ICT cloud-based platform and mobility services available, universal and safe for all users

D4.1 Methodology benchmarking for energy efficiency and carbon footprint

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Abstract: The Deliverable D4.1 presents the methodology framework for measuring the energy efficiency/energy consumption/carbon emissions of transport system applied to each of the pilot cities in the project. The outputs of the methodology are a common set of performance indicators for energy efficiency evaluation and recommendations for the incentives module.

HISTORY

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List of Abbreviations

<Abbreviation>	**<Explanation>**
ADEME	Agency for the Environment and Energy Management
ADT	Annual Distance Travelled
ALM	Alternative Modes
App	Application
CAFE	Corporate Average Fuel Economy
CC	Cubic Centimeter
CCF_{car}	Carbon Conversion Factor for private car
CCF_{mb}	Carbon Conversion Factor for motorbike
CCF_{PT}	Carbon Conversion Factor for Public Transport
CDG	Municipality of Genoa
CFP	Carbon Footprint
CO_2	Carbon Dioxide
Crten	Carbon emission per unit of energy
EC	Energy Consumption
EE	Energy Efficiency
EMT	Empresa Municipal de Transportes de Madrid
EPA	United States Environmental Protection Agency
EU	European Union
GDP	Gross Domestic Product
GPS	Global Positioning System
ICT	Information Communications Technology
ID	Identification
IEA	International Energy Agency
ISO	International Organization for Standardization
ITS	Information and Technology services
KPI,KP	Key Performance Indicator
MOST-MET	MOST Monitoring and Evaluation Toolkit
N/A	Not Applicable
OECD	Organization for Economic Co-operation and Development
OR	On-road Route

pkm	passengers per kilometer
PT	Public Transport
PV	Private Vehicles
QRY	Quaeryon
SICE	Sociedad Ibérica de Construcciones Eléctricas S.A.
SUMO	System for Evaluation of Mobility Projects
TECNALIA	Tecnalia Research and Innovation
TF	Traffic Free road
TRE	Tampereen Kaupunki
TUT	Tampere University of Technology
UITP	International Union of Public Transport
UK	United Kingdom
US	United States
WEC	World Energy Council
WP	Work Package
WWF	World Wildlife Fund

Executive Summary

Cities currently face common transport problems. Especially, European cities have recognized that energy consumption/carbon emissions in the transport sector constitute a considerable percentage of the total energy/emissions that continue to rise year by year. Therefore, cities must take action on this issue and achieve a more sustainable transport system where ITS systems play an important role. However, despite the fact that cities face similar difficulties, each city transport system works in a unique way, so their needs for a performance evaluation framework are also unique.

In the absence of a while accepted performance measures and transferable methodologies on Energy Efficiency (EE); it is difficult to globalize objectives and strategies to improve the EE for all the cities. Indeed, it is quite common that cities develop their own methodology and indicators for the evaluation process of their transport systems. Therefore, those methodologies and indicators become unique and are mostly used exclusively for each city. As a result, there is an absence of a framework in which all the system could be compare, transforming cities in isolate entities.

MoveUs benchmark Energy Efficiency Methodology approaches this problem by developing a common evaluation framework composed by a set of Key Performance Indicators (KPIs) and factors that affect energy efficiency and carbon footprint (CFP), as well as a methodology for the evaluation process. The first part of this document provides a list of KPIs that is based on the goals and objectives of several transport plans and projects. Specific performance objectives and the factors that can modify positively or negatively the transport system performance were identified. The selected KPIs are highly related with the aims of transport projects or/and transport policies.

The next part of the document addresses the variables that affect the habitual modal choices of transport for city inhabitants. By knowing the key factors affecting these choices and the reasons that discourage them, it is possible to estimate how those key factors affect the energy or/and emission levels in the transport sector.

The following chapter outlines the methodology that was developed to evaluate and define city transport projects for EE/CFP, especially for MoveUs Living Labs. The main objective of this methodology is used to help cities to improve their EE by defining strategies and taking actions in the transportation domain. Finally, the last chapter of this deliverable gives an overview of the energy Apps and recommendations for the incentives module in MoveUs project.

1 Introduction

This Deliverable was created within the framework of Task 4.1 (Methodology benchmarking for energy efficiency and carbon footprint assessment) of WP4 (Energy efficiency assessment) of MoveUs project. It includes a research of the state of the art in Energy efficiency and a selection of KPIs and affecting parameters for EE/CFP measure for the transport sector. Additionally the document provides the description and implementation of the MoveUs methodology for energy efficiency assessment in the transport sector.

1.1 Key Performance Indicators and affecting parameters

The key performance indicators, as the name suggests, are indicators used to evaluate performance; in the case of MoveUs is the Energy Efficiency and/or Carbon Footprint (EE/CFP) of the transport sector. The measures for EE are directly related with the evaluation of the transport strategies that each city has. These actions aim to change their transport system in a more sustainable one and this can be only achieved by changing the mobility behavior of the city's inhabitants, moving from private car to public transport (PT) and alternative modes (ALM), such as bicycle and walking.

In order to increase the EE and reduce the EC/CFP of the city, many policies and strategies had been presented from diverse scenarios. Those strategies can be classified into two groups: 1) cleaner vehicles, which are strategies that try to reduce fuel consumption per Kilometer; and 2) mobility management strategies, which try to reduce the amount of travelled kilometers. Based on these strategies, a list of key performance indicators (KPIs) was created containing the most relevant KPIs for the transport domain.

Performance measurement can impact significantly on the development, implementation and evaluation of transport projects. Especially in the last one, they are the reference for determining if the project was successful or not from the energy efficiency point of view. In section 3 of this document, a more detailed explanation about each of the indicators can be found as well as the needs of performance measurement and EE/CFP in urban traffic are defined.

Nonetheless performance measure has a considerable impact on the different stages on a transport project, it is also important to recognize the parameters that affect the EC/CFP values of the city. Well-known factors like weather are considered, however the main idea behind the parameters that we identify can be found in the factors that influence the individuals' transport choice. Citizens' daily actions have a significant impact not only because their decision can affect others, but also because the number of same actions are an important cause of the final EC/CFP city value. Section 4 addresses the variables affecting the habitual modal choices in the transport sector and by knowing the key factors affecting these choices and the reasons that discourage them, it is possible to estimate how those key factors affect the energy or/and emission levels in the transport sector.

1.2 Methodology for energy efficiency assessment

This document provides guidelines for measuring the impact of transport projects in EE/CFP and for performing an energy efficiency evaluation of the city at the beginning of the projects. These measurements can be expensive and time-consuming and at the same time cities may question the cost-benefit of these efforts. One challenge in measuring the effect of the transport projects is that results are usually not immediately tangible and there is not a common frame for the evaluation, which complicates a future comparison with other project or even with other cities.

The methodology that was developed for MoveUs project and that is presented in this deliverable, will help cities that are conducting transport projects to measure their impacts in terms of EE/CFP and over time effectively evaluate the progress toward established objectives and goals. The defined steps encourage cities to make a consistent process that will suit specific city applications, local conditions and target groups. The process is divided into eight steps and each step is explained in detail in section 5. By following all steps in the evaluation period (step 8), the results can be used to refine transport project and achieve the city objectives.

1.3 Recommendations for Incentives

The research on this part of the deliverable is based on a state of art in energy applications and which are the main features that they are offering to users. It is well known that there are several journey planning tools available, which are specifically designed for specific transport modes (e.g. bus, train, car, bicycle or walking). Other websites focuses only on providing information on the environmental footprint on the users' transport choices, enabling users to compare the emission from different journey options and finally, other applications only focus on the driver behavior.

There are several ways to influence inhabitants' travel choices in order to make mobility more sustainable. ICT services can promote the most sustainable way to make a journey and also promote more efficient use of vehicles. It can also make sure that the vehicles are using, in an efficient way, the city infrastructure. Some of the most relevant lessons that were found on the research in the incentives applications includes: the message should be delivered in an early stage and should be focused on the practical and positive alternatives on mobility modes to current patterns travel choices. A more detail description of the applications and suggestion for the incentives models is presented in Section 6 of this deliverable.

1.4 Terminology

The following set of definitions will be used through this document. It is important to make a clear description of its meaning of use:

MOVEUS process	the transportation of a person from source point A to source point B, via one of many possible *journey options (i.e. routing + mobility option)*.
Journey option	routing option and mobility option
Routing option	Travel option in terms of streets/pathways available
Mobility option	Travel option in terms of means of transportation available

2 State of the Art on Energy efficiency and Carbon footprint assessment in the transportation sector

The evaluation of environmental and energy efficient in cities is a priority for implementing actions in order to reduce the use of energy, especially in the transport sector. The expected growth in traffic and modal shift from rail and water to road transport, and the decreasing share of public transport (PT) are going to contribute to the current increase of energy consumption (EC).

This chapter explores and collects a number of projects that are implemented in cities across Europe. Those projects deal with mobility issues connected to many of the challenges that cities face in terms of energy efficiency (EE) and carbon footprint (CFP) in the transport sector. Then, chapter 3 focuses on the energy efficient key performance indicators that were defined from experiences of those mobility projects and the standard indicators that will be used for evaluating the energy performance of cities.

2.1 State of The Art of European projects, pilots and tools

Energy efficiency (EE) is determinate by two factors: Energy Consumption (EC) and mobility. Statistics from Eurostat show that EC in transport sector represent 32,6% of total EC in Europe and one of the highest EC sectors as can be see it in Figure 1. Looking at the behaviour of EC through time, it tends to only grow each year. Analysing more deeply inside of the transport sector, transport by road represent the 81.8%, and specifically for passengers' private car has the highest percent with 72, 4% (see Figure 2).

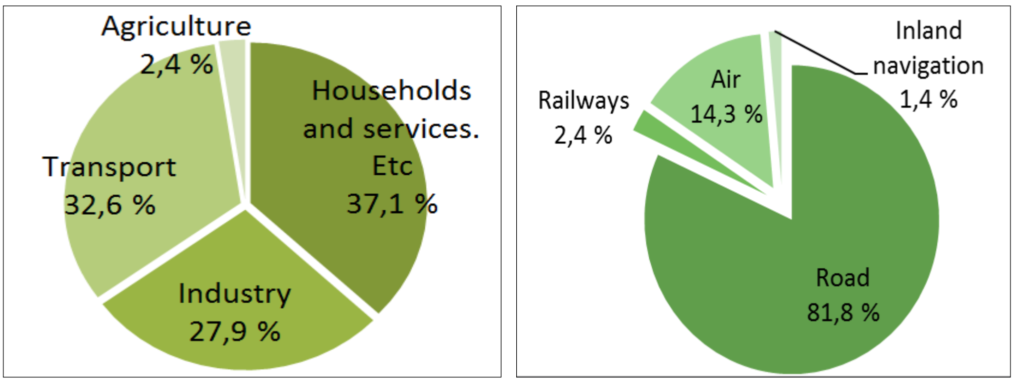

Figure 1: Estimation of energy consumption by sector (1 150 Mtoe[1]) in 2007. Base in data from Eurostat

[1] Mtoe is Million Tonnes of Oil Equivalent

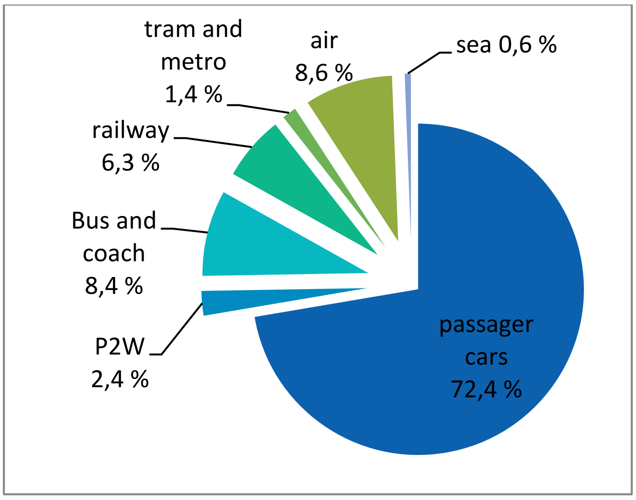

Figure 2: Passenger transport P2W= powered 2- wheelers

EE technology initiatives can be classified in four classes: improvements in the engine fuel utilization, changes in use of transport modes, management of traffic and new alternative fuels production. As can be see, two of these initiatives classes depend on developments in the vehicles production (cars, aircrafts, trucks, etc.) and petroleum industry.

One indicator that is used to measure EE in the transport sector is the energy consumption per unity of transported elements (passengers or goods) per distance travelled in kilometres. Concretely, initiatives in this point aim to produce engines that reduce its specific fuel consumption resulting in vehicles that can transport more elements (people or goods) with less energy.

Depending of the type of vehicle, the consumption will change, for example, PT in cities consume half of the energy compared with tourism transport per passenger. In freight transport, light commercial vehicles (<3,5t) consume four times more energy per tons of goods than heavy commercial vehicles (>16t). The type of technology is also an indicator of efficiency, for example diesel systems consumes less fuel units per km than gasoline systems [1][2]

As it is mentioned before, this factor is highly related with vehicle manufacturing companies. Based on this, initiatives are mainly focused on informing buyers about the vehicle consumption. Applications such as ***Fuel Consumption***[3] *Ratings* from the Government of Canada, ***Energywise***[4] from New Zealand's Energy Efficiency and Conservation Authority (EECA), ***Fuel economy***[5] from U.S. department of energy (see Figure 3), ***Green Vehicle Guide***[6] from Australian Government and ***UK Car Fuel Economy And Emissions***[7], offer an economic point of view to users, so he/she can not only know how much the vehicle consumes, but also compare different models in order to choose a more economical option, which at the same time is the most energy efficient.

Figure 3: Fuel economy and environmental label, from U.S. department of energy

Other initiatives, from Spain, are ***RENOVE*** and ***PREVER***[8]. Unlike previous applications, these have as objective to replace old vehicles that consume more resources than new cars by more efficient vehicles. Similar projects includes ***CIVITAS***[9]***,*** a European program for helping cities to implement urban PT that is more efficient, environmental friendly and sustainable. Same as CIVITAS, ***Clean Fleets***[10] project assists public authorities and fleet operators with the implementation of the Clean Vehicles Directive and the procurement or leasing of clean and energy-efficient vehicles.

Regarding the change in use of transport modes, some initiatives promote the use of PT. The offer of PT defined by vehicle's km per hectare, foments the use of PT, and as a consequence, save energy mainly in cities where PT covers a wide area (hectares ha). As can be seen in data from the EU energy and transport in figures report, the use of PT goes from 6.5% in cities where the volume is low (<1500km/ha) to 42.5% in cities where volumes are higher (~ 5000 km/ha) [1].

Other initiatives such as ***PTP-Cycle***[11] which is a project using Personalised Travel Planning (PTP) methods to promote a shift from private motor vehicle use towards cycling, walking and PT. ***ELECTRA***[12]***,*** Electric City Transport, promotes electric scooter sharing in cities. The project allows to raise awareness on citizens and tourists for changing daily behaviours to promote sustainable activities and public bodies and stakeholders, like transports operators, associations, universities and firms, to develop other innovative transport means (e.g. electric car and buses). Similar ***MOBI***[13] project encourage employers and their employees to use energy efficient and sustainable transport modes for their commute and business travel journeys inside of EU.

Alternative programs like ***Marco Polo***[14], aim to change the freight transportation from roads to short distance navigation, train and inland navigation. This project is supported by ***NAIADES***[15] that promotes transport in inland navigation. These two programs no only represent changes in the user shift preferences, but also an inversion in infrastructure. Respect to infrastructures, ***the infrastructure and transport strategic plan (PEIT)***[16] aims the design and construction of new highways that can connect water ports, and also new railways that connects the land with those ports, reducing time in transportation of goods. ***TEN-T***[17] is a new transport infrastructure policy that connects the continent between East and West, North and South in EU.

Intelligent transport systems such as navigators and driver assistance are developing nowadays to improve road safety, energy efficiency and behaviour in roads. In particular satellite navigation systems, like the one develop in ***GALILEO***[18] project, will facilitate transport management reducing traffic and environment damage as well as promote developments on multi modal transport application and optimization of road, air, railway and sea traffic.

Connected with GALILEO, ***single European sky***[19]***,*** an initiative that aim to ensure safe and efficient utilization of airspace and the traffic management system within and beyond the EU. As the utilization is more efficient the EC in this sector is expected will decrease. ***SESAR***[20] is a project that incorporates technologies for air traffic management in single European sky initiative, to reduce fuel consumption.

The promotion of intermodal transport systems is fundamental to achieve energy saving. Programs such as ***Kombiverkehr***[21]***,*** facilitates intermodal transport for forwarders and transport companies in EU and no-EU by logistics that are both cost-effective and environmentally friendly. Analogous program like ***Oy Langh Ship***[22] offers an intermodal between sea, rail and river transport between Finland and Central Europe.

For new alternative fuels production, ***ALTER-MOTIVE***[23] achieves a significant increase in innovative alternative fuels (AF) and corresponding alternatives for more efficient automotive technologies (AAMT) to head towards a sustainable individual & PT system. ***STEER***[24] promotes a more sustainable use of energy in transport by increasing energy efficiency, developing new and renewable fuel sources, and the take-up of alternatively propelled vehicles. Other initiatives such ***Alternative Fuel Data Center***[25] informs to users about alternative fuel characteristics as well as benefits and locations where they can find those fuels.

Finally initiatives in monitoring like ***ODYSSEE-MURE***[26], used for monitoring of EC and efficiency trends as well as of energy efficiency policy measures by sector. ***SMILE***[27] project focuses on the development of innovative strategies, plans and measures on energy efficient mobility solutions and their implementation in smart Mediterranean cities (Barcelona, Bologna, Montpellier, Piraeus, Rijeka and Valencia).The Table 1 resume all the projects mentioned before.

