Parameters Affecting the Energy Performance of the Transport Sector in Smart Cities

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Abstract: The energy requirements of cities' inhabitants have grown during the last decade. Recent studies justify the necessity of reducing the energy consumption/emissions in cities. The present paper gives an overview of the factors affecting the energy consumption of the citizens based on studies conducted in cities across the globe. The studies cover all the factors that affect citizens' mobility choice that at the end, affects in the same way their final energy consumption. The results of the review are being used to support authorities in mobility decisions in order to achieve a sustainable transport sector in smart cities.

1 INTRODUCTION

Cities authorities have to face a constant growing population in less space, which not only means overcrowded systems but also a great demand of energy. Additionally, it increases traffic jams, health care problems, etc., resulting in a compromise quality of life. Solutions to those problems include integrated systems that use real time data to optimize individuals' mobility in a city scale without compromise travellers' destination.

It is relevant to understand the factors that influence individual choice, so authorities can modify citizens travel patterns. At the moment, goverments have been changing infrastructures capacity either by pricing roads or taking back fuel subsides. However, authorities actions have a limited impact if the affecting factors, like weather. have a higher impact on citizen choice.

Currently, city authorities lack a tool to determinate the future or current energy/emissions in transport sector. In (Mantilla R. et al., n.d.) a procedure for cities to measure the energy performance of the transport sector has been provided. However, it does not specify the parameters that can be use to assest energy efficiency evaluation. A set of performance indicatos reported in (M. Fernanda Mantilla R. et al., n.d.) and in the current document, will provide a metric for authorities to judge the energy efficiency impact of mobility projects.

This paper present the extensive literature review that provides a initial stage for the development of mobility projects, not only for authorities, but also for all the sectors interested in inhabitants mobility preferences or individual mobility choices. The paper is organize as follows: section 2 gives an overview of the affecting parameters. Section 3 presents the summary of idenfitied affecting parameters. Section 4 sugest an application, and section 5 present the conclusions and future work.

2 REVIEW OF PARAMETERS AFFECTING ENERGY CONSUMPTION/CARBON FOOTPRINT VALUES

This section presents the parameters that affect the Energy Consumption (EC)/Carbon Foot Print (CFP) values. In the first place, environmental factors such as a bad weather, may increase congestion, travelled time, operational cost, or reduce PT reliability. In this group of parameters, precipitations reduce average speed on 5-40% with snow and 3-16% with heavy raining (Leviäkangas et al., 2011). These reductions leads to longer travel times, higher fuel consumption, and higher EC from services such as heating, air-conditioning and lighting (Considine, 2000; Guo et al., 2007).

Another environmental factor is the temperature,

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(Guo et al., 2007) which has a correlation between thermal sensitivity and drive travel demand. High temperatures increase outdoor activities while on the contrary low temperatures lead to decline them. In the case where outdoors activities are in a walk or cycling distance, the EC does not increase, however countries like Finland, where the common vacations are taking in cottages by 4 or 5 hours driving, results in an increase of energy use and/or carbon emissions.

Other system that is highly affected by the weather is the PT. Several studies had shown that buses are usually more sensitive to weather than trams/trains, in addition, the trip purpose (work, leisure, etc.) and time of the week (working days vs weekend) increases or decreases that sensibility (Considine, 2000; Guo et al., 2007; Winters et al., 2007). Despite the weather influence over the transport sector, the core in the emission levels/EC depends on each of the people decisions on where to go and how. In other words, *"daily actions of millions of individual actors. Reducing transports environmental impact ... will... ultimately require a more thorough understanding of how individuals travel decision are motivated and/or constrained by other factors"* (Sitlington, 1999).

The following section describes some of the variables that affect people's transport choices. Having in mind that those decisions are the heart of the final EC, they represent a great potential for reducing the overall consumption and/or emissions.

2.1 External Factors

2.1.1 Public Transport

Increases in the use of Public Transport (PT) can increased by understanding the factors that discourage its use, such as crowding, service reliability, high prices, frequency, speed, lack of information, and accessibility (Guo et al., 2007; Sitlington, 1999; Paulley et al., 2006). High prices decrease the PT use, contrary, low prices, increased number of vehicles and their frequency raise PT share. Factors with similar effect includes: high population density, Gross domestic product (GDP) per capital and the number of buses operating per 1000. G. Santos et.al. (2013) (Santos et al., 2013) found that passenger's characteristics such as age, number of children and gender affects their modal choice. Fuiji et al. (Fujii and Taniguchi, 2006) concluded that the primary reason of the citizens for not using PT is the negative image associated with it (personal perception). In case of habitual car users, they had a lack of knowledge about Alternative Modes (ALM) or PT in terms of perception of time control (travelled time). Extra facilities like intermodal connection can change the public PT perception, by promoting advantages of each of the modes (Danish Ministry of Transport, 1996).

