Goal and Objectives

The main goal of Tampere's energy efficiency project described in this paper is to contribute to Tampere's sustainable mobility goals by increasing the share of walking, cycling and public transport. Therefore, the main objectives include:

1. Reduce the use of private car
2. Increase the modal share percentage for alternative modes (cycling and walking).
3. Increase the use of public transport
4. Increase public transport service awareness in the Tampere area

5.2 Target Group

Tampere city target groups are car users and commuters. Indirect Tampere's target group is its population of 220,446 inhabitants. The number of private cars registered in Tampere is 90,906.

5.3 Identified Variables

Tampere energy sources for transport mainly consist on conventional fuels such as gasoline, diesel and natural gas. However their composition is, by law, a combination of Biofuels with traditional fuels called Bio-share, which in 2014 constitute 8% in both gasoline and diesel. Additional sources are electricity which is in initial states to be implemented. Some of the identified variables can be seen in the following Table 1.

Table 1: Identified variables for Tampere city.

Variable	Objective
Energy consumption per vehicle	1,3,4
Fuel consumption per vehicle	1,3,4
Calories consumption in alternative modes	1,2
Modal share percent in each mode	1,2,3,4
Number of public transport passengers	3,4
Number of cyclists	2

5.4 Energy Evaluation

5.4.1 Energy Revision

Transport has an important role in total emissions for Tampere City; however it had decreased its emission from 300 ktCO_2 in 2010 to approximately 280 ktCO_2 by 2013. Part of the reductions might come from changes in the modal share distribution, Figure 2 shows that PT and Alternative modes (ALM, walking and cycling) had been increased and car use decreased. Even though the emissions have been reduced, increases in car ownership had been maintaining an average increase of 4% per year (Välimäki et al., 2013).

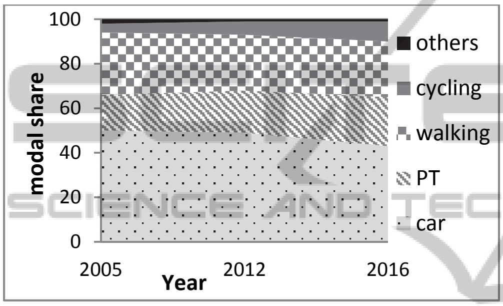

Figure 2: Tampere transport modal share, 2005-2012-2016.

Tampere PT is mainly bus traffic, since 2006 the city has been implementing different strategies such as extending bus services, lanes and traffic light priorities in order to promote its use. PT awareness has been done through maps and books, and new media, such as website and mobile applications ("Tampere City Public Transport," n.d.)

In ALM, Tampere values has been growing as well as the cycle/walking path network. Awareness is done by a cycle route planner only available online through the journey planer website. Additional measures includes improvements in the roads, campaigns like Minä poljen in 2012, and studies such as vitality from walking and cycling (*vitality from walking and cycling*, 2014).

5.4.2 Performance Indicators

Based on the previous information and the objectives that Tampere city has defined, a number of KPIs that reflect the performance of the system as well a set of factors that affect the system were identified, see Table 2 and Table 3.

The table below presents a list of factors that affect the energy efficiency of the different transport modes in Tampere city. The letter *u* shows the energy efficiency scale up. Letter *d* represents the energy efficiency scales down.

Table 2: List of KPIs for Tampere city.

ID	Name
KP4	Density of passenger transport
KP5	Number of passenger transported by fuel unit
KP6	Number of fuel units per passenger
KP8	Total CO_2 emissions for travel passengers
KP10	Private vehicles density rate
KP13	Share of public transport in total passenger traffic
KP16	Presence of alternative fuels vehicles
KP18	Traffic-free (TF) and on-road (OR) routes
KP19	Annual usage estimation in alternative modes
KP23	KPI's change per time unit
KP24	KPI's percentage of change

Table 3: Factors affecting energy efficiency on Tampere city.

	Modes		
	ALM	PT	PV
Station/Stops distance	-	u	-
Amount available Car	-	d	d
Travel distance	-	d	d
Travel time	-	d	d
Temperature	-	u	u
Precipitation	-	d	d
Fog	-	d	d
Support during winter	-	d	d
Car parking	-	-	d
Lights	-	d	d

5.4.3 Baseline

Due to the amount of data and the number of parameters selected on previous steps, only one of the KPI will be used as an example to illustrate of the process done in this step as well as in further steps.

One way to represent ALM modes is by the kilometres of Traffic Free (TF) and On Road (OR) routes. KP18 in Figure 3 shows how the network has been constantly growing. The opportunity implementation can be seen as the savings in emission of citizens that make use of the TF and OR network. One way to calculate the savings is by assuming a reference scenario, in this case will be a car, with average gasoline car carbon conversion factor (CCF) of 217gCO2/km. The equation use to get the savings is:

$$KP18s = KP18\ [km] * CCFcar\ [gCO2/km] \quad (1)$$

Tampere has the potential to increase the emission saved by users cycling through the extension of the network kilometres. The Figure 7 shows the baseline equation (graph on the upper-left of the chart), based on the equation for 2016 the probably saving will be 142.45 $kgCO_2$ (Baseline), with the implementation of extension is expected to increase the saving by 5% reaching 149.58 kgCO2 (Target line) by the same year.

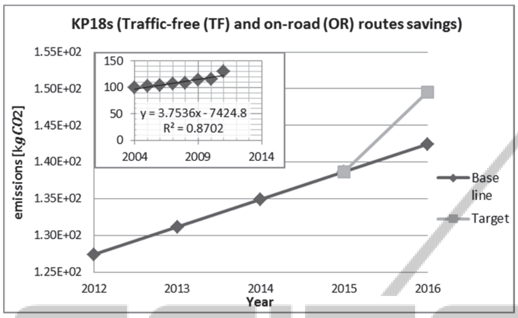

Figure 3: KP18s Traffic-free (TF) and on-road (OR) routes savings for Tampere city.

The same process is done on the others KPIs. So in that sense the behaviour of Tampere's transport system was simplified through the methodology implementation, so now authorities can focus on Applying actions to improve different areas of the system, by taking into account the previously described process.

6 CONCLUSIONS

This paper presented a methodology that support cities to assess energy efficiency in their transport sector. The methodology presents a systematic and logical process that offers the opportunity to compare targets with other cities and in consequence opens a way to learn from results. In addition, it facilitates collecting data and organizing it in a way that is easy to establish cause and affect relationships.

Future work is under progress, and the implementation of the mobility services for Tampere city support the steps 6, 7 and 8, of this methodology in which 7 and 8 will be part of the evaluation process of the system that will be reported in the future.

Eventually the methodology that is proposed here will be under evaluation of the cities where it was implemented. This feedback will be use to refine the process, so the methodology's potential use as a common part of energy efficiency projects in the transport sector and its potential in making the public sector work more efficiently will increase.

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