Focus Area	Initiative	Description
Applications with information to consumers	Fuel Consumption Natural Resources Canada Government of Canada	Website application to help identify the most fuel-efficient vehicle that meets user everyday needs by comparing the fuel consumption information of different models.
	Energywise New Zealand's Energy	Website application that shows to user the most economical

	Efficiency and Conservation Authority (EECA). 2012- ongoing	vehicle models available, and allows model comparison.
	Fuel economy U.S. department of energy	Information on greenhouse gas (GHG) emissions from transportation sources and how those emissions affect our climate. Also provides an application for vehicles consume information
	Green Vehicle Guide Australian Government	Website where the government of Australia provides multiple applications to calculate of search information about consume and emission of vehicles.
	UK Car Fuel Economy And Emissions Find the Best United Kingdom	Application and data base about car fuel and emissions data.
Implementation of sustainable public transport	RENOVE and PREVER (MURE) Spain	Objective to replace old vehicles that consume more resources than new cars, with vehicles more efficient.
	CIVITAS European Union 2006- ongoing	Is European program for help cities to develop an efficient and environmental friendly public transport.
	Clean Fleets Intelligent Energy Europe (IEE) 2012-ongoing	The project assists public authorities and fleet operators with the implementation of the Clean Vehicles Directive and the procurement or leasing of clean and energy-efficient vehicles.
changing daily behaviours by promoting change in modes	PTP-Cycle Intelligent Energy Europe (IEE) 2013-ongoing	Is a project using Personalised Travel Planning (PTP) methods to promote a shift from private motor vehicle use towards cycling, walking and public transport.
	Ele.c.tra Intelligent Energy Europe (IEE) 2013-ongoing	Aims to promote the "green" mobility and the reduction of atmospheric and acoustic pollution in cities.
	MOBI Intelligent Energy Europe (IEE) 2013-ongoing	Encourage employers and their employees to use energy efficient and sustainable transport modes for their

		commute and business travel journeys.
Change the freight transportation mode	MARCO POLO European Union 2013-ongoing	Aims to ease road congestion and its attendant pollution by promoting a switch to greener transport modes for European freight traffic. Railways, sea-routes and inland waterways have spare capacity.
	NAIADES European Union 2006-ongoing	Is to enhance the use of inland navigation as part of intermodal freight solutions, in order to create a sustainable, competitive and environmentally friendly European wide transport network.
Infrastructures	PEIT Spain government 2005- ongoing	Achieve an efficient and sustainable transport system that meets the needs of quality mobility, restore the balance between different types of transport
	TEN-T European Commission Mobility and transport 2014-ongoing	New transport infrastructure policy that aims to close the gaps between Member States' transport networks, remove bottlenecks that still hamper the smooth functioning of the internal market and overcome technical barriers such as incompatible standards for railway traffic. It promotes and strengthens seamless transport chains for passenger and freight.
Navigational systems	GALILLEO European union European space agency 2005-ongoing	Europe's initiative for a state-of-the-art global satellite navigation system, providing a highly accurate, guaranteed global positioning service under civilian control.
	Single European Sky (SES) European Commission 2001- ongoing	Ensuring the safe and efficient utilisation of airspace and the air traffic management system within and beyond the EU.
	SESAR (SES) 2004-ongoing	As the technological pillar of Europe's ambitious Single European Sky (SES) initiative,

		SESAR is the mechanism which seeks to coordinate and concentrate all EU research and development activities in ALM.
Intermodal transport	Kombiverkehr 2007-2011	Facilitates intermodal transport for forwarders and transport companies on virtually all European routes.
	Oy Langh Ship 2001-ongoing	Offers an intermodal between sea, rail and river transport between Finland and Central Europe
Alternative fuels	ALTER-MOTIVE Intelligent Energy Europe (IEE) 2008-2011	Increase in innovative alternative fuels (AF) and corresponding alternative more efficient automotive technologies (AAMT) to head towards a sustainable individual & public transport system.
	STEER European Commission Intelligent Energy Europe	Promote a more sustainable use of energy in transport
	Alternative Fuel Data Center (AFDC) Clean cities program National Renewable energy laboratory. U.S. Department of Energy 1991- ongoing	Information about advanced transportation technologies. The AFDC offers transportation decision makers unbiased information, data, and tools related to the deployment of alternative fuels and advanced vehicle.
Measurement	ODYSSEE-MURE Intelligent Energy Europe (IEE) 2012-ongoing	Monitoring of energy consumption and efficiency trends, as well as of energy efficiency policy measures by sector.
	SMILE Europe in the Mediterranean (med) and European Regional Development Found 2013-ongoing	Focus on the development of innovative strategies, plans and measures on energy efficient mobility solutions and their implementation in smart Mediterranean cities.

Table 1: Current and completed projects in energy efficiency in the transport sector.

2.2 Key performance indicators in the transportation sector

Energy Efficiency (EE) is popularly defined as a process for using less energy to produce the same amount of services. Another popular definition of EE is when less energy is used as input while maintaining an equivalent level of economic activity or service. There are many EE performance indicators in literature, depending mainly on the aim of the analysis and the type of sector studies; therefore, studies based on different EE are not comparable [28][29][30][31]. Over time, some international organizations such as IEA, OECD, WEC, [2] have been producing information and reports to specify definitions and methods to calculate EE indicators and promote common practices for governments. Nevertheless, today there is no universally accepted definition of EE and either a common way to measure it.

The EE measures are mainly related with evaluation of transport policies, which aims energy conservation and emission reduction. Various studies catalogued those strategies in two groups: cleaner vehicles strategies that try to reduce emission rates per vehicle-kilometre, and mobility management strategies, which try to reduce total vehicle travel (kilometres) [28] [30] [32] [33]. Some of the strategies are summarized in Table 2 from Victoria transport Policy Institute energy report. In this report, the institute conducted a quantitative analysis, which indicates that mobility management strategies generally achieve more planning objectives than cleaner vehicle strategies, particularly if cleaner vehicle strategies have rebound effects[3] [30].

Cleaner Vehicles (Reduce fuel consumption and emission rates per unit of travel)	**Mobility Management** (Reduce total vehicle travel)
• Anti-idling programs and regulations • Special fees on inefficient vehicles and rebates on efficient vehicles • Fleet management and driver training • Fuel efficiency standards (such CAFE[4]) • Fuel quality improvements • Fuel tax increases • Inspection and maintenance programs • Low emission vehicles • Promote purchase of cleaner	• Car-free planning and vehicle restrictions • Commute trip reduction programs • Distance- based vehicles insurance and registration fees • Efficiency parking management and pricing • Freight transport management • Fuel tax increases • Mobility management marketing • Non-motorized transport improvements • Ridesharing improvements and incentives • Road pricing • Smart growth development

[2] International Energy Agency (IEA), the organization for economic Co-operation and development (OECD), World Energy Council (WEC).

[3] Rebound (also called take back) effects refers to the increase vehicle travel that result from increased fuel efficiency, cheaper fuels or roadway expansion that increases traffic speeds.

[4] Corporate Average Fuel Economy (CAFE)

vehicles • Promote motorcycle and small vehicle use • Resurface highways • Roadside "high emitter" identification	policies • Telework encouragement • Transit improvements and incentives

Table 2: List of energy conservation and emission reduction strategies types [5].

The main objectives for those policies, used by several EU countries, is to address energy reduction issues in the transport sector from an eco-efficiency perspective based on zoning, demand management, restraining the use of cars and promoting collective transport [33][34]. Although there is not a standard to measure the effectiveness in the implementation phase, most of the studies agree on the main issues: the irrational use of private vehicles, urban mobility and surrounding areas depending on private vehicles, and lack of alternative fuels and eco-efficient vehicles.

Improvements in transport generate a wide range of benefits to the whole mobility system such as: reduction of pollution, general cost savings, improved health conditions, environmental sustainability and others.[29] To evaluate direct user impacts, these strategies[5] can be divided into three major categories: strategies that improve transport options (walking, cycling, public transit, car sharing, etc.), some pricing reforms (distance-based insurance and parking cash out) provide direct user savings and smart growth policies, which result in more compact and multi-modal communities [32]. Aranda Usón et al. (2011) [33] consider several indicators, e.g. fuel consumption, infrastructure, time travelled and environmental cost (defined in term of cost for nature replacement) of the transport time saving, they found bus, regional train and on foot transport modes to be more EE.

Most of issues in transportation, such as traffic, share the same origin, population growth, which indicates the demand for personal or household vehicles. In addition, the number of persons working or studying defines the needs of frequent transportation, and the distance they travel is correlated with EC and with EE [35]. Indicators such as the number of vehicles per 1000 inhabitants (Eurostat) reflect the number of car ownership levels, as well as, the opportunities to implement EE politics. As an example Eurostar had calculated that if users of vehicles which have not being manufactured could cover their needs by using PT, the efficiency would improve by 80%[6][33].

The number of vehicles is related as well with the average of inhabitants' income. Statistics from ADEME (2012) shows that passenger mobility is (measured in km/capita) lower in Romania (below 5000 Km/year) and in most central and Eastern European countries (lower income); and higher between 12000 and 16000 km in countries like Finland, Slovenia, France, UK, Sweden, Germany and Norway (higher income) where the level of car density rate is higher than 700 cars per

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[5]Strategies related with mobility management

[6] the number of vehicles per 1000 inhabitants will drastically decrease from 411 to 250 vehicles

1000 inhabitants [31]. Other study run by P.Y. Lipscy and L. Shipper (2013) shows that denser countries have both, lower total per capita travel and a higher share of that travel in public and alternative modes (ALM) [34].

Other factors, such as the current rising of fuel prices, the increasing urbanization, changing consumer preferences, increasing health and environmental concerns, are reducing demand for automobile travel and increasing demand for other modes [30]. Frank, et al. [36] found that smart growth features like transit accessibility, residential density, and street connectivity tend to increase the per capita walking and reduce per capita motor vehicle fuel consumption.

In order to evaluate clean vehicles policies, it is required to know the fleet composition by vehicle category and fuel type, along with the age distribution for each vehicle category[37]. For each category, the total travelled distance within a specific time frame are all crucial factors to know the vehicles' energy impact or the final EC in the transport sector. Statistics from ADEME (2012) show a high value (in the average specific consumption of the car fleet) in Sweden, which can be partly explained by the fact that it is the country with the most powerful cars and the lowest share of diesel cars. On the other side Italy, is a country with the least powerful cars and a high penetration of diesel.[31] As a result, the average car size and horsepower and the share of diesel are important factors.

Diesel engines are usually more efficient, for example, a typical gasoline powered automobile is only about 25% efficient. In other words, out of the 100% thermal energy potential of a gallon of gasoline, only about 25% of the energy is converted to real mechanical work that turns the wheels of the car, the other 75% is lost in the form of wasted heat and friction[7]. On 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).[31]. Additionally transport's specific consumption for a lorry is around 15 times higher than using a railway[33]. General aviation vehicles are the most energy intensive, smaller general aviation planes consumed over two and one-half times more jet fuel than commercial air carriers to move one passenger[35].

Energy savings can be achieved by performing improvements in the technical performance, changing driving behaviour, changing the average car size or horsepower, or by increasing car occupancy[31]. However, vehicles that are more efficient, are connected with regressions in driving behaviour, by growth in the number of vehicles and their kilometres travelled; therefore, overall consumption tends to rise[28].

EC not only occurs while actually using the car, there is also an energy cost in its manufacture, maintenance, recycling and in the provision of required infrastructures (roads and parking places etc.). Therefore, it is important to understand the environmental impact, sustainability and energy efficiency during life cycle of each of its processes[33][38].

[7] is the definition used to monitor the Energy Services Directive ESD

In order to quantify the environmental impact and EC associated with manufacturing and vehicle use, J. Aranda et. (2011) using IDEMAT 2001 and ECOINVENT v2.0 database information calculated the Kilo-points (according to Ecoindicator 99 H/A) of vehicles. The calculation includes material, energy and water use in the manufacturing processes. Rail and road materials are also accounted. Infrastructure is included, addressing issues such as land use, building, and road and parking construction[33].

The total amount of carbon dioxide emissions in the manufacturing process and the one used by the vehicle determinates the Carbon Foot Print (CFP). CFP represents the direct/indirect impact of the transport needs on the climate. Indirect impacts are for example the distance the fuel has to travel before it is consumed by vehicles or how far away the vehicles that inhabitants use are made. Direct impacts are the carbon emissions of cars, buses, aeroplanes and electricity (for electric car or trams) needs that generally come from fossil fuel burning power plants[39], other direct impacts are on the health effects [40].

Main EE measures focus on cars efficiency (fuel expend per Km). Moreover, a growing number of studies aim to reduce the fuel consumption of the car fleet (e.g. eco-driving, speed limit) and modal shift for passengers from private car to PT, and modal shift for freight from road to rail and water transport [29].Examples from Italy and France illustrate the feasibility of behaviour change to achieve social changes, by implementing rewards [41][42]. Although automobile travel will not disappear, many people would prefer to drive less and rely more on alternatives, if they perceive that there are enough facilities to affect the mode change[30].

In the case of France and Italy, mobility projects are promoting active mobility while creating financial incentives to employees for cycling to work. This system exists in Belgium[8] and Germany[9] and these types of project bring economic and environmental benefits as they promote a healthier and cheaper way of transport. There are other projects with the objective of creating secure areas in train stations for cyclists to safely store their bikes. Another key methods for stimulating modal shift includes building an attractive environment for pedestrian traffic and introducing traffic calming measures for motor vehicles, improving the quality of cycling routes and adding the missing route links, ensuring proper maintenance of pavements and cycle paths[38][43].

Other key factor in the choice of a mode is the distance. Transport system and land use patterns have a strong mutual influence on the each other´s development [37]. Land use describes the nature, intensity and spatial distribution of different functions or human activities in a certain area of considerations. Japan transport polities aim on low activities levels and modal structure rather than modal energy intensity. Japanese transportation is considered one of the most efficient systems in part because of factors like demographics (high population), geography (use of land) and higher energy cost, in consequence Japanese travel shorter distances and are much more likely to travel by rail or other ALM (walking or cycling)[34].

[8] Where employees receive a 21 cents/km compensation.

[9] prizes awarded in a lottery to the employees that satisfy a certain quota of miles biked to work per year

J. Aranda et. (2011) studied and compared the efficiency of several transport modes from the assessed environment life cycle viewpoint, including any necessary infrastructures and fuel consumption. They have also included the amount of time invested in travelling, and the environmental cost. Current society tends to minimize working time to increase leisure time at high price in terms of energy use. That is why the use of land is crucial because not only affects the travel time but also the decision of which mode to use [33].

Despite the fact that Japan has one of the most efficient transport systems, there is also a high amount of mini-cars, usually occupied by single-drivers, therefore the average fuel use per passenger-km intensity is similar to car travel in US. In terms of new auto fuel economy, the Japanese fleet uses about 15% less fuel/km than that in the US. In addition, Japanese cars are considerably smaller and less powerful. Therefore, the main reason why those levels are similar is congested traffic [34].

With the example of Japan it is possible to see that urban traffic management, especially traffic efficiency, usually is one of the rises in fuel consume causes. A study from Imperial College London divides the traffic management into the following categories: mobility, operational efficiency and system condition and performance. [37] Mobility reflects the ability of people and goods to reach different destinations using different modes. Reliability reflects the ease or difficulty of people and goods to perform their trips. Finally, system conditions and performance refers to the physical condition of the transport infrastructure and equipment.

Finally, as it is explained previously, the indicators for both passenger and freight transportation modes depend on the energy content of the fuel being used. This allows all types of fuel to be evaluated and compared. Choice in fuel varies by transportation mode, e.g. automobiles consume gasoline, diesel, and alternative fuels; trucks run on diesel fuel, gasoline, and liquefied petroleum gas; aircraft fly with jet fuel and aviation gasoline; and marine vessels burn distillate and residual fuel oil.[35] In Germany EE goals in transportation are achieved by shifting private transport from petrol to diesel, using electric vehicles and methanol or biofuel for light and heavy trucks.[29]

The aim of this document is to present a list of KPIs for each of the previous explaining policies and facts that can affect the EC in the transport sector. The list of KPIs is base of the goals and objectives of several transport plans and project. The specific performance objectives were identified and the factors that can modify positively the transport system performance. The selected KPIs are highly related with the aims of transport projects or/and policies.

ID	Name	References
KP1	Performance of freight transport	[29][34][35]
KP2	Fuel consume by freight transport	[29][33][34][35]
KP3	Unitary gross annual energy savings	[29][41]
KP4	Density of passenger transport	[29][35]
KP5	Number of passenger transported by fuel unit	[29][31][34][35][37]
KP6	Number of fuel units per passenger	[29][31][34][37]
KP7	Offer volume in public transport	[35][37][41][42]

KP8	Total CO_2 emissions for travel (multiple modes) passengers	[31][33][37]
KP9	Total CO_2 emissions for travel (multiple modes) freight	[35]
KP10	Private vehicles density rate	[30][33][42]
KP11	Average vehicle power	[29][31][34]
KP12	Share of diesel engine in total vehicles	[29][31][37]
KP13	Share of public transport in total passenger traffic	[30][31][33][37][42]
KP14	Share of heavy trucks in total freight traffic	[29][37]
KP15	Share of new units in vehicles fleet	[29][30][37]
KP16	Presence of alternative fuels vehicles	[29][37]
KP17	Presence of alternative fuels vehicles offering	[37]
KP18	Traffic-free (TF) and on-road (OR) routes	[36][38][41][43]
KP19	Annual usage estimation in alternative modes	[30][33][36][38][43]
KP20	Facilities density in alternative modes	[36][38][30]
KP21	Density of links in multimodal	[30][36][41]
KP22	Link's Length in multimodal	[34][37]
KP23	KPI's change per time unit	
KP24	KPI's percentage of change	

Table 3: Identified KPIs in the transportation sector.

3 Key performance indicators and associated computation methods

This section presents a more detail definition of each of the KPIs, which includes the ID, title, its mathematical expression, description and goal. As it is previously explained, the KPIs do not have a standard measure unit, for that reason in order to be able to perform mathematical operation with them, their units should be combined with the conversion factors that are described in section 3.1.3. Finally, the list of KPIs for each Living Lab and the evaluation of the data sources for the calculation of the selected KPIs is provided.

3.1 General KPIs description and computational methods

Key performance indicators (KPIs) measure the level of performance of a process. In MoveUs, this process is the transportation of a person from source point A to source point B, via one of many possible *journey options (i.e. routing + mobility option)*.

3.1.1 Energy efficiency

Energy performance is defined as the relationship between energy consumption and how much of that energy is converted into work. According to the ISO 50001:2001 [19] energy performance is defined by indicators which are data measurable related with:

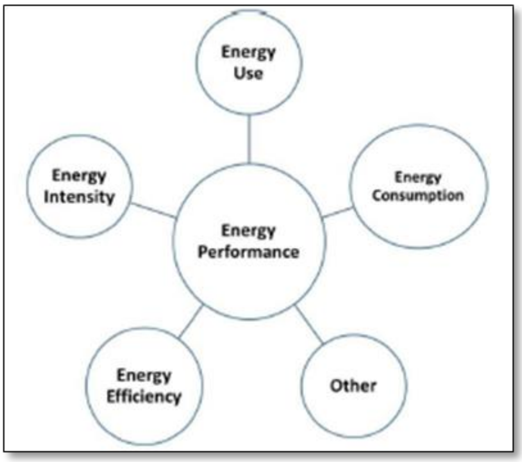

Figure 4: Energy performance composition [19] .

Energy use: (also referred to as type of consumption) is the grouping of energy consuming products by which the consumer needs are covered. For example: Lighting, Heating, Informatics, etc.

Energy efficiency (EE): related to the technology of the energy use, e.g. lux per Watt in a lamp

Energy consumption (EC): all the consumed energy of a facility (Wh). The more periodically measures we have, the more knowledge we have of the facility.

Energy intensity: consumption is normalized between facilities, in order to compare them with each other, e.g. Wh/m2.

Others: other events or data related with the energy performance could be measured which aren't included in the categories listed below. One of the most important indicators of category is the energy comfort. During an activity, the human being should ignore the environment, that situation is comfort. In energy terms, each energy consuming product and each use of energy must operate within a comfort range, e.g. the temperature inside a room should be between 20 and 26 degrees, and outside this range, users feel cold or hot.

Each one of the identified KPIs is described following the template shown in Table 4.