2.1.2 Cycling and Walking

Precipitation and temperature have strong influences on cycling choice. Studies found that rain, wind and temperature have independent effects. In (extremely) low temperatures people commonly switch from biking to car/PT, otherwise people walk or cycle, especially with higher temperatures (>15). Heavy snow reduces cycling by 60%, slippery surface by 20% and cold weather by 10% (Sabir et al., 2008; Nankervis, 1999; Flynn et al., 2012). A way to reduce the impact on biking is by bringing more infrastructure support such as snow clearing and sanding of ice along cycling routes, dedicated bike lines and bike-friendly transit (Winters et al., 2007). Other factors that increase bicycle use include traffic-calmed streets, safe and dry and easy access network, and facilities like parking and PT share (Sitlington, 1999).

As an example, cities like Örebrö, Sweden has a priority plan for snow removal and sanding of cycle paths in the winter time and removal of sand in spring. Oulu has same priority as well as Zaanstad in the Netherlands (Heikkilä, 2013). Another example is Copenhagen, where 80% of cyclists keep on going in winter, where 90% of Copenhageners own a bicycle ("Encourage Winter Cycling: Managing mobility for a better future," 2014).

Danish are a success story where bicycle is perceive as a practical alternative for a safe and fast travel. A survey found that Copenhagen cyclists ride because: it is easy and fast (54%), for exercise (19%) and only 1% for environmental reasons ("Københavns Kommune: Borger," n.d.). As a conclusion, providing well usable infrastructure, encouragement (incentives) and help with bicycle maintenance can bring higher split percent's of cycling riding in cities.

2.1.3 Car Use

The use of private car is less efficient and high energy demanding. The Environmental Protection Agency determined that a drop in temperature from 24°C to 7°C increases fuel consumption in urban trips from 12% to 28% ("US Environmental Protection Agency," n.d.; "Fuel Economy in Cold Weather," n.d.). This efficiency reduction is caused by several phenomena that happen inside the cars. One of the causes is the time that takes for the engine to reach its most fuel-efficient temperature, warming up the vehicle before starting decreases the efficiency as car is using fuel without moving. Additionally, resources in comfort, such as heated seats, window defrosters, and heater fans, requires additional power (“Fuel Economy in Cold Weather,” n.d.).

Authorities all over the globe are encouraging users to switch to other modes through means of promotion of energy efficient behaviour, including energy efficient driving, car-pooling, car sharing, and car-free zones/areas inside to cities (Danish Ministry of Transport, 1996). But changes have to break Travel Choice (TC) processes that are mainly automatic, people only drive without considering other alternatives and the cause of this is the availability of a private vehicle, car ownership is the principal determinant of car use (Sitlington, 1999; Scheiner, 2010).

2.1.4 Infrastructure

Infrastructure refers to physical routes, buildings, etc. that involve long-term capital investment and determines the drive (car, bicycle etc.) conditions during the whole year. Winter and spring are the months for maintenance actions that influence safety, accessibility, mobility and vehicle cost. Winter maintenance operations represent a very substantial portion of year-round maintenance costs (Guo et al., 2007; Tyrinopoulos and Antoniou, 2013). In Canada $1,3 billion are used annually on activities related with snow and ice control in public roads (Leviäkangas et al., 2011). In Finland the cost of maintenance during winter is 54% of the total budget.

Additionally, the design of the infrastructure can determinate the perception of the users. In the case of PT, distance from start or destination point to stops as well as the facilities during winter or autumn (lights and shelter) can change travellers’ waiting and transfer experience. The greatest impact of the infrastructure is in the mode choice. In compact cities with high population density and low available land, short trips are the main kind of trips and use of PT, walking/cycling mode are the main choices (Considine, 2000; Tyrinopoulos and Antoniou, 2013; Scheiner and Holz-Rau, 2007).