ID KP2	**Title: Fuel consume by freight transport**
KPI category	Energy efficiency, vehicles
Mathematical expression	$\frac{\sum W_i}{ADT} * C_i \ [Kg \ per \ Litre]$
Description	W_i = Annual total weight of goods transported by a unit [Kg] ADT= Annual distance travelled of the unit [Km] C_i= unit of fuel consumption in [Km/litre]
Goal	Aims to improving vehicle energy efficiency, by showing the relation between total fuels consume and weigh. The transport system is more efficient if the quantity of goods is higher than the consumed fuel.
Comment	This KPI can be use also to find the total gross annual energy savings by multiple with N°: number of units The indicator can be implemented by mode and by type of fuel

Table 4: KPI template.

The fields in the template are:

- **ID**: each KPI includes an identifier to facilitate tracing through subsequent phases. The identifier is formed by two letters and a number; in case of a pilot city specific KPI there is an additional letter at the end, **T** for Tampere, **M** for Madrid and **G** for Genoa.
- **Title**

- **Mathematical expression**: mathematical formulation indicating which variables are included in the KPI and how they are related to each other. It also gives an idea of the dimension of the indicator (dimensionless, percentage, etc.)
- **Description**: explanation of what the indicator shows, and how the variables are related to each other.
- **Goal**
- **Comment**

3.1.2 General KPIs

ID KP1	**Title: Performance of freight transport**
KPI category	Energy efficiency, vehicles
Mathematical expression	$\frac{\sum W_i}{ADT}$ $[Kg\ per\ Km]$
Description	$W_i =$ Annual total weight of goods transported by a unit [Kg] $ADT =$ Annual distance travelled of the unit [Km]
Goal	Aims to improving vehicle energy efficiency, by showing the relation between distance and weigh. The transport system is more efficient if the quantity of goods is higher than the distance.
Comment	This KPI can be use also to find the total gross annual energy savings by multiple with N°: number of units The indicator can be implemented by mode and by type of fuel
Indicators	↑

ID KP2	**Title: Fuel consume by freight transport**
KPI category	Energy efficiency, vehicles
Mathematical expression	$\frac{\sum W_i}{ADT} * C_i\ [Kg\ per\ Litre]$
Description	$W_i =$ Annual total weight of goods transported by a unit [Kg] $ADT =$ Annual distance travelled of the unit [Km] $C_i =$ unit of fuel consumption in [Km/litre]
Goal	Aims to improving vehicle energy efficiency, by showing the relation between total fuels consume and weight. The transport system is more efficient if the quantity of goods is higher than the consumed fuel.
Comment	This KPI can be used also to find the total gross annual energy savings by multiple with N°: number of units The indicator can be implemented by mode and by type of fuel
Indicators	↓

ID KP3	**Title: Unitary gross annual energy savings**
KPI category	Energy efficiency, vehicles
Mathematical expression	$(En_{inef\ fveh} - En_{ef\ fveh}) * ADT\ \ [gCO_2\ per\ Km]$

Description	En_* = Energy consumption of a certain transport mode. Distinguee between efficient and inefficient modes ADT = Annual distance travelled of the unit
Goal	Aims to improving vehicle energy efficiency, to prevent a number of consumers to buy inefficient vehicles. This indicator helps to create a baseline. Additionally the baseline can be used as a base for new target in vehicles efficiency
Comment	This KPI can be used also to find the total gross annual energy savings by multiple with N°: number of units The indicator can be implemented by mode and by type of fuel
Indicators	↑

ID KP4	**Title: Density of passenger transport**
KPI category	Energy efficiency, vehicles
Mathematical expression	$\frac{\sum P_i}{ADT}$ $[N\ passengers\ per\ Km\ (pkm)]$
Description	P_i = Annual total passengers transported by a unit ADT = Annual distance travelled of the unit [Km]
Goal	Aims to improve vehicle's energy efficiency by showing the relation between distance and passengers. The transport system is more efficient if the number of passengers is higher than the distance.
Comment	This KPI can be also used to find the total gross annual density of passengers by multiple with N°: number of units
Indicators	↑

ID KP5	**Title: Number of passenger transported by fuel unit**
KPI category	Energy efficiency, vehicles
Mathematical expression	$\frac{\sum P_i}{ADT * C_i}$ $[N\ passengers\ per\ Litre]$
Description	P_i = Annual total passengers transported by a unit ADT = Annual distance travelled of the unit [Km] C_i = unit consume in [litre/km]
Goal	Aims to improve vehicle's energy efficiency. The indicator shows the number of passengers transported by a unit of fuel (litre). The transport system is more efficient if the quantity of passengers is high per unit of fuel.
Comment	This KPI can be use also to find the units of fuel per passenger The indicator can be implemented by mode and by type of fuel
Indicators	↑

ID KP6	**Title: Number of fuel units per passenger**
KPI category	Energy efficiency, vehicles

Mathematical expression	$\frac{ADT * C_i}{\sum P_i}$ $[N\ Litre\ per\ passenger]$
Description	P_i = Annual total passengers transported by a unit ADT= Annual distance travelled of the unit [Km] C_i= unit consume in [litre/km]
Goal	Aims to improve vehicle energy efficiency. The indicator shows the number of fuel units per passenger. The transport system is more efficient if the quantity of units is low.
Comment	The indicator can be implemented by mode and by type of fuel
Indicators	↓

ID KP7	**Title: Offer volume in public transport**
KPI category	Energy efficiency
Mathematical expression	$\frac{ADT}{A}$ $[km\ per\ \mathrm{km^2}]$
Description	ADT= Annual distance travelled by the unit [Km] A= area where the unit travels [km^2]
Goal	Aims to improve vehicle energy efficiency. The indicator shows the volume of public transport offer.
Comment	This indicator can be implemented by mode
Indicators	↑

ID KP8	**Title: Total CO_2 emissions for travel (multiple modes) passengers**
KPI category	Energy efficiency, modes
Mathematical expression	$\frac{\sum P_i}{ADT} * S * ADT * En_* \ [gCO2\ per\ pkm]$
Description	$\frac{\sum P_i}{ADT}$ = density of passenger transport [N passengers per Km (pkm)] S = Modal shares in total activity. [%] En_* = Energy consumption of a certain transport mode [gCO_2] ADT= Annual distance travelled of the unit [Km]
Goal	Shows the energy use for passengers transportation using several transport modes, and the energy intensities of each mode.
Comment	The KPI can be used to identify energy efficient combination of modes to transport passengers
Indicators	↓

ID KP9	**Title: Total CO_2 emissions for travel (multiple modes) freight**
KPI category	Energy efficiency
Mathematical expression	$\frac{\sum W_i}{ADT} * S * ADT * En_* \ [gCO2\ per\ km]$
Description	$\frac{\sum W_i}{ADT}$= performance of freight transport [Kg per Km]. S = Modal shares in total activity. [%] En_* = Energy consumption of a certain transport

	mode [gCO_2] ADT= Annual distance travelled of the unit [Km]
Goal	Shows the energy use for freight transportation using several transport modes, and the energy intensities of each mode.
Comment	The KPI can be used to identify energy efficient combination of modes to transport goods
Indicators	↓

ID KP10	**Title: Private vehicles density rate**
KPI category	Energy efficiency, vehicles
Mathematical expression	$$\frac{V_{pi}}{H} * 1000\ [vehicles\ per\ 1000\ inhabitants]$$
Description	H= total number of inhabitants [inhabitants] V_{pi} = number of private vehicles [vehicles]
Goal	Shows the number of private vehicles per inhabitants, lower number of private vehicles, less emissions
Comment	The KPI can be used to identify the levels of private vehicles ownership.
Indicators	↓

ID KP11	**Title: Average vehicle power**
KPI category	Energy efficiency, vehicles
Mathematical expression	$$\frac{\sum V_{hpi}}{N_i}\ [hp]$$
Description	N_i= total number of vehicles [vehicles] V_{hpi} = unit total horse power [hp]
Goal	Shows the average vehicle power, more power is related with higher average specific consumption of the vehicles fleet.
Comment	The KPI can be used to identify the average power in vehicles
Indicators	↓

ID KP12	**Title: Share of diesel engine in total vehicles**
KPI category	Energy efficiency, vehicles
Mathematical expression	$$\frac{N_{Di}}{N_i} * 100\ [\%]$$
Description	N_i= total number of vehicles [vehicles] N_{Di} = total units with diesel engine [number of units]
Goal	Shows the percent of vehicles that use diesel engines from total number of unit vehicles. Higher share level (%) means that vehicles fleet is more efficient.
Comment	The KPI can be used only in cases where vehicles fleet has gasoline and diesel engines, example cars.
Indicators	↑

ID KP13	**Title: Share of public transport in total passenger traffic**
KPI category	Energy efficiency

Mathematical expression	$$\frac{P_{pi}}{P_i} * 100\ [\%]$$
Description	P_i= Annual total passengers transported by a unit P_{pi} =Annual total passengers transported by a unit of public transport
Goal	Shows the percent of share of public transport in total passenger traffic. Higher share means more energy efficient
Comment	The KPI can be used per type of unit vehicle or as a total vehicle fleet
Indicators	↑

ID KP14	**Title: Share of heavy trucks in total freight traffic**
KPI category	Energy efficiency
Mathematical expression	$$\frac{V_{ht}}{V_{ft}} * 100\ [\%]$$
Description	V_{ht}= total heavy trucks V_{ft} = vehicle use for freight transport
Goal	Shows the percent of share of heavy trucks (>16 tons) in total freight traffic. Higher share means more energy efficient
Comment	The KPI can be used only in road transportation. Vehicles use for freight transport for this KPI means transportation in roads.
Indicators	↑

ID KP15	**Title: Share of new units in vehicles fleet**
KPI category	Energy efficiency, vehicles
Mathematical expression	$$\frac{V_{yi}}{V_i} * 100\%\ [\%]$$
Description	V_i= Total vehicles V_{yi} = Total vehicles with new technology
Goal	Aims to show the share of new vehicle units with cleaner technologies (more efficient or less emissions)
Comment	The KPI can be used with different types of vehicles The y refers to the reference year, e.g. y=2010 so vehicles newer than 2010 are consider more efficient
Indicators	↑

ID KP16	**Title: Presence of alternative fuels vehicles**
KPI category	Energy efficiency, vehicles
Mathematical expression	$$\frac{V_{Ai}}{V_i} * 100\%\ [\%]$$
Description	V_i= Total vehicles V_{Ai} = Total vehicles with new technology that use alternative fuels
Goal	Aims to show the share of new vehicle units, which use alternative fuels
Comment	The KPI can be use with different types of vehicles

	and with different types of alternative fuels (electricity, ethanol etc.)
Indicators	↑

ID KP17	**Title: Presence of alternative fuels vehicles offering**
KPI category	Energy efficiency, vehicles
Mathematical expression	$\frac{V_{Aoi}}{V_{oi}} * 100\% \; [\%]$
Description	V_{oi}= Total vehicles model offering V_{Aoi} = Total vehicles with new technology that use alternative fuels offering
Goal	Aims to show the availability of vehicle model that use alternative fuels
Comment	The KPI can be used with different types of vehicles and with different types of alternative fuels (electricity, ethanol etc.)
Indicators	↑

ID KP18	**Title: Traffic-free (TF) and on-road (OR) routes**
KPI category	Energy efficiency, facilities for alternative modes (walking and cycling)
Mathematical expression	$\sum A_r \;\; [Km]$
Description	A_r= Total traffic-free (TF) and on-road (OR) routes in km
Goal	Aims to show the availability of TF and OR routes
Comment	The KPI can be used for walking and cycling modes
Indicators	↑

ID KP19	**Title: Annual usage estimation in alternative modes**
KPI category	Energy efficiency, alternative modes
Mathematical expression	$\sum A_u \;\; [number\ of\ users]$
Description	A_u= Total number of cyclists and pedestrians that use the TF and OR routes
Goal	Aims to show the usability of TF and OR routes
Comment	The KPI can be used for walking and cycling modes It can be used by age range and other population classification e.g. students and workers Alternatively, can be used by journey type such as displacement to work or school or as a leisure trip.
Indicators	↑

ID KP20	**Title: Facilities density in alternative modes**
KPI category	Energy efficiency, facilities for alternative modes (walking and cycling)
Mathematical expression	$\frac{\sum A_f}{\sum A_r} [facilities\ per\ Km]$
Description	A_r= Total traffic-free (TF) and on-road (OR) routes

	[km] A_f = Total alternative modes facilities
Goal	Aims to show the availability of facilities per km of TF and OR routes
Comment	The KPI can be used for walking and cycling modes Facilities should be directly related with the activity (walking or cycling) e.g. safe parking places for bicycles or Safe drinking water in parks
Indicators	↑

ID KP21	**Title: Density of links in multimodal**
KPI category	Energy efficiency, multimodal transportation
Mathematical expression	$$\frac{\sum L_{im} P_S}{A} \; [Links\ per\ Km^2]$$
Description	L_{im}= Total links between modes A= area in where the units travel $[Km^2]$ P_S = importance of the link
Goal	Aims to show the density of links between different transport modes in multimodal transportation
Comment	The KPI can be used all the modes and can be differentiate by the type of mode and service (public, private, passengers or freight etc.) Links should be calculated according to seasonal importance. The weight of a link (P_S) should be reflecting its changing importance during the year.
Indicators	↑

ID KP22	**Title: link's Length in multimodal**
KPI category	Energy efficiency, multimodal transportation
Mathematical expression	$$\frac{1}{n}\sum L_{ilm} P_S \quad [Km]$$
Description	L_{ilm}= link's length between modes [Km] n= number of links between modes. P_S = importance of the link
Goal	Aims to show the average link length between different transport modes in multimodal transportation
Comment	The KPI can be used all the modes and can be differentiate by the type of mode and service (public, private, passengers or freight etc.) Links should be calculated according to seasonal importance. The weight of a link (P_S) should be reflecting its changing importance during the year.
Indicators	↓

ID KP23	**Title: KPI's change per time unit**
KPI category	General all KPIs
Mathematical expression	$$KPI_i - KPI_{i-1} \, [KPI's\ unit]$$
Description	KPI_i= KPI in time unit i and KPI_{i-1} = KPI in a time unit $i-1$
Goal	Aims to follow the performance of each KPI in a unit

	of time
Comment	The unit of time can be hours, months, years etc. but it must be the same unit for both values. E.g. number of fuel units per passengers in year 2014 – number of fuel units per passengers in year 2015
Indicators	↑

ID KP24	**Title: KPI's percentage of change**
KPI category	General all KPIs
Mathematical expression	$$\frac{KPI_i - KPI_{i-1}}{KPI_{i-1}} * 100\% \; [\%]$$
Description	KPI_i= KPI in time unit i and KPI_{i-1} = KPI in a time unit $i-1$
Goal	Aims to follow the performance of each KPI in a unit of time and observe respect with previous data (positive or negative) changes
Comment	The unit of time can be hours, months, years etc. but it must be the same unit for both values. E.g. number of fuel units per passengers in year 2014 – number of fuel units per passengers in year 2015
Indicators	↑

3.1.3 General KPIs conversions

In order to derive the corresponding overall energy use/ CFP, or to be able to perform mathematical operation with KPIs selected, the data should be combining with the following conversion factors.

To acquire overall CFP, the factor for conversion is the average carbon emission per unit of energy (crten) $\left[\frac{gCO_2}{kWh}\right]$[10] that is, the emission factor. This emission factor varies significantly from country to country as the mix of different energy generation technologies varies. In addition, this factor can be used to obtain the conversion from carbon emission to energy by using its inverse.

Greenhouse gas emissions from fuels are expressed in terms of grams of CO_2 equivalent per fuel kilogram. Example: 8,887 gCO_2/gallon of gasoline x 1gallon/3,785 Litres x Specific weight 0,75 kg/litres. This value changes from fuel to fuel and factors as fuel quality varies from country to country. Carbon Conversion Factor for private car (CCF_{car}) depend on technical information about the vehicle. This factor unity is in $\left[\frac{gCO_2}{km}\right]$. Carbon Conversion Factor for PT (CCF_{PT}) is calculated by dividing the amount of emissions per kilometer by the average number of passengers $\left[\frac{gCO_2}{pkm}\right]$.

[10] Grams of Carbon dioxide

Finally 1 Litre of fuel is equal to 1000cc, and Horsepower (hp) is equal to Kilowatt-hour times 1,34 or hp=1,34 x kWh. This conversion is a universal standard.

Other units like Kilometres of TF and OR routes can be turned into energy saved or emission units by proposing a reference scenario, which is the worst scenario. For example for KP18, the worst reference scenario is a private car with low occupancy level, and high energy consume per km, energy/km x KP18[11]= Total energy saved.

The forward table shows the suggested conversion for each KPI. The fields in the table are:

- **ID**: each KPI includes an identifier to facilitate tracing through subsequent phases. The identifier is formed by two letters (KP), one small letter below the text baseline (e=emissions and s=saving), and a number; in case of a pilot city specific KPI there is an additional letter at the end, **T** for Tampere, **M** for Madrid and **G** for Genoa.
- **Title**
- **Conversion to gCO_2:** mathematical formulation indicating the conversion of the KPI unit to gCO_2.
- **Description**: explanation of what the indicator shows, and what is the reference scenario.

ID	Title	Conversion to gCO_2	Description	Indicator
KP1	Conversion is not required			
$KP2_e$	Emissions produce by freight transport $[kg/gCO_2]$	$KP2\left[\frac{kg}{litre}\right] * conv\left[\frac{litre}{gCO_2}\right]$	Use conversion Litre to emissions, depends of the fuel type.	↓
KP3	The unit of this KPI is already gCO_2 do not require a conversion			
$KP4_e$	Emissions per km of passengers $[gCO_2]$	$KP4[pkm] * CCF_{PT}\left[\frac{gCO_2}{pkm}\right]$	Carbon emissions of total passenger transported by a PT unit	↓
$KP4_s$	Emission saved by passengers in public transport $[gCO_2]$	$KP4[pkm] * CCF_{car}\left[\frac{gCO_2}{km}\right] - KP4e$	Carbon emission saved in 1km from total passenger transported by PT. Use of reference scenario of private car with low occupancy	↑
$KP5_e$	Number of passenger	$\frac{KP5\left[\frac{p}{fuel\ litre}\right]}{conv\ fuel\left[\frac{gCO_2}{fuel\ litre}\right]}$	Use the conventional conversion fuel to emissions	↑

[11] KP18 unit is km

	s per fuel emissions $\left[\frac{P}{gCO_2}\right]$			
KP6ₑ	Total emissions per passenger $\left[\frac{gCO_2}{P}\right]$	$KP6\left[\frac{fuel\ kg}{p}\right] * conv\ \ fuel\ \left[\frac{gCO_2}{kg\ fuel}\right]$	Use the conventional conversion fuel to emissions	↓
KP7ₑ	Emission volume in PT $\left[\frac{gCO_2}{Km^2}\right]$	$KP7\left[\frac{km}{Km^2}\right] * CCF_{PT}\left[\frac{gCO_2}{pkm}\right]$	Use the PT carbon conversion factor	↓
KP7ₛ	Emission volume saved by PT $\left[\frac{gCO_2}{Km^2}\right]$	$KP7\left[\frac{km}{Km^2}\right] * CCF_{car}\left[\frac{gCO_2}{km}\right] - KP7e$	Use of reference scenario of private car with low occupancy.	↑
KP8	The unit of this KPI is already gCO_2 do not require a conversion			
KP9	The unit of this KPI is already gCO_2 do not require a conversion			
KP10ₑ	Private vehicle emissions density rate $[gCO_2\ per\ 100($	$KP10[VpI] * CCF_{car}\left[\frac{gCO_2}{km}\right] * ADT[km]$	Use the car carbon conversion factor and annual average distance (ADT) [12]	↓
KP11ₑ	Average emission equivalent from average vehicle power [gCO2]	$\frac{KP11[hp]}{1{,}34\left[\frac{hp}{kWh}\right]} * crten\left[\frac{gCO_2}{kWh}\right]$	Use of Horsepower conversion to Kilowatt-hour and conversion of average carbon emission per unit of energy (crten)	↓
KP12ₛ	Share of diesel engine in total vehicles emissions savings $[gCO_2]$	$(CCF_{car} - CCF_{carDiesel})\left[\frac{gCO_2}{km}\right] * N_i * KP12 * ADT$	Carbon emissions save by diesel vehicles use CCF_{car} is car carbon conversion factor for gasoline and $CCF_{carDiesel}$ is car carbon conversion factor for diesel fuel. Use of reference scenario of private car with low occupancy	↑
KP13ₛ	Share of PT in total	$(CCF_{car} - CCF_{PT})\left[\frac{gCO_2}{km}\right] * P_i * KP13 * ADT$	Carbon emissions savings. Use of	↑

12 VpI is vehicles per 1000 inhabitants

	passengers traffic emissions savings $[gCO_2]$		reference scenario of private car with low occupancy	
KP14$_s$	Share of heavy trucks in total freight traffic emissions savings $[gCO_2]$	$(CCF_{fta} - CCF_{fth})\left[\frac{gO_2}{km}\right] * V_{ft} * KP14 * ADT$	Carbon emissions savings, average freight truck carbon conversion factor for all the vehicle fleet (CCF_{fta}) and heavy vehicles(CCF_{fth}). Use of reference scenario of full capacity truck	↑
KP15$_s$	Share of new units in total vehicles emissions savings $[gCO_2]$	$(CCF_{car} - CCF_{carN})\left[\frac{gCO_2}{km}\right] * V_i * KP15 * ADT$	Carbon emissions savings, average car carbon conversion factor for all the vehicle fleet and new vehicles. Use of reference scenario of private car with low occupancy	↑
KP16$_s$	Presence of alternative fuels vehicles emissions savings $[gCO_2]$	$CCF_{car}\left[\frac{gCO_2}{km}\right] * V_i * KP16 * ADT$	Carbon emissions savings, assuming that the alternative fuel vehicles are zero emission, if that is not the case, it is necessary to considerate their emissions. Use of reference scenario of private car with low occupancy	↑
KP17	Conversion is not required			
KP18$_s$	Emission saved in TF and OR routes $[gCO_2]$	$KP18\,[km] * CCF_{car}\left[\frac{gCO_2}{km}\right]$	Use of reference scenario of private car with low occupancy	↑
KP19$_s$	Savings from TF and OR usability $[gCO_2]$	$KP19\,[users] * CCF_{car}\left[\frac{gCO_2}{km}\right] * KP18[km]$	Use of reference scenario of private car with low occupancy	↑
KP20	Conversion is not required			
KP21	Conversion is not required			
KP22	Conversion is not required			
KP23	Conversion is not required			
KP24	Conversion is not required			

KP25M	Conversion is not required			
KP26M	Conversion is not required			
$KP27_sM$	Cycling intensity savings $[gCO_2]$	$KP28M\,[\%] * T_i * CCF_{car}\left[\frac{gCO_2}{km}\right] * ADT$	Use of reference scenario of private car with low occupancy. The emissions are per kilometre, this value can be multiply by the average distance	↑
KP28M	Conversion is not required			
$KP29_eM$	Average emission equivalent from average vehicle cubic capacity $[gCO2]$	$\frac{KP29M[cc]}{1000\left[\frac{cc}{fuellitre}\right]} * convfuel\left[\frac{gCO_2}{fuel\ litre}\right]$	Use of cc conversion to litres of fuel and conversion of average carbon emission per unit of energy (crten)	↓
$KP30_sM$	Share of CNG in total vehicles emissions savings $[gCO_2]$	$(CCF_{car} - CCF_{NCG})\left[\frac{gCO_2}{km}\right] * N_i * KP30M * ADT$	Carbon emissions save by CNG vehicles use CCF_{car} is car carbon conversion factor for gasoline and CCF_{CNG} is car carbon conversion factor for CNG fuel. Use of reference scenario of private car with low occupancy	↑

Table 5: List of KPIs conversions.

3.1.4 Analysis of data sources (TUT, SICE, QRY, TRE)

A matching of the data sources and the KPIs helps to identify which KPIs can be implemented in each of the pilot cities. The categories of which data can be classified in order to perform the calculation of the KPIs are:

Demographic data: data related with population for example working-inhabitants density.

Geographic data: data related with the land use, e.g. density of road in a specific area

Activity level data: data related with the performance in transport sector, such as total weight of goods transported.

Energy data: Data referred to the technical unit performance, e.g. fuel consumption in (Km/litre) or fuel efficiency.

Traffic data: data related with the vehicle fleet composition, such as number of private vehicles.

Keep in mind the categories of data sources required for calculating the KPIs. The following template table will summarize the data sources, as well as, describe and identify its origin and finally define the functionality.

ID	Name	Description	Information Category	Origin	Functionality
DST1	Cycling and pedestrian roads	Total traffic-free and on-road routes in km	Geographic data	Pilot site	KPI15

The fields in the template are:

- **ID**: each Data Source includes an identifier to facilitate tracing through subsequent phases. The identifier is formed by a letter to identify the pilot site (A for all the pilot sites, T for Tampere, M for Madrid and G for Genoa) and a number.
- **Name**
- **Description**: explanation of what the data source shows, and how the variables are related to each other.
- **Information Category:** categories of which data can be classified.
- **Origin:** refers from where the information is taken. For example data from sensors or historical data saved in a server.
- **Functionality:** refers to the KPIs that can be calculated with the data source.

3.2 KPIs, computational methods and data sources evaluation for MoveUs pilots

This section presents the list of **selected Key Performance Indicators (KPI)** that are relevant for the energy evaluation of the transport sector in each MoveUs pilot (Tampere, Genoa and Madrid). Additional to the list of KPIs in section 2.2, cities proposed their own KPIs for their cities' conditions. Finally, each of the MoveUs pilots evaluated the availability of data sources for the KPIs' calculation. The next Table 6 resumes the KPIs indicators selected by the pilot cities.

ID	Name	MAD	GEN	TRE
KP1	Performance of freight transport			
KP2	Fuel consume by freight transport			
KP3	Unitary gross annual energy savings			
KP4	Density of passenger transport	X	X	X
KP5	Number of passenger transported by fuel unit	X	X	X
KP6	Number of fuel units per passenger	X	X	X
KP7	Offer volume in public transport	X		
KP8	Total CO_2 emissions for travel (multiple modes) passengers			X
KP9	Total CO_2 emissions for travel (multiple modes) freight			
KP10	Private vehicles density rate	X	X	X
KP11	Average vehicle power			
KP12	Share of diesel engine in total vehicles	X	X	
KP13	Share of public transport in total passenger traffic			X
KP14	Share of heavy trucks in total freight traffic			
KP15	Share of new units in vehicles fleet	X		
KP16	Presence of alternative fuels vehicles	X		X
KP17	Presence of alternative fuels vehicles offering			
KP18	Traffic-free (TF) and on-road (OR) routes	X		X
KP19	Annual usage estimation in alternative modes			X
KP20	Facilities density in alternative modes	X		
KP21	Density of links in multimodal			
KP22	Link's Length in multimodal			
KP23	KPI's change per time unit	X		X
KP24	KPI's percentage of change	X		X
KP25M	User spending in transport	X		
KP26M	Public transport reliability	X		
KP27M	Cycling intensity	X		
KP28M	Local pollution	X	X	
KP29M	Private vehicles cubic capacity average	X		
KP30M	CNG vehicles in public fleet	X		

Table 6: List of KPIs for the three pilots.

3.2.1 Tampere pilot

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 (multiple modes) 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 7: List of KPIs for Tampere pilot.

Based on the list of KPIs selected, the available data sources are indicated in the following table:

ID	Name	Description	Information Category	Origin	Functionality
DST1	Inhabitants	Number of inhabitants in the area	Demographic data	National Statistics Institute	KPI10, KPI25
DST2	Vehicles	Number of private vehicles	Traffic data	Finnish transport safety agency statistics	KPI10, KPI11, KPI12, KPI15, KPI16, KPI17
DST3	Passengers	Passenger transported by a unit (bus)	Traffic data	Pilot site, Public transport unit	KPI4, KPI5, KPI8
DST4	Distance travelled	Annual distance travelled by the unit (bus)	Traffic data	Pilot site, Public transport unit	KPI4, KPI5, KPI6, KPI8
DST5	Fuel consumed (bus)	Unit consumed in km/l (bus)	Energy data	Pilot site, public transport	KPI5, KPI6,KPI8
DST6	Modal share (bus)	Modal share in total activity	Traffic data	Pilot site, City	KPI8[13]

[13] The modal PT share is calculated only every four years

		(%)		of Tampere	
DST7	Energy consumption of bus	Energy consumption of public transport (buses) (gCO2)	Energy efficiency data	Pilot site, Public transport	KPI18
DST8	Vehicles with alternative fuels	Total vehicles with new technology that use alternative fuels	Traffic data	Finnish transport safety agency statistics	KPI16
DST9	Traffic-free and on-road routes	Total traffic-free and on-road routes in km	Geographic data	Pilot site, City of Tampere	KPI18
DST10	Total number of cyclists	Total number of cyclists	Traffic data	Pilot site, city of Tampere	KPI19

Table 8: Data sources for KPIs calculation in Tampere Living Lab.

3.2.2 Madrid pilot

The selected General KPIs for Madrid pilot are indicated in the following list:

ID	Name
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
KP10	Private vehicles density rate
KP12	Share of diesel engine in total vehicles
KP15	Share of new units in vehicles fleet
KP16	Presence of alternative fuels vehicles
KP18	Traffic-free (TF) and on-road (OR) routes
KP20	Facilities density in alternative modes
KP23	KPI's change per time unit
KP24	KPI's percentage of change
KP25M	User spending in transport
KP26M	Public transport reliability
KP27M	Cycling intensity
KP28M	Local pollution
KP29M	Private vehicles cubic capacity average
KP30M	CNG vehicles in public fleet

Table 9: List of KPIs for Madrid pilot.

There are other KPI's proposed specifically for Madrid pilot:

ID KP25M	**Title: User spending in transport**
KPI category	Energy efficiency, others
Mathematical expression	$\sum S_{UT_i}$ [€]
Description	S_{UTi}= Spending by user and trip.
Goal	Aims to evaluate the spending that users make in their trips.
Comment	The KPI can be referred to public transport or private car. The unit of time can be hours, months, years etc.

ID KP26M	**Title: Public transport reliability**
KPI category	Energy efficiency, others
Mathematical expression	$\frac{T_{IT}}{T_T} * 100\%$ [%]
Description	T_T= total trips and T_{it} = In time trips
Goal	Aims to evaluate the compliance according to the established frequency.
Comment	This KPI is referred to public transport and can be used to detect an irregularity in the line course.

ID KP27M	**Title: Cycling intensity**
KPI category	Energy efficiency, Others
Mathematical expression	$\frac{B_i}{Ti} * 100\%$ [%]
Description	B_i= Number of bicycles used in year i Ti= Number of total modes of transport used in year i
Goal	Aims to obtain the percentage of cycling among the rest of surface transport modes used in a specific area.
Comment	The KPI is usually referred to year 2008. It grows according to the cycling offer increase.

The use of KP23 and /or KP24 applies in KP28.

ID KP28M	**Title: Local pollution**
KPI category	Energy consumption, energy efficiency
Mathematical expression	C_P $[ug/m3]$
Description	C_P= Pollutant concentration
Goal	Aims to follow the evolution of the impact of the mobility system in the local pollution.

Comment	This KPI can be applied to NO2 and PM10 pollutants per year.

ID KP29M	**Title: Private vehicle cubic capacity average**
KPI category	Energy consumption, energy efficiency
Mathematical expression	$CC\ [cm3]$
Description	CC= average Cubic capacity
Goal	Aims to follow the evolution of vehicles amount, according to their cubic capacity.
Comment	This KPI is referred to private vehicles.

ID KP30M	**Title: Share of CNG engine in public fleet**
KPI category	Energy efficiency, vehicles
Mathematical expression	$\frac{N_{NCGi}}{N_i} * 100\ [\%]$
Description	N_i= total number of vehicles [vehicles] N_{Di} = total units with compressed natural gas engine [number of units]
Goal	Shows the percent of vehicles that use CNG engines from total number of vehicle units. Higher share level (%) means that vehicles fleet is more efficient.
Comment	The KPI can be used only in cases where vehicles fleet has diesel and CNG engines, example buses.

Based on the list of KPIs selected, the available data sources are indicated in the following table:

ID	Name	Description	Information Category	Origin	Functionality
DSM1	Inhabitants	Number of inhabitants in the area	Demographic data	National Statistics Institute	KPI10
DSM2	Vehicles	Number of private vehicles	Traffic data	National Statistics Institute	KPI10, KPI12, KPI15, KPI28M, KPI29M
DSM3	Fleet size	Number of vehicles of the public transport fleet	Traffic data	Pilot site	KPI12, KPI15, KPI28M, KPI30M
DSM4	Alternative vehicles	Alternative to fuel vehicles (bicycles)	Traffic data	Pilot site	KPI27M,

DSM5	Engine	Cubic capacity	Energy data	Pilot site	KPI12, KPI28M
DSM6	Passengers	Passenger transported by a unit	Demographic data	Pilot site	KPI4, KPI5, KPI6
DSM7	Public Transport card	Credential of public transport users	Demographic data	Pilot site	KPI4, KPI5, KPI6, KPI25M
DSM8	Bike card	Credential of bike (alternative vehicle) users	Demographic data	Pilot site	KPI27M
DSM9	New technology	Vehicles technologically improved (>2010)	Energy data	Pilot site	KPI15
DSM10	Fuel	Fuel spent per trip per km	Energy data	Pilot site	KPI5, KPI6
DSM11	Area	City area with service coverage	Geographic data	Pilot site	KPI7
DSM12	Road length	Km of service coverage for vehicles	Geographic data	Pilot site	KPI18
DSM13	TF-OR length	Km of service coverage to cycling/walking	Geographic data	Pilot site	KPI18
DSM14	Distance	Covered distance (km) by a mode of transport	Geographic data	Pilot site	KPI4, KPI5, KPI6, KPI7
DSM15	Bike parking	Number of bike parking	Activity level data	Pilot site	KPI20
DSM16	Time	Unit of time	All	Pilot site	ALL
DSM17	Ticket price	Fares of the public	Economic data	Pilot site	KPI25M

		transport			
DSM18	Reliability	Public transport timetable and its compliance	Activity level data	Pilot site	KPI26M
DSM19	Pollution	NO2 and PM10 measurements	All	Pilot site	ALL
DSM20	Alternatives to fuel	Bio-diesel, hybrid, CNG, ethanol,...	Energy data	Pilot site	KPI16, KPI17, KPI30M

Table 10: Data sources for KPIs calculation in Madrid Living Lab.

3.2.3 Genoa pilot

The selected General KPIs for Genoa pilot are indicated in the following list:

ID	Name
KP4	Density of passenger transport
KP5	Number of passenger transported by fuel unit
KP6	Number of fuel units per passenger
KP10	Private vehicles density rate
KP12	Share of diesel engine in total vehicles
KP28M	Local pollution

Table 11: List of KPIs for Genoa pilot.

Based on the list of KPIs selected, the available data sources are indicated in the following table:

ID	Name	Description	Information Category	Origin	Functionality
DSG1	Inhabitants	Number of inhabitants in the area	Demographic data	National Statistics Institute	KPI10
DSG2	Vehicles	Number of private vehicles	Traffic data	National Statistics Institute	KPI10, KPI12
DSG3	Fleet size	Number of vehicles of the public transport fleet	Traffic data	Pilot site	KPI12

DSG4	Engine	Unit total horse power	Energy data	Pilot site	KPI12
DSG5	Passengers	Passenger transported by a unit	Demographic data	Pilot site	KPI4, KPI5, KPI6
DSG6	Fuel	Fuel spent per trip per km	Energy data	Pilot site	KPI5, KPI6
DSG7	Distance	Covered distance (km) by a mode of transport	Geographic data	Pilot site	KPI4, KPI5, KPI6
DSG8	Time	Unit of time	All	Pilot site	ALL
DSG9	Pollution	NO2 and PM10 measurements	All	Pilot site	KP28M

Table 12: Data sources for the calculation of the KPIs in Genoa Living Lab

4 Parameters affecting energy consumption / carbon footprint values

Parameters whose scale-up are known to directly correlate with increases in energy consumption / carbon footprint values (e.g. number of traffic lights, impact of winter/summer time on lighting needs on the streets, etc.). Wherever applicable, this list will include clear quantification of the influence the scale up /down the considered parameters may have on overall energy consumption/carbon footprint.

Environmental factors

Weather influences almost every aspect of transit service. Bad weather can reduce transit ridership, lengthen vehicle running and dwell time, reduce service reliability, and increase the cost of operation. Some of the weather impacts are summarized in the next Table 13 (2011) [44].

Traffic flow impacts / Road weather variables	Air temperature and humidity	Wind speed	Precipitations (type, rate, start/ end times)	Fog	Water level
traffic speed	N/A	X	X	X	X
travel time delay		X	X	X	X
accident risk		X	X	X	X
road capacity			X		
speed variance				X	

Table 13: Weather Impacts on Traffic flow.

Precipitations is an important weather factors, specifically light raining and snow that in normal levels they reduce average speed by 3 to 13 %, heavy snow can decrease average speed by 5-40% and heavy raining by 3-16% [44]. Proportional with the reductions in the average speed the travel time increases, causing more fuel consumption. Additionally to the previous mentioned affected parameters, car services such as heating, air-conditioning and lights rise the consumption [45][46].

There are several studies in the impact of weather on roads; however those approach weather measurements during a limited period of time in the year. Research from T. J. Considine (2000) [45] involves estimation of monthly models of energy demand where the monthly data provided more detail on seasonal variations in weather conditions. They found that weather can affect the average consumption, but still consumption stays stable in cases were lower and higher temperatures are present from the use of the additional services in cars (air-conditioning and heating).

An additional approach from Z. Guo et. al. (2007) [46] says that weather not only affects the travel experience (like deterioration in transit service quality), but also affects the activities that drive travel demand. They found that hot dry weather, increases recreation activities at beaches and parks, while cold wet weather may depress outdoor sports, recreation, and even social events. In cases where recreational spaces are in one cycling or walking distance energy consume does not increase, contrary, cases like Finland where common vacations are taking in cottages by 4 or 5 hours driving, can increase energy use and/or carbon emissions.