2.1.5 Cost and Income

Relative cost of transport modes is an important factor in TC. In the case of PT, the ticket price usually reflects the cost of the system. Instead, private car price is no clear, as it does not include all their external cost, part of the unclearness comes from the fact that most of that cost is subsidy for local governments, representing 7.3% of the European gross domestic product (Sitlington, 1999). On the other hand, household income defines the availability of private car. Results from Mobility Management and housing program (2008) shows that higher average income increases the number of cars per house and their use by 34%. In comparison, modal split with ALM and PT decreases in higher proportion (de Jong and van de Riet, 2008; Tyrinopoulos and Antoniou, 2013; Mobility Management and housing, 2008).

2.1.6 Trip Characteristics

Some trip characteristics such as trip length, time flexibility and trip purpose may affect the weather impact on user’s TC. Long travel distances are more sensitive to weather because of the exposure time. Short trip times are less sensitive to weather conditions. Important trip purpose (e.g. work) might be more sensitive to weather than leisure ones (Guo et al., 2007).

Trip length and time travelled are mainly defined by infrastructure configurations. Basic facilities in suburban areas such as the closest grocery, can determinate the TC. If the perception of the distance is high, car is generally accepted, in contrary, if the distance is short, the use of bicycle or walk is acceptable (Scheiner and Holz-Rau, 2007). M. Sabir et.al. (2008) shows that an additional kilometre of distance increases car use by 26,7% and PT with 2,2%, contrary to walking and cycling that decrease by 23,1% and 7,4% respectively (Sabir et al., 2008) Additionally, TC decisions are mainly done at home and at work, so land design patterns between these two destinations are crucial (Tyrinopoulos and Antoniou, 2013; Mobility Management and housing, 2008; Frank et al., 2007).

2.1.7 Information

At the present time a considerable amount of information is exchanged from transport system consultation. Some of that information tried to motivate car users to switch to PT by empowering them with localised and advice information about ALM/PT and leaving the choice to them (Department of Transport, Australia, 2013). They found that prioritized and effective distributed information improves user’s perception (Sitlington, 1999; Department of Transport, Australia, 2013;

Brög et al., 2002).

2.2 Personal Factors

Several factors can affect the travel behaviour of the city inhabitants. On one side, personal factors can be described as social-demographic characteristics, such as gender, age, education or profession etc.; and attitudinal factors like values, norms and attitudes or perceptions about one specific mode.

2.2.1 Social-demographic Characteristics

Social-demographic characteristics, such as age, gender, income etc., are the source of different choices on similar conditions. By all means, a teenager may view snow differently from an elderly person. M. Sabir et al. (2008) found that age has a great effect on TC, accordingly, older people (older than 60) walk more than people younger than 18. Similar studies in Canada have shown that older adults and women with lower education and higher income are much less likely to cycle than teenagers and men (Winters et al., 2007). However countries like Netherlands, where cycling is broadly-entrenched with daily activities, the cycling rates do not vary across gender or age (Sabir et al., 2008).

Other population that seems to get no affected by weather conditions is the students. It is probably cause by their limited transport options (cycling is cheaper), combined with shorter distance. Consequently, cities with high proportion of students have higher cycling and walking rates (Santos et al., 2013; Scheiner and Holz-Rau, 2007).

2.2.2 Motivations for Change

Initially, to generate some changes, it is required to define and find the inhabitants habits. J. Prillwitz et al. (2009) defined habits as an obstructive factor, as they reduce conscious awareness. Habitual behaviour simplifies and accelerates transport users' actions and/or decisions, reducing perception of travel alternatives, and increase cost for PT/ALM. Both effects become more significant with an increasing frequency of use of the TC. In this study they found two ways to breakup habits, the first one is by interrupted automatic actions and the second one, by changing users' contextual conditions (Prillwitz and Barr, 2009).

One interrupting action is to introduce moral considerations and at the same time ALM information. Web sites such as bike Seasons not only provide useful tips on how to drive a bicycle in all seasons, but it is also used for creating cycling groups. Similar interrupting action is by giving information about their TC environmental impact, especially in early ages. "Traffic snake game" in some countries of Europe, aim to encourage schools, children and parents to adopt ALM, car sharing or PT when travelling to and from school ("Game | Traffic Snake Game,"). In conclusion this kind of actions break the traditional barriers associated with ALM/PT like the additional effort and little comfort perceptions (Prillwitz and Barr, 2009).

To summarize, psychological attachment to car, lack of information and moral are factors that block transport behavioural changes. A good quality of PT, education and moral obligation reduce car use.

2.2.3 Critical Incidents

Another point of view is the critical incidents, where the changes come from incidents like a crash car or having a new car. P. van der Waerden et al. (2003) identified two types of incidents: a change in the number of available alternatives and a change in its characteristics (Waerden et al., 2003).