However most of the studies conclude that in general, good weather tends to increase ridership, while bad weather tends to reduce it. They also showed that the use of buses is usually more sensitive to weather than trains, and weekend driving is more sensitive to weather than weekday ridership (trip purpose)[45][46][47]. It is difficult to conclude a general effect of the weather on mode choices, especially because most of the studies focus their research on the general impact of climate change on transport choices and the period only cover a few months. Those periods are insufficient, since weather condition change over the year season by season. In addition, the weather indicators were recorded once a day and the number of indicators were limited. It is a difficulty in weather conditions in countries such as Finland were it can change hourly [48].

Nonetheless weather has a considerable impact on energy consume or/and carbon emissions levels. The heart of current transport activities are "daily actions of millions of individual's actors. Reducing transports environmental impact ... will... ultimately required a more thorough understanding of how individuals travel decision are motivated and/or constrained by other factors" [49]. This part of the document addresses the variables affecting the habitual modal choices of transport sector. By knowing the key factors affecting these choices and the reasons that discourage them, it is possible to estimate how those key factors affect the energy or/and emission levels in transport sector. Travel mode choice is one of the main causes of global ecological problems. CO_2 emissions caused by traffic play a major role in the greenhouse effect[50].

A study on modal split for journeys to work in 112 medium-size cities in Europe found that: car share increases with car ownership and GDP per capita; motorcycle share decreases with petrol price and raise with motorcycle ownership; bicycle share increment with the length of the bicycle network in the city; PT share rise with resident population [51]. Other studies from M. Winters et.al. (2007)[47] investigated individual-level factors such as age, gender, income, education, ethnicity, and commute distance, as well as community-level factors such as safety, weather, traffic, topography, cycling infrastructure, proportion of student, and population density as determinants factors of ridership. However most of the studies focus on few factors especially in PT use, like high fare, lack of PT information and bad accessibility to the network [52].

The key factors that influence modal choice are similar in most cities. However the way of influence or the level of impact of factors varies [49]. A resume of this factors can be seen in Figure 5 [53], where, factors are classified in two types: personal and external. Personal factors are divided into accessibility of transport modes, social- demographic aspects, attitudinal aspects and physical constitution. On the other hand, external factors are classified in location of opportunities/purpose of traveling, distance/travel time, natural environment, information and communication offers and transport and mobility offers.

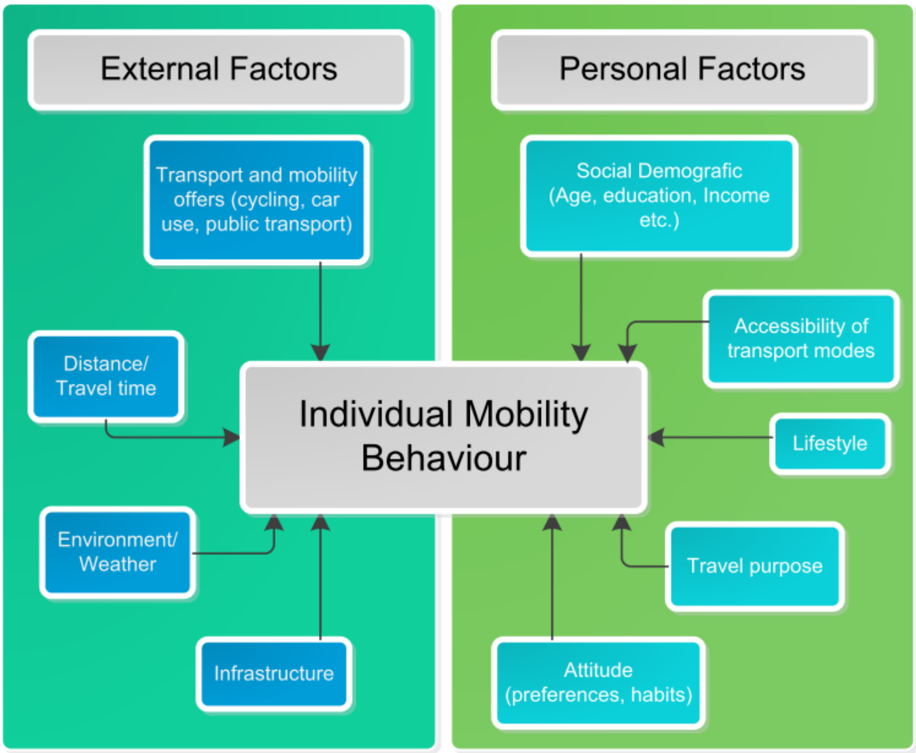

Figure 5: Factors of Influence on Individual Mobility Behaviour (modify from Mobility Management and housing (2008) [53]).

4.1 External factors

Generally external factors and especially infrastructural factors have a great impact on mobility behaviour, because they determine behavioural options. But individual patterns of mobility also diversify depending on personal factors. In this chapter the impacts of external factors are explained in more detail.

4.1.1 Public transport

In order to be able to change the mode choice from car to public transport (PT) is important to understand the degree in which factors discourages the use of PT. Some of these factors are: crowding, service reliability (related with sense of control), high fare, lack of PT information and bad accessibility[52].

A study in U.S. found that the availability of PT in some resident areas can make the difference [49]. They found that some resident areas where designed for private car, so PT in this areas is generally limited, making car use a necessity. Other problem is the lacks of facilities for specific part of the population such elders and people with disabilities or people with young children and baggage.

PT characteristics such Journey speed, are represented by frequency and speed of the PT service. Connectivity, that is how easy and the speed of transfer between modes and lines for example in the case of sub-urban train and intercity bus system. Reliability and accessibility that can be physical, like where are the stops and distance between stops, and in terms of information, such as mobile apps or timetables on stops. All of those factors can be used to rank the quality of service and affect the frequency of use [46] [49] [54].

PT use decreases proportionally with the cost of a monthly ticket. Contrary, increasing the number of buses are likely to increase PT share, similar effect includes the increases of resident population, GDP per capita and the number of buses operating per 1000 population. In some cases, weather precipitation increases PT share, but it is a factor that additionally depend of the passenger characteristics [51].

Increasing PT share is more than providing and effective PT, including adaptive transit services, modern infrastructure, traffic management tools, awareness campaigns, well-coordinated mobility schemes and advance ITS solutions; it, also requires a deep understanding of the local mobility conditions and patterns as well as the factors that dominate the preferences and modal choices of citizen.

G. Santos et.al. (2013) [51] found that passenger characteristics like age and number of children as well as their gender affects their modal choice, so elderly residents and family with more than one small child are unlikely to use PT. In cities with larger student populations, people use more PT and are more likely to cycle or walk. Fuiji et al. [55] conclude 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 ALM or PT, in terms of perception of time control (travelled time).

Finally, facilities that integrate PT and other modes can change the PT perception, by promoting new advantages. For example, train services that connect suburbs with the city that offer free bicycle places, in that situation, the user can see multiple benefits, such as saving money, health and time [56].

4.1.2 Cycling

Precipitation and temperature are relatively strong influences on cycling choice. Several studies on the effect of weather on bicycle choice found that rain is the main factor, followed by wind and temperature. Several weather factors had independent effects, in (extreme) low temperatures, people commonly switch from biking to car and/or PT, otherwise people prefer walking and biking, especially when temperatures increase [48][57][58].

Reduction on cycling is mainly caused by sensations of coldness and slipperiness, bad weather in general. Heavy snow reduces cycling by 60%[14], slippery surface by 20% and cold weather by 10%. These reasons are related with the perception of the mode. A survey in Oulu[15] (Finland) reported that citizens stop cycling in winter because they thought it was too dangerous (because the poor level of winter maintenance), too difficult or too dark [59]. A way to reduce the impact of precipitations and freezing temperatures on biking is by bringing more

[14] Reductions percent are from Oulu city webpage.

[15] Oulu is the winter capital of winter cycling, is a city of 193,902 inhabitants in the North of Finland. It is the fifth most populous city in the country

infrastructure support like snow clearing and sanding of ice along cycling routes, dedicated bike lines, bike-friendly transit, bike gear, bicycle tires and breaks for rainy or icy conditions and education about how to ride safely [47]. Other reasons are related with facilities at destination such as showers or bicycle parking. However, the connection of weather and cycling is not strong as is general conceiving, data from M. Winters et.al. (2007), found that weather doesn´t need be a strong barrier to the cycling community if cities offer the necessary facilities [47].

Raining, lack of end trip facilities and low safety perception are the main factors that decrease the use of bicycle. In consequence regular use of cycling and walking as a means of travels depends in part on the availability and proximity of facilities. Street design, lighting, aesthetics and accessibility contribute to how safe people perceive walking and cycling [49][52].

Some facilities that contribute to cycling and walking choices are: bicycle lines, safe main roads cycling crossing (who have the priority) and off-road paths, in the case of cycling, the distribution of space is crucial. Different research has shown that provision of designated road space for cyclists makes both cyclist and drivers more predictable and more comfortable with each other [34][51][52]. Other factors include traffic-calmed streets, safe and dry and easy access network, and facilities like parking and PT share (trains with place for bicycles).

Facilities to combine cycling with other modes of transportation is limited in some cities due to the inability of buses and some trains to accommodate bicycles, as well as the extra charges that some trains have for use this facility (e.g. 5 extra euros in Finland) provides further disincentives to mixed mode travel [49].

Same survey from Oulu (Finland) found that some reasons why citizens use bicycle are: it is a good exercise, the quickest journey, it is cheap, also the feeling of freedom to move, it is a green way of living, good bicycle connections, they don't own a car, and poor PT connections [34]. Is seems that cycling is used because of the convenience and quick travel time, also fitness, environmental friendly and enjoyment. Cycling offer an alternative to congested traffic, convenience to parking and door to door travel.

In cities where cycling is an important mode, cycle path clearance during winter is top priority, generally they invested heavily in specialist snow clearing machines and other technologies to keep paths clean. Örebrö, Sweden has a priority plan for snow removal and sanding of cycle paths in the winter and for the removal of sand in spring. Oulu has same priority as well as Zaanstad in the Netherlands, cleaning and information are also a priority. They have installed a website on which cyclists can report slippery road conditions.

Oulu is known as a success story because cycling is part of Oulu's culture; even on winter the sharing of cycling is high. It has one of the most extensive bicycling networks in the world, in total 613 km. Therefore, Oulu has 4.3 meters of cycle paths per inhabitant, a cycling modal split of 22% and a high winter maintenance levels [59]. Another example is Copenhagen, where 80% of cyclists keep on going in winter, which number is lower when there is a hard winter with snowstorm after snowstorm, but the numbers are still high, 90% of Copenhageners own a bicycle [60].

Danish learned how to ride a bicycle in early age, schools teach traffic classes, so cycling become a part of the children everyday life. They perceive as a practical alternative, safe and fast way to travel, so Danish government can enjoy healthier citizens and lower health cost. Mikael Colville-Andersen[16] declared "And rule No. 1 is what I call 'A to B-ism,' and that is, if you make it the quickest way to get around town, everyone and their dog will do it. Men in suits, mothers with children. … The basic anthropology of encouraging people to ride is to make it easier". A survey found that Copenhagen cyclists ride because: 54% it is easy and fast, 19% for exercise and only 1% for environmental reasons [61]. As a conclusion, providing well usable infrastructure, encouragement (incentives) and help with bicycle maintenance can bring higher split percent's of cycling riding on cities.

4.1.3 Car Use

The use of private car is one of the most energy demanding and less efficient transportation systems. The target should be to pursue users to opt for other modes through means of promotion of energy efficient behaviour, including energy efficient driving, car-pooling facilities through applications, car sharing facilities, especially in residential areas, and car-free zones/areas inside to cities, like city centre or touristic places [56].

Most of the studies agree that car ownership is the principal determinant of car use. The car is even used in trips where other modes are most cost effective or energy efficient; those choices processes are mainly automatic, people only drive without considering other alternatives [49][62]. The main problem is that people are not aware about the real cost when they drive in this short distances and in adverse weather conditions like winter. Studies from U.S. Environmental Protection Agency had determined that a drop in temperature from 24°C to 7°C increased fuel consumption in urban trips by 12% to 28%. For a vehicle that typically achieves a 500 km range on a full tank represents a loss of 60 to 140 km per fill-up during the winter [63][64]. This efficiency reduction is caused by several phenomena that happened inside of the cars, additionally to the increase of use of resources in comfort.

One of the main causes is the time that takes for engine to reach its most fuel-efficient temperature; in short trips this has a higher effect because the engine spends more of the trip in less efficient temperature. Warming up the vehicle before starting the trip decreases the efficiency and increases the level of emissions, as car is using fuel without move. Additional factors like aerodynamic drag increase because air is denser, this also influences tire pressure increasing resistance with the pavement. Run cars comfort such as heated seats, window defrosters, and heater fans require additional power when at the same time the battery performance decline requiring more energy from the alternator [64].

[16] Mikael Colville-Andersen, Denmark's unofficial ambassador of bicycle culture. He is a frequent consultant to the Copenhagen government on bicycle issues and author of the internationally famous bicycle blogs Copenhagenize.com and Cyclechic.com

4.1.4 Infrastructure

Infrastructure refers to physical routes, buildings, and vehicles that involve long-term capital investment by governments. The technology used for the physical routes, e.g. pavement, affects the movement of vehicles under various weather conditions. For example ice and snow on streets, roads and cycle paths cause problems for users during winter and spring, resulting on maintenance actions that influence safety, accessibility, mobility and vehicle cost. Winter maintenance operations also represent a very substantial portion of year-round maintenance costs and often impact our environment [46][65].

Government and industry spend large sums of money responding to those requirements. In Canada $1,3 billion are used annually on activities related with snow and ice control on public roads [44]. In Finland the cost of maintenance during winter is 54% of the total budget (Figure 6). It is approximately 98 million euros that represents a cost of 1 200 - 1 300 euros per kilometre. In Germany, the average cost of the winter maintenance during 2000-2010 was: on motorways 6930 euros per kilometre and on federal state roads 1 818 euros per kilometre [66].

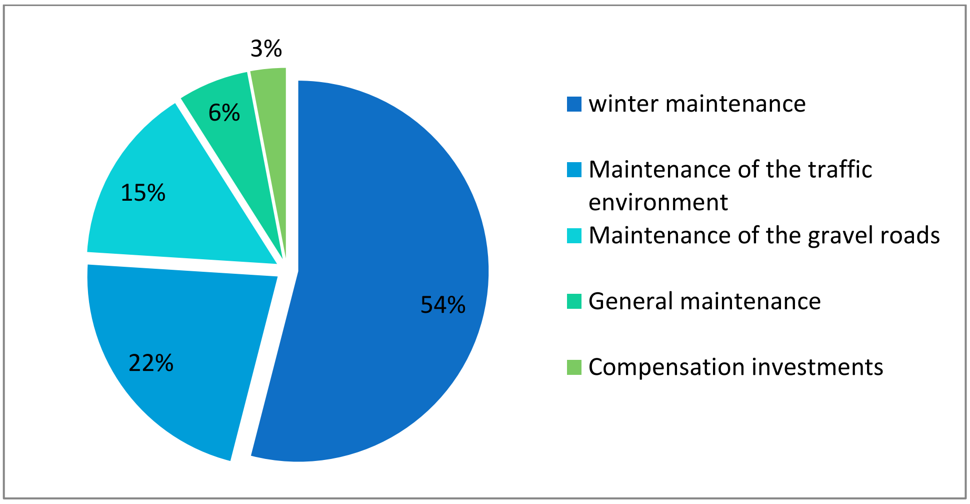

Figure 6: The distribution of the cost in road maintenance (Finnish Transport Agency 2011).

The requirements in maintenance during winter, not only increase the energy use and carbon emission, but also the infrastructure design, such as the different types of station/stop, with or without weather protection, or a simple stop affect travellers' waiting and transfer experience, which is more relevant during winter season than summer. The distance between station/stops that affects the access and exit walking distance, and thus the time exposed to weather conditions. The greatest impact of the infrastructure design is on 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 [45][52][67].

Another part of the infrastructure is street lighting. Lights' working hours vary with the geographical natural light situation during the whole year (variations by season). However the E-street project found that on average there is not a significant difference between northern and southern European countries. Normal Lights' working hours calculation without dimming and switching on/off based on the remaining daylight level is 4150 hours per year on average throughout Europe. Nonetheless, based on the existing installations within Europe, the project had identified an annual saving potential of 38 TWh of electricity by changing old installations with adaptive lighting, this represents 63.7 % of present annual consumption for street lighting [68].

4.1.5 Cost and Income

Relative cost of transport modes is an important factor in travel mode choice, for example high PT fares decrease its share level. PT price usually reflect real cost of the system, in case of private car owners the price is no clear, they usually do not recognize the real driving cost, like health impairment (because of air pollution), accidents and noise. In Europe, this external cost is approximately 7.3% of the gross domestic product [49]. And most of these external costs are subsidy for local governments. To obtain a more accurate cost of car use, the social account should include not only direct and external cost but also the cost associated with the manufacturing of the vehicle, its life cycle, as well as the infrastructure that require.

Another determinant for mode choice is the household income that defines the availability of private car [69]. Results from the Mobility Management and housing (2008) show that higher incomes increases the number of cars per house and the possibility to use a car by 34%, in comparison, modal split with ALM and PT decreases in higher proportion. Consistently, groups without a car are mostly single retired persons as well as students [52][53].

4.1.6 Trip

Trip characteristics, like trip length, time flexibility and trip purpose, may affect the weather impact user perception. A longer trip is sensitive to weather because the exposure time is higher than if it is a short trip. If a trip time is important it may be less sensitive to weather conditions, and the decision fall on the user time control perception. If the trip purpose is a personal situation rather than mandatory like work, it might be more sensitive to weather [46].

As residential areas grow out of the city, the connection between suburban and urban distance is a considerable factor. Main facilities like distance to the closest shop can determinate which mode to use. If the perception of the distance is high, car is generally accepted as the best option and if the distance is short, the use of bicycle or walk is acceptable [67]. 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 [48][52].

The purpose of the travel plus the perception on the transport mode time affects the choice, for example, business trips are more likely to use private car than recreational trips. Mode choice decisions are mainly done at home and at work, so land design patterns between these two destinations are crucial. In Europe nearly 4 of 5 trips start at home [52][53][70].

As mentioned before, time travel is a factor, but user perception of speed has different levels of relevance depending of the trip purpose. It is generally known that car gives sense of control in time because car is perceived as fast, reliable, flexible and comfortable [49][70]. However in a study presented in [52], individuals that were more aware of environmental issues were more motivated to use PT, while travellers more sensitive to stress tend to prefer car over others modes.

4.1.7 Information

An international demonstration project called “Switching to Public Transport”, initiated by the UITP (International Union of Public Transport) an operators' association with scientific leadership from Social data had performed about 45 projects in 13 European nations related with switching of private car use to PT. Most of the projects were about empowering people by providing them with localised information, advice and encouragement about ALM of transport, and leaving the choice to them[71].

On all those project the main tool for making changes was the priority that has given to effectively distributing information to users by customizing transport information based on several traveller characteristics or/and necessities. This personalized information can motivate users to think more effectively about their daily travel. As a result, people should receive information that enables them to improve their perception and motivate and empower them to make their own decisions, rather than telling them what they should do because that can create an aversion to the project [49][71][72].

The information should be related with specific needs of the users and alternative potential modes, however surveys in several projects had shown that this information does not reach the respective target groups [71]. One way, as mentioned before, is to generate social changes through direct contact with specialized groups like cyclist associations or cycle chic. This personalised approach gives as a result that the information goes to the user and is provided in a very specific way.

4.2 Personal factors

There are two types of factors that are relevant for individual mobility: social-demographic characteristics, determined by individual options and necessities such as gender, age, education or profession etc.; and attitudinal factors like values, norms and attitudes that are symbolical estimations about the mode (perceptions). In this chapter user’s characteristics and attitudes are analysed, as well as their effect on transportation mode decision.

4.2.1 Social-demographic characteristics

Social demographic characteristics of the users’ are relevant factors in their transport mode choice. Some main characteristics are income, age, gender; education level, etc… see Figure 7 [51].

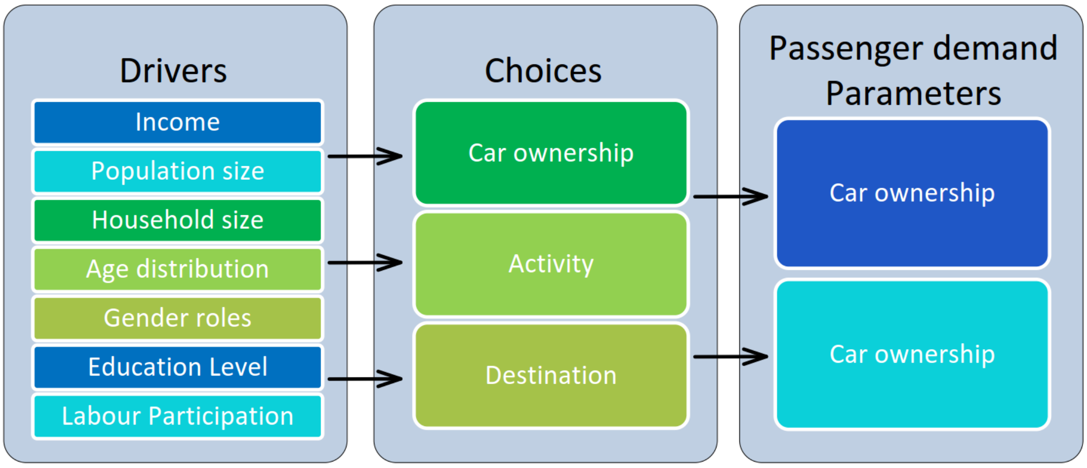

Figure 7: : Drivers of user transport demand (modify from G. C. de Jong and O. van de Rie (2008)) [69].

According to [51], weather condition can affect personal characteristics in two ways:

1. Different people may respond differently to same weather, for example, a teenager may view a snowfall differently from an elderly person and a professional in a suit may respond differently to rain than a runner in shorts.
2. People may have different travel options and their response to weather may vary accordingly. The transit travel of people who don't own a car may be less affected by weather compared to people who can easily switch to auto, as it was explained previously.

The studied presented by M. Sabir et al. (2008) shows that age has a considerable effect on transport mode choice. It shows that older people walk more compared to the other two age groups, younger than 18, 18 to 60, and older than 60 [48]. In addition, the number of trips made for each travel purpose also affects the mode selection [46].

In the Canadian urban population, older adults and women with lower education and higher income are much less likely to cycle for utilitarian purposes than teenagers and men [47]. These findings are similar to results from the U.S. travel survey. The results contrast with data from European centres, where men and woman are equal likely to cycle and cycling rates vary little across age like in Netherlands [48].

Cycling patterns in students have lower variations on different weather conditions, this may be because students have fewer transportation options, cycling is economical cheaper, or that student generally make shorter trips by cycling, commonly they live close to schools or universities. Analysis in the United States has shown that cities with higher proportion of students have higher cycling rates [51] [67].

4.2.2 Motivations for change

Motivational events for changing mobility behaviour are based on the analysis of the social-physiological factors like attitudes towards the environment and toward certain mode of transport, and the importance of moral obligation and environmental believes with society [73]. Those factors can be classified into two groups: perceived behavioural control and perceived mobility necessities. In general, mobility behaviour is influenced by situational and personal factors.

Perceived behavioural control refers to user's personal habits or custom mobility actions. J. Prillwitz et al. (2009) defined habits as an obstructive factor as they reduce conscious awareness. Habitual behaviour simplifies and accelerates users' actions and/or decisions, and habits reduce perception of travel alternatives, and increase cost for alternatives modes. Both effects become more significant with an increasing frequency of use of the chosen travel mode. In this study they found two ways to breakup habits, fist one is by interrupted automatic actions and second, by changing users' contextual conditions [73].

One way to interrupt users' automatic actions is by introducing moral considerations and at the same time information about alternatives for a more sustainable mobility [73]. However the behavioural changes can only be achieved by major societal changes, such as creating a group where all the members can identify with that new way of mobility. An example of this is web sites like bike Seasons[17] that was born from a passion for cycling and a desire to showcase the many faces of cycling and the seasons of the year , other from Copenhagen is cycle chic, where cycling culture is combine with fashion[18].

Another way to give information is by making users' more aware of environmental cause effect chains and trying to change destinations and mode of transport. A success action is education at early age (at schools), for example, since 2004, transport and education departments in England have funded a ''school travel plan'' program for all elementary and junior high schools [55]. Multiple cases around Europe with the program traffic snake game aim to encourage schools, children and parents to adopt walking, cycling, car sharing or PT when travelling to and from school[19].

This way of education breaks barrier to use ALM that are usually associated with additional effort and decreasing of comfort [73]. Additionally on older residents, there is a change in attitudes, mainly on moral and environmental beliefs and are more willing to sacrifice comfort for more sustainable lifestyles.

Other factor is the perceived mobility necessities. J. Scheiner and C. Holz-Rau (2007) found that for individuals with strong social orientation, good access to PT

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[17] Bike Seasons is a photo blog and online magazine from Finland, where Finns and foreigners can share their own cycling photos and experiences http://www.bikeseasons.fi/

[18] Cycle chic refers to cycling in fashionable everyday clothes, was created in Copenhagen http://www.copenhagencyclechic.com/

[19] The Traffic Snake Game is a campaign for primary schools that stimulates and enables young children and their parents to go to school in an environment-friendly, safe and healthy way. http://www.trafficsnakegame.eu/game

and urbanity in general is more important than others. Consequently they prefer to live in urban areas, where distances are shorter, so they are more likely to use public or alternative transportation than the car, and less travelled kilometres. In contrast, individuals in elder age or with family tend to prefer suburban areas, because suburban are perceived as more peaceful areas, which are out of the city for that reason and others, like comfort; they are more likely to use private car and as a consequence, vehicle kilometres are higher than those who live in city [67][70].

As a conclusion, physiological attachment to the car, lack of information and lack of moral use implications are factors that block transport behavioural changes. A good quality of PT, congestion, education and moral obligation reduce car use.

4.2.3 Critical incidents

Transport mode choice is not only influenced by planning, but also by key events and critical incidents. A key event is an important event in the personal life that will create a change in users' travel behaviour. On the other side the change can also come from critical incidents, like being involved in an accident. P. van der Waerden et al. (2003) identify two types of events: a change in the number of available alternatives and a change in its characteristics [74].

In general, changes in the number of available alternatives refer to key events that affect the composition of transport modes. The key events, such as getting a driver licence and getting a new car, result in a diminution of alternatives decision. Less impact but similar effects are starting to work and starting a family. Few studies concentrate in states that make changes in life, like first work, or marry or have the first child, and use their change potential to break travel behaviour habits [73][74].

J. Scheiner and C. Holz-Rau (2008) also found a connection between life situation, lifestyle, choice of residential location and travel behaviour. The results indicate that lifestyle (affecting location attitudes and location decisions) influence mode choice, although just slightly, but life situation like a high income outpace the lifestyle effect [67].

Change on the characteristics of available alternatives refers to modifications in mode like time, cost, and comfort. The resulting modification in users' behaviour depends on their attitude. Users' attitude is defined as the relationship between the event and the perception of the mode, so those changes can promote a switch to positive, negative and no influenced attitude [73].

The forward Table 14 summarize all the factors that could affect transport mode choice. N represents a negative effect, meaning that the factor reduce user probability to choice that mode. Contrary to N, P represents a positive effect, so the factors increase the user probability for that mode.

	MODES			
	Walking/ cycling	Public Transport	Private Car	Motorbike
External Factors				

Transport and Mobility offers				
Station/Stops distance[20]	N	N	P	P
Share facilities[21]	P	P	N	N
Price				
Fuel	P	P	N	N
Ticket PT	P	N	P	P
Information[22]	P	P	N	N
Service reliability	P	P	N	N
Specific facilities [23]	P	P	N	N
Amount available				
Car/motorbike[24]	N	N	P	P
Bicycles/ Buses	P	P	N	N
Trip characteristics[25]				
Travel distance	N	P/N	P	N
Travel time	N	P/N	P	N
Environment/weather conditions[26]				
Temperature	P	P	N	P
Precipitation	N	P	P	N
Fog	N	N	P	N
Infrastructure				
Support during winter (cleaning)	P	P	P	N
Bike parking	P	P	N	N
Showers	P	P	N	N
Car parking	N	N	P	P
Street design				
Bike lines/bus lines	P	P	N	N
Highways	N	N	P	P
Personal Factors				
social demographic[27]				
Younger age	P	N	P	N

[20] Higher distance

[21] Flexibility to transfer from one mode to other, e.g. allow bicycles on trains or trams

[22] More personalize mobility information

[23] Refers to facilities for a specific part of the population such elders, people with disabilities or young children.

[24] Level of car ownership and motorbike ownership

[25] Higher distances or travel time

[26] Higher temperatures and higher level of precipitations per year

[27] Younger age is younger than 18 as passenger, middle age between 18 and 60, older age are older than 60 pensioned condition. Higher population density and higher income

Middle age	N	N	P	P
Older age	P	P	N	N
Gender (feminine)	N	N	P	N
Student	P	P	N	P
Population density	P	P	N	P
Income	N	N	P	P
Lifestyle				
Events[28]	N	N	P	P
Life stage[29]	N	N	P	N
Others				
Travel purpose[30]	N	P/N	P	P/N
Attitude	N	N	P	P
Education	P	P	N	P/N

Table 14: Factors affecting transport mode choice.

Table 15 presents some of the factors that affect the energy efficiency of the different transport modes. The up arrow shows the direct correlation to increase (scales up) energy efficiency, meaning that the energy consumption/carbon foot print values decrease. Down arrow represents the energy efficient diminishes (scales down), indicating that the energy consumption/carbon foot print values increase.

	MODES			
	Walking/ cycling	**Public Transport**	**Private Car**	**Motorbike**
Transport and Mobility offers				
Station/Stops distance	—	↑	—	—
Share facilities	↑	↑	—	—
Price increment				
Fuel	—	↑	↑	↑
Ticket PT	—	↓	—	—
Specific facilities	—	↑	—	—
Amount available				
Car/Motorbike	—	—	↓	↓
Bicycles/ Buses	↑	↑	—	—
Trip characteristics				
Travel distance	↑	↓	↓	↓
Travel time	↑	↓	↓	↓

[28] like getting a driving licence and getting a job

[29] life stage like starting a family life or getting older prefer to live in suburbs

[30] Travel purpose refers to going to work or school

Environment/weather conditions				
Temperature	—	↑	↑	↑
Precipitation	—	↓	↓	↓
Fog	—	↓	↓	↓
Infrastructure				
Support during winter (cleaning)	—	↓	↓	↓
Bike parking	↑	—	—	—
Car parking[31]	—	—	↓	↓
Lights	—	↓	↓	↓

Table 15: Factors affecting energy efficiency.

4.3 Affecting parameters in MoveUs pilots

The following tables are a simplified compilation of the affecting parameters that apply to each of the city pilots. As same as the Table 15, the tables presented in this section have a list of factors that affect the energy efficiency of the different transport modes. The up arrow shows the energy efficiency scale up. Down arrow represents the energy efficiency scales down.

4.3.1 Tampere pilot

	MODES			
	Walking/ cycling	**Public Transport**	**Private Car**	**Motorbike**
Transport and Mobility offers				
Station/Stops distance	—	↑	—	—
Amount available				
Car/Motorbike	—	↓	↓	↓
Trip characteristics				
Travel distance	—	↓	↓	↓
Travel time	—	↓	↓	↓
Environment/weather conditions				
Temperature	—	↑	↑	↑
Precipitation	—	↓	↓	↓
Fog	—	↓	↓	↓
Infrastructure				

[31] Car parking factor can affect the EE in different ways depending of the parking type, for example in cases where the parking is placed on the city centre the EE decrease. On the other side, car parking outside of the city specially placed for users to commute with the city PT, increase the energy efficiency.

Support during winter (cleaning)	—	↓	↓	↓
Bike parking	—	—	—	—
Car parking	—	—	↓	↓
Lights	—	↓	↓	↓

Table 16: Factors affecting energy efficiency on Tampere pilot.

4.3.2 Madrid pilot

	MODES			
	Walking	**Cycling (Electrical motor)**	**Public Transport**	**Private Vehicles**
	Transport and Mobility offers			
Number of Station/Stops	—	↓	↓	↓
Distance between Stations/Stops	—	↑	↑	↑
Price increment				
Fuel	—	—	↑	↑
Ticket PT	—	—	↓	—
Amount available				
Car	—	—	—	↓
Bicycles	—	↑	—	—
Public buses	—	—	↑	—
	Trip characteristics			
Travel distance	—	—	↓	↓
Travel time	—	—	↓	↓
Velocity	—	—	↓	↓
Uphill	—	↓	↓	↓
Downhill	—	↑	↑	↑
	Environment/weather conditions			
Extreme Temperatures	—	↓	↓	↓
Precipitation (rain, snow,…)	—	↓	↓	↓
Fog	—	↓	↓	↓
	Infrastructure			
Bike parking	—	↑	—	—
Car parking	—	—	—	↓
Traffic lights	—	↓	↓	↓

Table 17: Factors affecting energy efficiency on Madrid pilot.

4.3.3 Genoa pilot

	MODES			
	Walking/ cycling	Public Transport	Private Car	Motorbike
Transport and Mobility offers				
Station/Stops distance	—	↑	—	—
Share facilities	↑	↑	—	—
Price increment:				
Fuel	—	↑	↑	↑
Ticket PT	—	↓	—	—
Trip characteristics				
Travel distance	↑	↓	↓	↓
Travel time	↑	↓	↓	↓
Environment/weather conditions				
Temperature	—	↑	↑	↑
Precipitation	—	↓	↓	↓
Infrastructure				
Car parking[32]	—	—	↓	↓
Lights	—	↓	↓	↓

Table 18: Factors affecting energy efficiency on Genoa pilot.

[32] Car parking factor can affect the EE in different ways depending of the parking type, for example in cases where the parking is placed on the city centre the EE decrease. On the other side, car parking outside of the city specially placed for users to commute with the city PT, increase the energy efficiency.

5 MoveUs methodology for energy efficiency assessment

This chapter outlines the methodology that was developed to evaluate and define city transport projects for energy efficiency (EE) and especially for MoveUs Living Labs and the specification of the energy calculator module. The main objective of this methodology is to help cities to improve their EE by defining strategies and taking actions and in the specific case of MoveUs project, in the transportation domain. In order to define it, several standards and European frameworks were reviewed to identify gaps.

This methodology begins at the project planning stage, by defining the energy efficient/carbon emission goals, identifying the target groups and variables. Forward an energy evaluation is conducted as well as is defined the set targets values for the performance indicators, that are the result of the energy evaluation step, after it proceed with the implementation, and finally an analysis and strategy evaluation are conducted as it is shown in Figure 8. This Methodology is useful because gives clarity and direction to the process. In there the city can evaluate every step of the process from start to finish, so it is easy to notice if the mobility project is on track or off-track.

The methodology is based on two well-known European frameworks for mobility management projects impact measurement (European Union's MOST MET program [75] and Sweden's SUMO program [76]), and the international standard ISO 50001 for energy management. MOST-MET was set up as a part of the EU project MOST (Mobility management Strategies for the next decades), that ran between 2000 and 2002. MOST included about 30 partners in several countries in Europe. MET (Monitoring and Evaluation Toolkit) was the tool design for evaluate MOST project. SUMO as well as MOST MET are systems that could be utilized in planning long term mobility management projects. The models ensure that relevant indicators and evaluation resources are set and people are committed to them already in the planning phase.

SUMO stands for System for Evaluation of Mobility Projects; it is based on MOST MET, it was adapted to suit Swedish conditions by Trivector on the commission of the Swedish Road administration. Was created to offer a common indicator to similar projects, targets and indicators can be specified at different levels. ISO 50001 supports organizations in all sectors to use energy more efficiently, through the development of an energy management system (EnMS), which consist in follow a systematic approach to achieve continual improvement of energy performance, including energy efficiency, energy use and consumption.

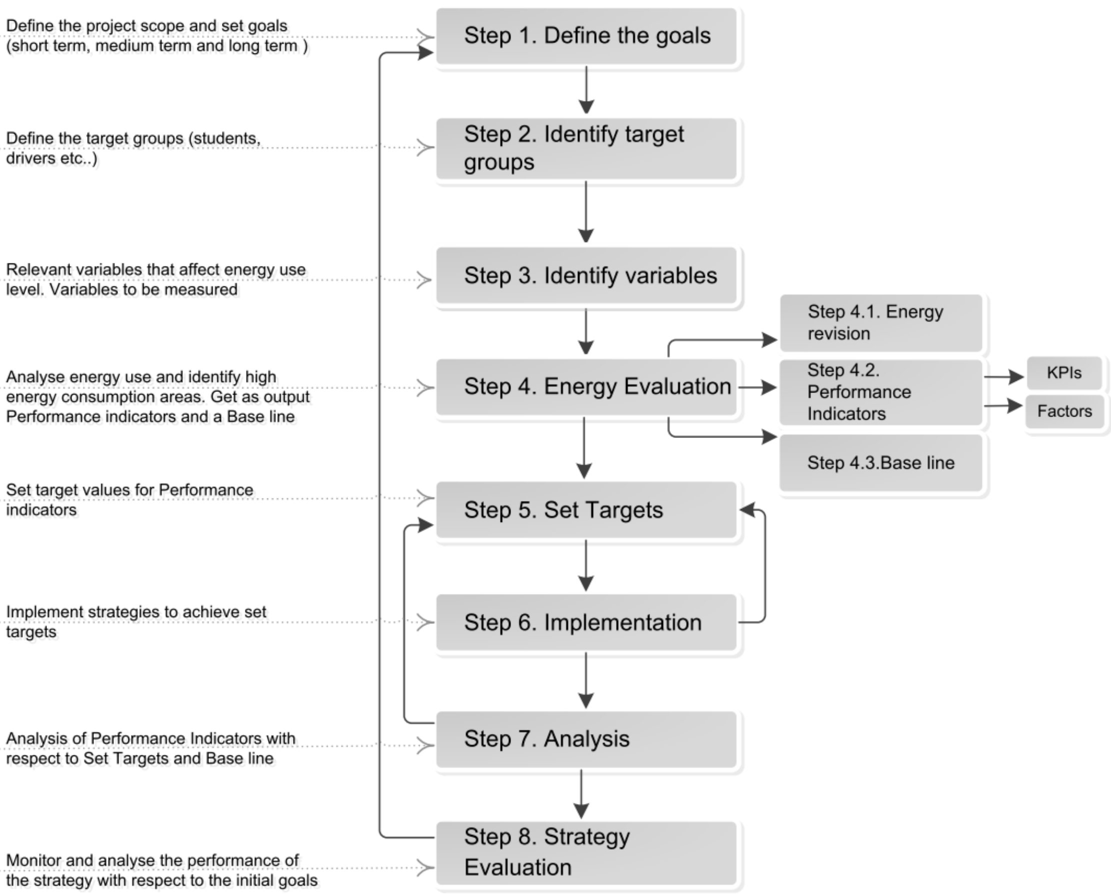

Figure 8: Methodology.