Changes in the number of available alternatives refer to events that modify the transport composition. A limited number of studies had research about life stages and their potential to break travel habits (Prillwitz and Barr, 2009; Waerden et al., 2003). Changes on the characteristics of available alternatives make reference to modifications in mode like time, cost, and comfort.

3 SUMMARY OF IDENTIFIED PARAMETERS THAT AFFECT THE ENERGY EFFICIENCY IN THE TRANSPOR SECTOR

All the factors that were identified and described in the previous section are summarized in Figure 1 the position of the parameter represent a positive effect. This list of parameters can be compared to the outcomes of the energy efficiency of the transport sector when they are under the effects of any (or several) of them.

4 APPLICATIONS

Mobility authorities have found that, when solving complex mobility problems, they can give incentives, so people will figurate out what to do,

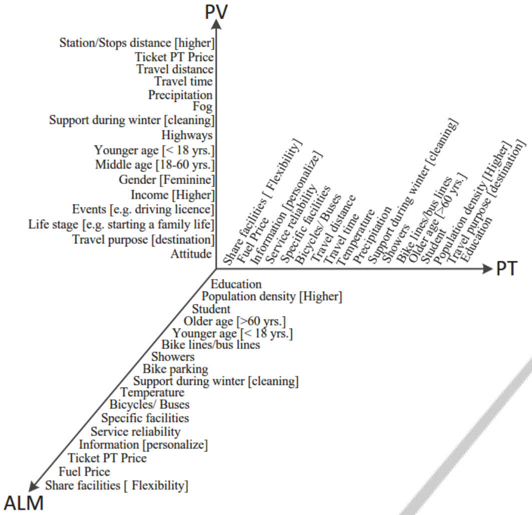

Figure 1: Affecting Parameters: positive effect.

claiming that the system will organize itself. An example from Stockholm showed reductions of cars on 20%, in this specific case, the incentive were a charge in bridges that connect downtown with surrender neighbourhoods, meaning that somehow the traffic flow organize itself (Eliasson and Mattsson, 2006). The factors affecting transport choices can be applied in a way that authorities can give incentives in the case where the target mode (PT or ALM etc.) is affected negatively by the factors, before users make choices or penalize it in situations where the factors are affecting positively so the opportunity for change can be stablished.

5 CONCLUSIONS

Some affecting parameters were presented and summarized in this paper. They are based on the numerous studies and research in mobility. The parameters are significant aspects related to the energy performance of the smart cities, specifically transport sector, which should be taken into account when authorities implement mobility projects. Therefore applications or services that use the parameter can have a better approximation or understanding the transport system performance. Finally, future work will be in the application of those parameters in smart cities.

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REFERENCES

Brög, W., Erl, E., Mense, N., 2002. Individualised marketing changing travel behaviour for a better environment, in: Paper Presented at the OECD *Workshop: Environmentally Sustainable Transport*. pp. 06–12.

Considine, T.J., 2000. The impacts of weather variations on energy demand and carbon emissions. *Resour. Energy Econ. 22, 295–314*. doi:10.1016/S0928-7655(00)00027-0.

Danish Ministry of Transport, 1996. *The Danish Government's Action Plan for Reduction of the CO2-Emissions of Transport Sector*.

De Jong, G.C., van de Riet, O., 2008. The driving factors of passenger transport. EJTIR 3.

Department of Transport, Australia, 2013. *TravelSmart / Living Smart* (WWW Document). URL http://www.transport.wa.gov.au/activetransport/24605.asp (accessed 8.21.14).

Eliasson, J., Mattsson, L.-G., 2006. Equity effects of congestion pricing: *Quantitative methodology and a case study for Stockholm*. Transp. Res. Part Policy Pract. 40, 602–620. doi:10.1016/j.tra.2005.11.002.

Encourage Winter Cycling: *Managing mobility for a better future* (WWW Document), 2014.EPOMM Eur. Platf. Mobil. Manag. URL http://www.civitas.eu/sites/default/files/epomm_eupdate_en_winter_cyling .pdf (accessed 8.13.14).

Flynn, B.S ., Dana, G.S., Sears, J., Aultman-Hall, L., 2012. *Weather Factor Impacts on Commuting to Work by Bicycle* (No. 12-006). Transportation Research Center Farrell Hall, Burlington.

Frank, L., Bradley, M., Kavage, S., Chapman, J., Lawton, T.K., 2007. *Urban form, travel time, and cost relationships with tour complexity and mode choice. Transportation* 35, 37–54. doi:10.1007/s11116-007-9136-6.

Fuel Economy in Cold Weather (WWW Document), n.d. URL http://www.fueleconomy.gov/feg/coldweather.shtml (accessed 8.13.14).

Fujii, S., Taniguchi, A., 2006. Determinants of the effectiveness of travel feedback programs—a review of communicative mobility management measures for changing travel behaviour in Japan. *Transp. Policy 13, 339–348*. doi:10.1016/j.tranpol.2005.12.007.

Game | Traffic Snake Game (WWW Document), n.d. URL http://www.trafficsnakegame.eu/game/ (accessed 2.11.15).

Guo, Z., Wilson, N.H.M., Rahbee, A., 2007. The impact of weather on transit ridership in Chicago. Presented at *the TRB 2007 Annual Meeting*, Massachusetts.

Heikkilä, P., 2013. winter cycling in Oulu- towards new challenges. P*resented at the Winter Cycling Congress,* Oulu, Finland.

Københavns Kommune: Borger (WWW Document), n.d. URL http://www.kk.dk/da/borger (accessed 8.18.14).

Leviäkangas, P., Tuominen, A., Molarius, R., Kojo, H., Schabel, J., Toivonen, S., Keränen, J., Ludvigsen, J., Vajda, A., Tuomenvirta, H., Juga, I., Nurmi, P., Rauhala, J., Rehm, F., Gerz, T., Muehlhausen, T., Schweighofer, J., Michaelides, S., Papadakis, M., Dotzek, N., Groenemeijer, P., 2011. Extreme weather impacts on transport systems.

Mantilla R., M.F., Nieto L., A., Martinez Lastra, J.L., Kotakorpi, E., n.d. Methodology for energy efficiency *assessment in the transport sector for smart cities*. Unpublished.

M. Fernanda Mantilla R., Nieto L., A., Martinez Lastra, J.L., n.d. Definition of Key *Performance Indicators for Energy Efficient Assessment in the Transport Sector*. (Unpublished).

Mobility Management and housing, 2008. Factors Influence Mobility Behaviour.

Nankervis, M., 1999. *The effect of weather and climate on bicycle commuting.* Transp. Res. Part Policy Pract. 33, 417–431.

Paulley, N., Balcombe, R., Mackett, R., Titheridge, H., Preston, J., Wardman, M., Shires, J., White, P., 2006. The demand for public transport: T*he effects of fares, quality of service, income and car ownership. Transp. Policy 13*, 295–306.

Prillwitz, J., Barr, S., 2009. *Motivations and barriers to adopting sustainable travel behaviour.*

Sabir, M., Koetse, M.J., Rietveld, P., 2008. The impact of weather conditions on mode choice: *empirical evidence for the Netherlands*. Dep. Spat. Econ. VU Univ. Amst.

Santos, G., Maoh, H., Potoglou, D., von Brunn, T., 2013. Factors influencing modal split of commuting *journeys in medium-size European cities. J. Transp. Geogr. 30,* 127–137. doi:10.1016/ j.jtrangeo.2013.04.005.

Scheiner, J., 2010. Interrelations between travel mode choice and trip distance: trends in Germany 1976–2002. *J. Transp. Geogr. 18, 75–84.* doi:10.1016/j.jtrangeo.2009.01.001.

Scheiner, J., Holz-Rau, C., 2007. Travel mode choice: affected by objective or subjective determinants? *Transportation 34,* 487–511.

Sitlington, J., 1999. Moving to Healthier people and Healthier Places. *VicHealth, health promotion foundation*, Autralia.

Tyrinopoulos, Y., Antoniou, C., 2013. Factors affecting modal choice in urban mobility. *Eur. Transp. Res. Rev. 5,* 27–39. doi:10.1007/s12544-012-0088-3.

US Environmental Protection Agency (WWW Document), n.d. URL http://www.epa.gov/ (accessed 8.18.14).

Waerden, P. van der, Timmermans, H., Borgers, A., 2003. Key Events and Critical Incidents Influencing Transport Mode Choice Switching Behavior: A descriptive analysis, in: The Physical and Social Dimensions of Travel. Presented at the 10 the *International Conference on Travel Behaviour Research*, Lucerne.

Winters, M., Friesen, M.C., Koehoorn, M., Teschke, K., 2007. Utilitarian Bicycling: *A Multilevel Analysis of Climate and Personal Influences. Am. J. Prev. Med. 32, 52–58*. doi:10.1016/j.amepre.2006.08.027.