The methodology is divided into eight steps that were defined and approached to the case of energy computation module for MoveUs considering the different Living Labs that are supported by MoveUs platform. A general description of the steps is provided below.

Step1. Define the Goals: This step starts the process with the definition of the goals defined by the city including deadlines for compliance following the SMART process. In MoveUs EE and CFP methodology, the cities have to define their objectives in three terms: short, medium and long term, in order to make possible the evaluation of the EE in different stages of the process and take corrective actions if needed. For example, a short-term goal could be that people use PT in at least 20% of their weekly journeys making a reduction on energy/carbon emissions. Medium term goal could be that people use PT at least 70%, long term could be 50% PT, 40% ALM (bicycle or walking) and 10% private car, so at the end each of the goals originates carbon emission reductions and increases in the overall energy efficiency. The cities may place the priority of the goals where city-specific considerations and necessities are reflected.

Step2. Identify target groups: Target groups are those whose behaviour is attempting to change during the project. This identification allows designing better and personalized strategies and to measure results more effectively, not only for the energy calculator module, but also for identifying users' incentives.

Step3. Identify variables: Relevant variables for determining energy use/carbon emission levels. It includes the variables to be measured over all methodology steps (e.g. average car efficiency [gCO_2/Km]).

Step4. Energy evaluation: In this step the status of the system in terms of energy and emission is evaluated, as a result of this step a list of KPIs and Factors is obtained as well as a base line. This step is based on the norm ISO 5001 and includes the following activities:

4.1 *Energy Revision.* Includes three stages: 1) Analyse current usage and energy consumption of the whole system (past and present) and all the energy sources. With this information is possible to 2) identify points with high energy consumption that changing the target groups habits is possible to have a 3) potential improvement with respect to the performances in other areas of the system. The potential could be prioritized based on the characteristics of each city.

4.2 *Performance indicators*. Based on the energy revision, the city might be able to choose a set of key performance indicators[33] to evaluate improvements in the energy behaviour of the system; in addition, external and personal factors shall be selected. These indicators should be directly related with the city's goals and must be measurable in a practical way using available data and calculation techniques.

4.3 *Base line*. The base line is the quantitative reference to measure the energy/carbon emission performance changes. It has to be stablished under a suitable period of time depending on the goals and time where the system is. For example a possible base line in the case of a person who is going from point A to B is the private car, which has an average fuel efficiency determinates by the country law (or European Union), as this law is changed periodically, the base line also should change.

Step5. Set Targets: After the definition of the base line and all the performance indicators, the city has to set reachable targets. For each indicator set a target and a time frame to be reached. The targets and time frame must be supported by the measurement of the generated data over time related with the chosen indicators.

Step6. Implementation: Depending on the targets and their time frame, cities should select the strategies that will be implemented in this step. The implementation step as well as other steps must correspond to city goals as well as its capacity to be implemented. If the set goals require an implementation that exceeds city capacity, the set target must be redefined.

Step7. Analysis: In this step, an analysis of the performance indicators with respect to the set targets is performed. The frequency of this analysis depends on implementation time and the goal terms (short, medium and long term).

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[33] KPIs values has specific units that should be changed to a common unit, by implementing conversion factors

Step8. Strategy evaluation: Monitor if the goals are achieved. If the goals are not achieved during the evaluation in this step, corrective actions are evaluated as well as the source of the delay (in achieving the goals) by performing an internal evaluation of the previous steps. To finalize the strategy evaluation, cities can establish new goals and optimize the process.

5.1 Definition of Energy efficiency methodology

The methodology framework guides cities to measure the impact of their energy initiatives against the program's goals. The process is divided into eight steps, as it was briefly explained before. Each step of the methodology is described further in this section.

5.1.1 Step1. Define the Goals

The project goals should answer the question: why is the city doing this project? To be able to answer the question, the cities can optionally implement the SMART (**S**pecific, **M**easurable, **A**chievable, **R**elevant and **T**ime framed) method [77]. In case the city has clear and well defined goals, it is not required to implement this methodology; however it can be a useful tool for defining goals that are not completely defined. By completely defined we refer to goals that have sub objectives that can be measured and classified according to a timescale.

5.1.1.1 SMART

The goals should be clear and measurable, realistic and set in a suitable way (understood and accepted by all the organization), additionally shall be possible to divide them into objectives[34], which allows a simple checking in the strategy evaluation (step 8). It is important to notice that if the system change or even one part of it (e.g. an increment of 10% in PT use) the objectives or/and goals definition or/and priority will change too. Priority is implemented in different points on SMART method, but is specially evaluated in the timescale banding.

SMART, refers to **S**pecific, **M**easurable, **A**chievable, **R**elevant and **T**ime framed.

Specific: A specific goal has an initial approximation of what the city wants to accomplish and how to do it, this initial definition is important because it will be consulted during all the methodology application process. To set a specific goal the smart city pilots must answer the five "Wh" questions:

1. Who is involved?
2. What does the city want to accomplish?
3. Where? Identify a location, if it is local impact [35]
4. When? Establish a time frame

[34] Goals are long-term aims that the city wants to accomplish. On the other hand objectives are concrete attainments that can be achieved by following a certain number of steps.

[35] Local impact means a goal that is specifically for a city area, e.g. new PT connections to connect area 1 and 2, so in this case the Where is area 1 and 2 but the goal is defined by the city.

5. Why? Specific reasons or benefits of accomplishing the goal

At the end of this stage the goals are subdivided in objectives.

Measurable: Establish concrete criteria for measuring process toward the attainment of each goal that the city pilot sets. To identify if the goal is measurable, cities should ask the following questions: How much? How many? And how will I know when it is accomplished?

Achievable: It is the initial classification of the goals. This stage is where the living lab should identify what goals are most important for them, and figure it out how to achieve those goals. Basically is defining how the goal can be accomplished.

Relevant: A relevant goal must represent believes that can be accomplished and also that deserve the resources that are required to achieve the goal. The challenge is to make the targets demanding and realistic.

Time frame: Goals should be time framed by attaching a target date. This is necessary to prioritize the work and is the last stage of the SMART method. At the end, the goals are allocated to time bands by consideration of when goals could be completed. The three time bands are: short (0-1 year), medium (2-5 year) and long (6-15 years) term[36]. The goals will be updated every certain period of time (defined by the city) to adapt to changing conditions and new cities' priorities.

5.1.2 Step2. Identify target groups

Target group is defined as the group of people that has similar needs and travel patterns but often different ways to approach the information. Identify the target group in the earlier steps allows to city pilots to measure results more effectively and to design more focused programs, so it makes easier to take data and calculate the impact of their strategies.

The mobility programs can be applied to the entire city, such as campaigns that target all the city inhabitants and visitors, or a specific area, like campaigns that target only residential areas or a specific neighborhood. However the target group can also be classified by demographic characteristics, such students in the city or families with children. It is important to describe carefully the target group so the mobility services can therefore focus on individual's needs.

The target groups should also be described, including typical characteristics and how they can be reached. Typical characteristics could include various travel habits. Notice that the evaluation and monitoring process is going to be carried based on the target group definition.

An example of a target group definition in a traveler project is:

The project focuses on car commuters at three major work places x, y and z. Of these the campaign particularly targets persons that live in towns with good bus

[36] The three time bands can be define by each of the smart city pilots depending of their necessities.

connections to each workplace. The selected people should be typical car commuters with an adequate PT alternative [76].[37]

5.1.3 Step3. Identify variables

The primary objective of this step is to identify the variables that describe the objectives of the project. The goal is to identify a set of regularly generated, well-documented, easily obtainable variables that can explain the variability of energy use/carbon emission levels. However, the task is not trivial because it requires previous knowledge on this kind of proposes. For this reason it is useful to considerate other projects with similar goals. Those projects can provide previous reviews, processes that have been already made, or measurement processes that can be seen as the sources of information in this step.

It is important to note that these variables cannot be analysed in isolation, as are often the specific combination and interaction of a collection of factors that influence the magnitude and direction of energy use/carbon emission levels. Current and past Energy use activities can be also a source of information to identify the variables. The approach could be used by the cities to identify opportunities for decreasing energy use.

Another important stage in this step is to identify all energy resources (electricity, types of fuel etc.) depending of the goals that are defined before. By identifying the energy sources (see Table 19), the tracking of which components of the transport system[38] are consuming the energy is easier and the variables will describe them.

Electricity
Biofuels: • **Ethanol** • **Biodiesel** • **Biogas**
Hydrogen
Conventional fuels: • **Gasoline** • **Diesel** • **Natural gas**

Table 19: Energy sources.

At the end of this step the city will have a list of variables that describe what components affect the energy consumption. The definition of what constitutes a "significant energy use" and an analysis of these factors will be approached in future steps so now those definitions are not relevant.

[37] Example is taken from the target group definition in SUMO definition methodology.

[38] previously enclose with the objectives

5.1.4 Step4. Energy evaluation

Energy savings implies an inventory of all energy consuming activities, activities along the transport system that were narrowed by the objectives. Based on the previous identified variables we identify the areas that have a considerable energy use, so in this step an energy revision is performed. As a result a list of KPIs and Factors is obtained as well as a base line.

The energy evaluation should be documented in a report that describes in detail the EC structure, the proposed improvement and the time schedule for implementation, as well as supporting technical data. The cities must record and maintain the energy revision update as the project require.

5.1.4.1 Step4.1. Energy Revision

The energy revision allows the cities to determine their energy performance based on data and/or actual measurements leading to identification of opportunities for improvement. The energy revision provides useful information for the development of the energy base line and the selection of the energy performance indicators (key performance indicators KPIs), as well as the factors that affect them. It also establishes the monitoring capacity of the city to support effective continuous improvement of the energy performance in the future.

A critical review of the system (based on the goals) may be carried out to identify the most significant energy consumers, which might warrant further analysis. Notice that from the previous step the list of identified variables is obtained, so this analysis review should be limited to those variables. However, definition of significance becomes an important matter in this respect. This methodology does not impose any criteria to define the significance but it leaves up to each city to decide this based on their necessities and particular conditions.

In the ranking process of significance the ISO 50001 advices to approach at first, the highest levels of EC in order to focus initially on the larger energy consumers, leaving the smaller ones to be dealt with later reviews and /or cycles.

To conduct the review, the organization shall establish a structure to evaluate the information sources. The source's data are required to identify the performance indicators and also to perform analysis and evaluations. For future purposes, the data sources are divided into three types: direct data, reported information and model outputs.

Direct data are data collected from direct observations. Reported information is data that are reported by another body (institution, private sector, other previous projects, etc.), so they are not directly observed. Finally model outputs are data that is delivered from models of the system; this can be a mathematical model.

5.1.4.2 Step4.2. Performance indicators

Based on the previous steps the cities might be able to choose a set of key performance indicators to evaluate improvements in the energy behaviour of the system; the indicators values will reflect energy efficiency achieved by specific improvement projects. They are specified for each target group and for each of the goals. Indicators should be chosen to be consistent with the objectives.

Definition of indicators should be as accurate as possible; they should preferably be in line with international standards to allow future comparison, internal and external as a reference point. When evaluating EE using these indicators the city must be careful to compare them in categories. For this case it might be advisable to use conversion methods to get a standard unit for all of them. To achieve this the cities can use conversion factors, such as $\left[\frac{gCO_2}{kWh}\right]$ or $\left[\frac{\mathrm{gCO2}}{\mathrm{fuel\ litre}}\right]$, other units like km of TF or number of electric vehicles that can be turned into energy/emission units by stablishing a reference scenario. In the last case the KPI will be identified by an *s* meaning savings, otherwise it will be identified by an *e* of emissions (see section 3.1.3 for more information).

In many parts of the transport sector, EC is the result of a combination of a large number of factors. This may include climatic conditions, fleet characteristics etc. so EC is dictated not only by the EC but also by the complexity of the factors that can affect it. As a result, each city has its own list of KPIs and factors that reflect the specific project goals that includes the environment in which the project is implemented.

5.1.4.3 Step4.3. Base line

The energy base line is one of the outputs of the energy analysis, however local and country regulations may be consulted for establishing a base line. This baseline constitutes a point of reference before the implementation of actions. This approach allows the comparison between before and after data and the estimation of progresses accomplished.

An energy base line is the quantitative reference to be used for determining future and actual data. It reflects the scope of the program's wanted impact. To be directly useful, the base line must be performance-based, which means that it should have the same units as the performance indicators. An energy baseline should detail energy data and take into account variables that influence EC (step3).

5.1.5 Step5. Set Targets

In this step, action plans should be developed to address all of the cities' energy goals, targets detailing how and when they are to be achieved, which will subsequently facilitate monitoring the progress in achieving the energy objectives. The action plans should include schedules, resources and responsibilities for achieving the targets. However, they should be flexible and be able to be revised to reflect any changes in the objectives.

Targets are often conveniently expressed in terms of improvement of the performance indicators over time. Their values should be practical and achievable, and must conform to the cities goals. The baseline will help the cities to understand the existing travel pattern and set ambitious but reachable targets. For each of the indicators, set a target and a time frame must be supported by a data collection plan that allows for consistent, timely measurement of the chosen indicators. Notice that it is important to study or be aware why changes have taken place. This means that the list of indicators should include reasons for the changes in behaviour, before the implementation, what are the reasons that cities believe would generate these changes?

At the end of this step the action plan would result in a large number of proposals on how to reduce this EC, however those need to be prioritized. Clear prioritization criteria may be appropriate according with cities' conditions and goals. One common prioritization is based on a combination of saving potential and financial return where significant costs are involved.

Based on the overall goals of the project, cities can have other target values depending of the level of implementation, but are not necessary related with the final goal of the project. For example, a project that wants to reduce energy use in daily commuter students and has as an objective to increase the awareness of mobility services. At the same time it can have a target of at least 80 percent of people at university know about the project, so as we can see the target is not directly related with the EC but it is related with the project objectives.

5.1.6 Step6. Implementation

After the prioritization of the proposals the action plan should be implemented taking into account the targets time frames. During the implementation is crucial to apply control procedures. Control procedures ensure that relevant activities are in place for controlling each of the energy use inside of the transport system. The implementation step, as well as other steps, must face the city goals as well as their capacity to be implemented. In the case of the set goal requires an implementation that overs city capacity, the set target must be redefined.

5.1.7 Step7. Analysis

It requires the cities to monitor, measure and analyze the key characteristics of its implementation, which determine energy performance at planned intervals. Equipment or procedures used for monitoring and measurement of key characteristics (or identified variables) should be calibrated to ensure data are accurate and repeatable.

Appropriate processes should be implemented to ensure the reliability of the data. Evaluation of actual versus expected (target values) of the performance indicators as well as reviews shall be carried out in previously established time periods.

The cities should also search and respond to significant deviations in performance parameters, and especially why the target values are not achieved as well as propose corrective actions to change the current behavior of the transport system.

5.1.8 Step8. Strategy evaluation

In this step, cities should establish a program to evaluate periodically their project implementation and check the effectiveness of the system in fulfilling their objectives. The strategy evaluation is different to the analysis in the way that the strategy evaluation evaluates the process and implementation of the project to determinate if they are appropriate to the cities capacities. It helps to identify nonconformities and opportunities for improvement of the energy efficient projects.

In general this step should cover: the specific activities that are going to be evaluated. Each project has its own strategies and this point can also be divided in objectives. The frequency, in which the evaluation will be performed, depends on the results of the Analysis step.

In case of nonconformity, the necessary corrective and preventing actions must be initiated and implemented. A fundamental principle in this methodology is that cities are capable of identifying and fixing the problems as well as taking actions to eliminate the cause of the problem. Corrective actions refer to actions to eliminate the cause of a detected nonconformity while preventing actions refers to actions that will eliminate the cause of a potential nonconformity.

The process to address nonconformities should include: an analysis on the cause of non-conformance, identification and implementation of corrective actions, modification of existing controls if it is necessary, establishment of preventive measurements where appropriate. It is important to notice that in some cases it is necessary to perform other studies in order to identify what actions are necessary to produce a specific system impact.

Time aspects in analysis and evaluation are important. Changing attitudes and behaviors takes time, so it often takes one or several years before the last two steps can be measured. Finally by following this methodology cities can establish new goals and optimize the process.

Methodology instantiation in MoveUs Pilots

5.2.1 Tampere pilot
5.2

Main goal

The main goal of Tampere pilot is to contribute to Tampere's sustainable mobility goals by increasing the share of walking, cycling and public transport.

Objectives

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

Question	Objectives			
	1	2	3	4
Who	Tampere city Transport TKL or Tampere City Council	Tampere city Transport TKL or Tampere City Council	Tampere city Transport TKL or Tampere City Council	Tampere city Transport TKL or Tampere City Council
What	Reduce the use of private car	Increase modal share of alternative modes	Increase modal share of Public transport	Increase public transport awareness
Where	In city urban area	In city urban area	In city urban area	In city urban area
When	Long term	Long term	Long term	Short term
Why	- Increase the energy efficiency and reduce carbon emissions. - Less pollution=air quality - Less congestion and traffic jams due to reduced number of cars	- Increase inhabitants health - Environmental protection (no pollution, no noise) - Maintenance of a safe and lively urban area - No emissions of greenhouse gases - Health	- Makes more energy efficient the system - Reduced noise - Larger green areas and a lower number of/ less need for car parks and parking lots - Faster and more reliable public transport	- Increase public transport modal share - Increase knowledge about energy efficiency - Increase the access to Public transport system

Table 20: Objectives and "Wh" questions for Tampere city.

The city urban area is defined as the area that is covered by the zone 1 of public transport as can be seen it in the map below. It shows the Public transport in Tampere region, which is organised jointly between eight municipalities, Tampere, Pirkkala, Nokia, Kangasala, Lempäälä, Ylöjärvi, Vesijärvi and Orivesi.

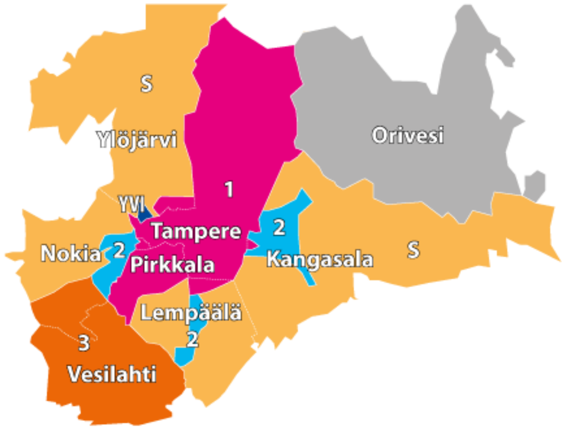


Figure 9: Tampere public transport zones [78].

Target group

There are three main target groups in Tampere city: private car users, commuters, and Tampere city inhabitants. Direct target groups are private car users and commuters. Tampere city inhabitants is a target group, however they are classified by multiple target groups like the ones mentioned before.

Tampere had 220,446 inhabitants by 31 December of 2012, which represents a population density of 410 inhabitants per square kilometre. The number of private cars registered in Tampere is 90,906; and in this case, Tampere will assume that one private car is equivalent to one user.

Identified variables

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

Table 21: Identified variables for Tampere city.

Energy Evaluation

Energy Revision

Energy sources:

Tampere has available all conventional fuels and electricity (see Table 22); however their composition is not the traditional (100% fuel). By law, Finland establishes a percentage of Biofuels in combination with traditional fuels call Bio-share, which for 2014 constitutes 8% in both gasoline and diesel. As shown in Figure 10, CO_2

emissions from bio components of fuel are defined as zero emissions. In 2020 this percentage is expected to be 10% in Europe but Finland has committed to a 20%.

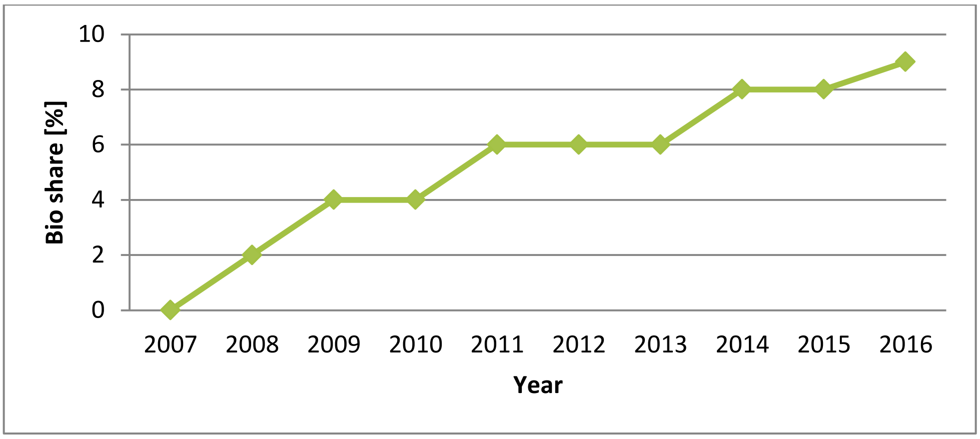


Figure 10: Bio-Share percentage in traditional fuels in Finland.

Electricity
Conventional fuels: Gasoline Diesel Natural gas

Table 22: Energy sources for Tampere city.

Transportation has an important percentage on Tampere's greenhouse gas emissions; fortunately, it has been decreasing in the last four years as shown in Figure 11 where the emissions of transport sector from 1990 to 2013 are evaluated.

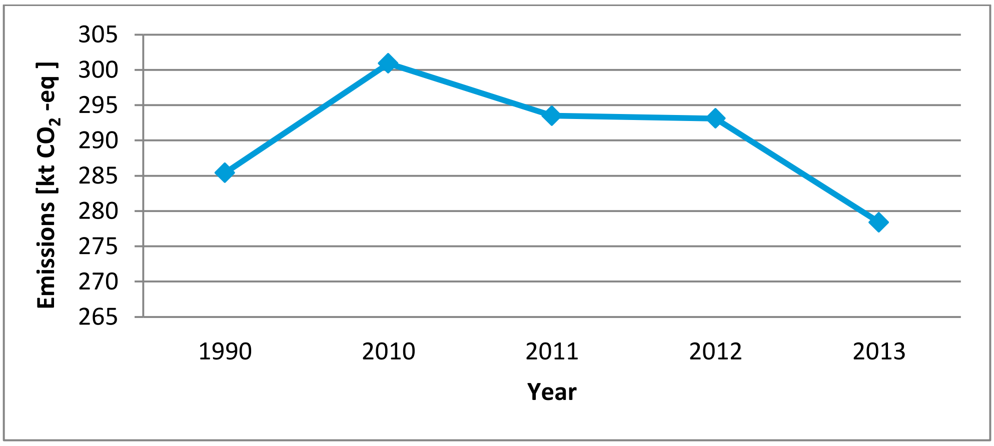


Figure 11: Transport sector emissions in Tampere.

Tampere current car ownership is 90,906, which increases every year 4% with respect of previous year and 18% with respect to 2000; so Tampere has on average of 425 cars per thousand inhabitants. In addition, there is a small presence of electrical vehicles that for 2004 the number was 20 in the city of Tampere, which were acquired for testing and for Tampere Adult Education Centre.

Related with the modal share, Figure 12 shows the evolution of modal split for Tampere city and its goals for 2016. As can be see, the percentage on public transport has increased with respect to 2005 and it will continue growing for 2016. In alternative modes, from 2005 to 2012 there was a small decrease but for 2016 tit is expected that the he percentage will increase.

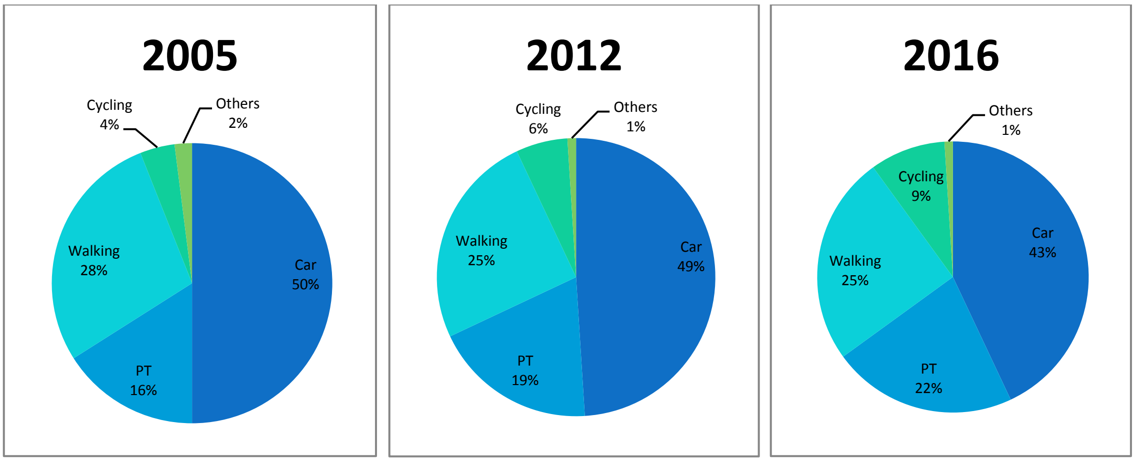


Figure 12: Tampere transport modal share, 2005-2012-2016.

Tampere public transport has grown from 2006 to 2012. In 2012, there were a total of 88570 commuters per day in the public transport system and it has increased compared to the previous year's travel volumes. Tampere public transport is mainly bus traffic; however there are some taxis and in the future a modern city tramline will be added to Tampere' public transport system. Since 2006 the city has been implementing different strategies such as extending bus services, lanes and traffic light priorities in order to promote the use of public transport. In addition, the city is expected to have its first tramline by 2020.

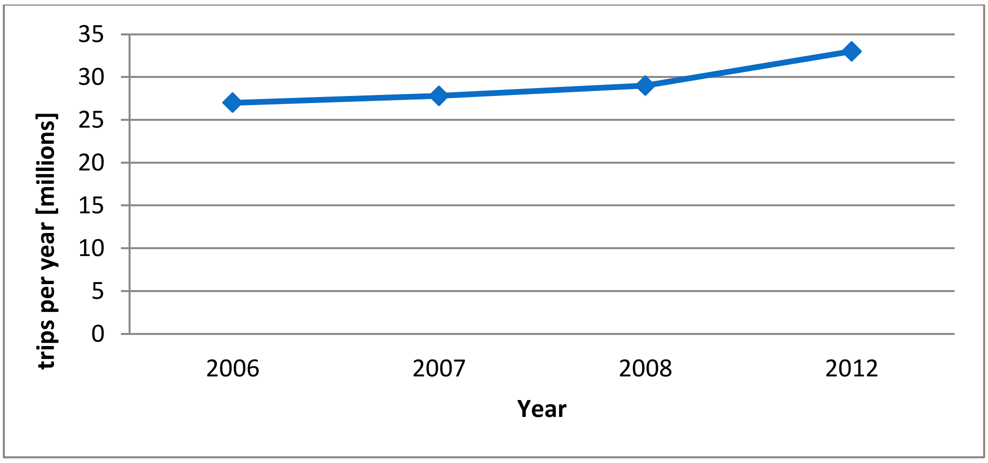


Figure 13: Commuters per year in public transport in Tampere city.

In alternative modes, cycling volume has been also growing, especially during winter season after a considerable decrease from 2008 to 2011. The bicycle path network length has grown at the same average every year, at the end of 2011, Tampere had 602 km of cycle paths which are composing by asphalt paved or gravelled. Some other measures, additionally to new cycling routes to promote the use of bicycles are: improvements in the roads such as new tunnels and bridges, and campaigns like Minä poljen in 2012.

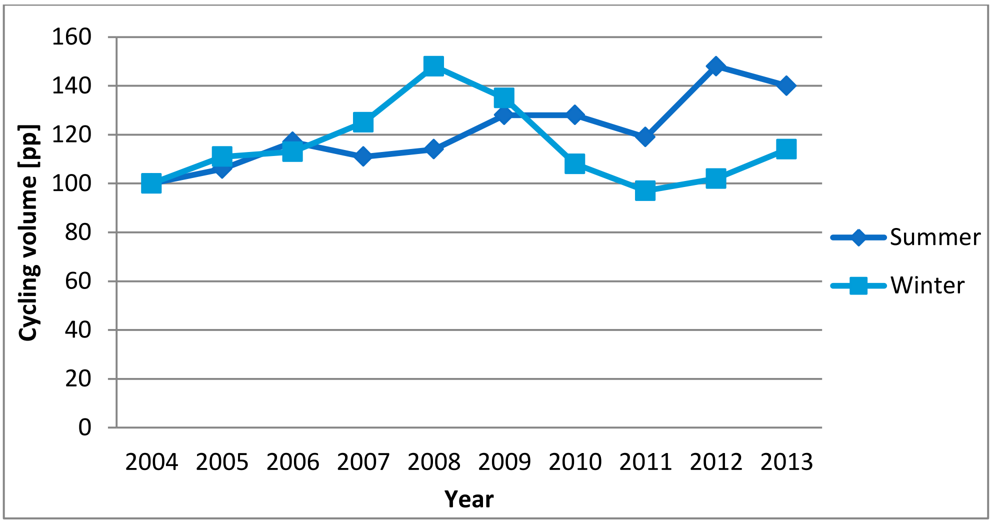


Figure 14: Tampere cycling volumes developed during winter and summer[39].

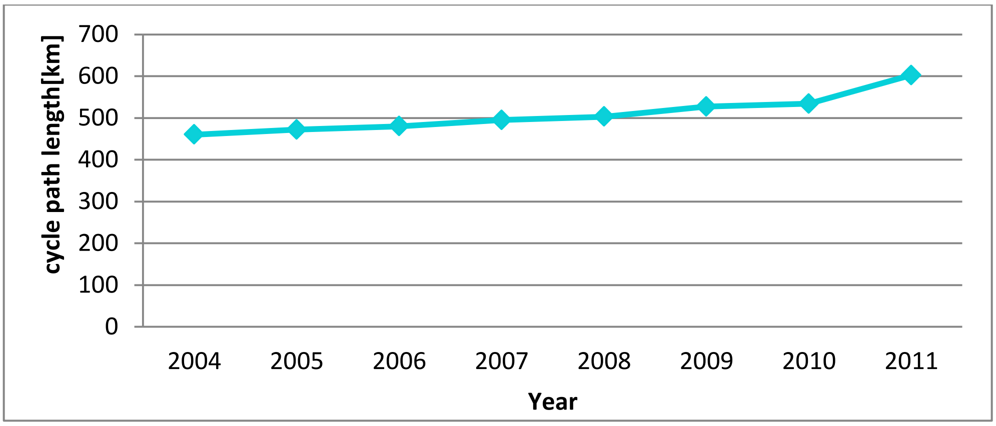


Figure 15: Tampere cycle path length per year.

The city has several projects in the alternative modes to encourage their selection. Some of them are:

- Walking and cycling communication plan, incl. Example. HEAT calculations (2014)
- Commuting walking- and cycling potential, UKK Institute (2014-2016)
- ARTICLE II: Commuter cycling potential and walking the streets (2014)
- Walking and cycling computations (2014)
- An urban walking and cycling follow-up model (2014)
- Waterway and bike parking information in the open window of data (2013)
- Pedestrian and bicycle paths exporting the digital road-II, Tampere, Finland a pilot project (2013)

[39] Pp refers to number of persons in this case cyclists

The public transport service awareness in the Tampere area has been done through traditional and new media. The traditional methods are maps that contain the public transport routes (see Figure 16) and books with more detail information about times and stops for each bus line.

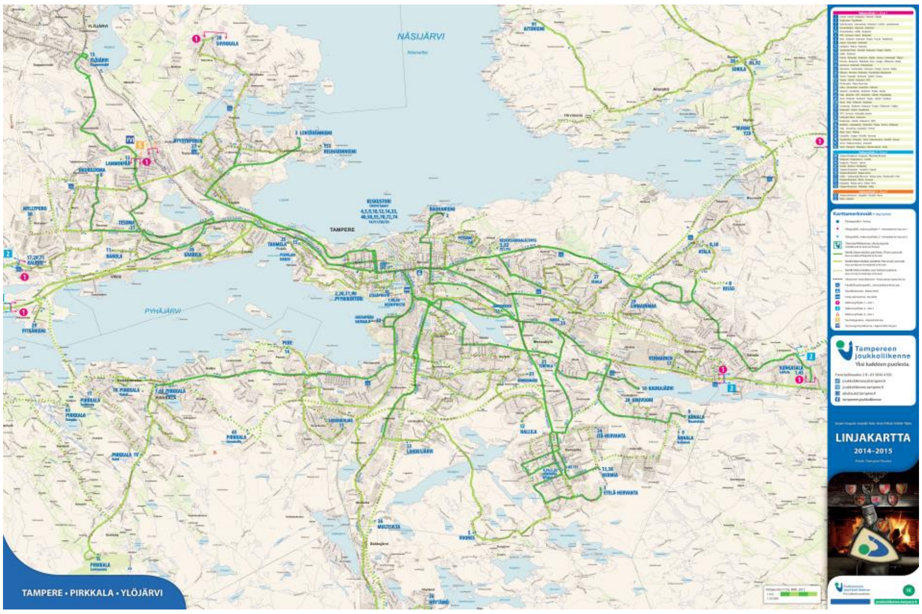


Figure 16: Tampere public transport routes Linjakartta 2014-2015[78].

The new medium is the Tampere public transport web site where users can consult several aspects of the public transport service. This web site also includes a journey planner call REPA, which contains the Timetables, Journey planner, Transit map, Cycle route planner and Traffic monitoring. The Timetables are disposed in an interactive way where users can choose the bus line and access for each of its stops, the next three departures and time tables per day (Monday-Friday, Saturday and Sunday) see Figure 17.

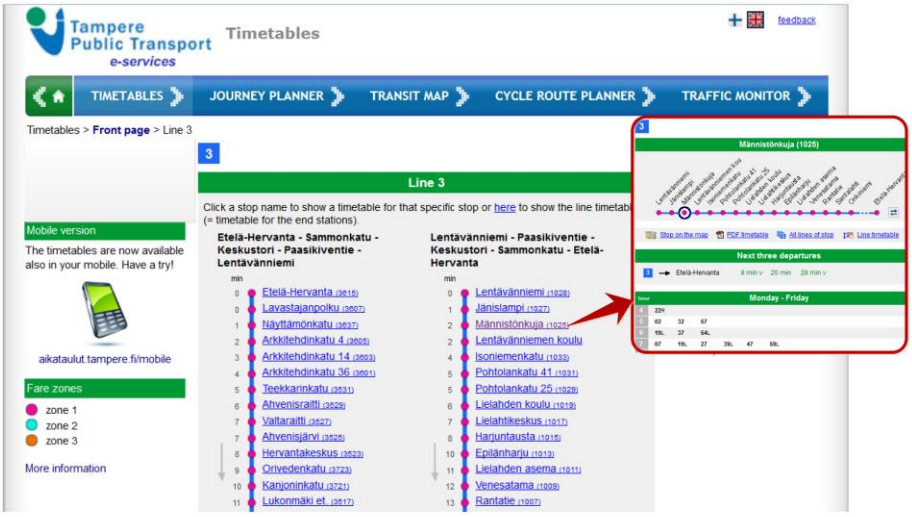


Figure 17: Tampere public transport REPA time table [78].

The journey planner consists in a route search that allows users to enter the departure and destination as well as the time and date of arrival or beginning of the trip. After the user enters that information, the system calculates the route and gives to the user several suggestions, which include the bus number, its time in departure and destination place, and the meters that the user should walk to get to his/her final destination. This information is complemented by a map that shows the route suggested (see Figure 18).

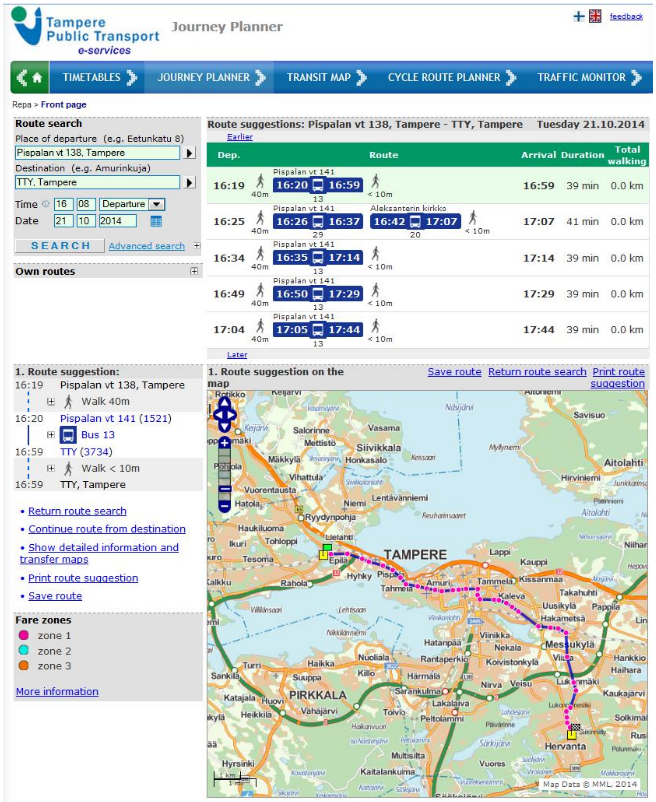


Figure 18: Tampere public transport REPA Journey Planner [78].

Transit map shows the bus lines information over the map, so by choosing the line the users access to all the stops and can select the stop which its location is display on the map with a red circle as can be seen in the forward Figure 19.

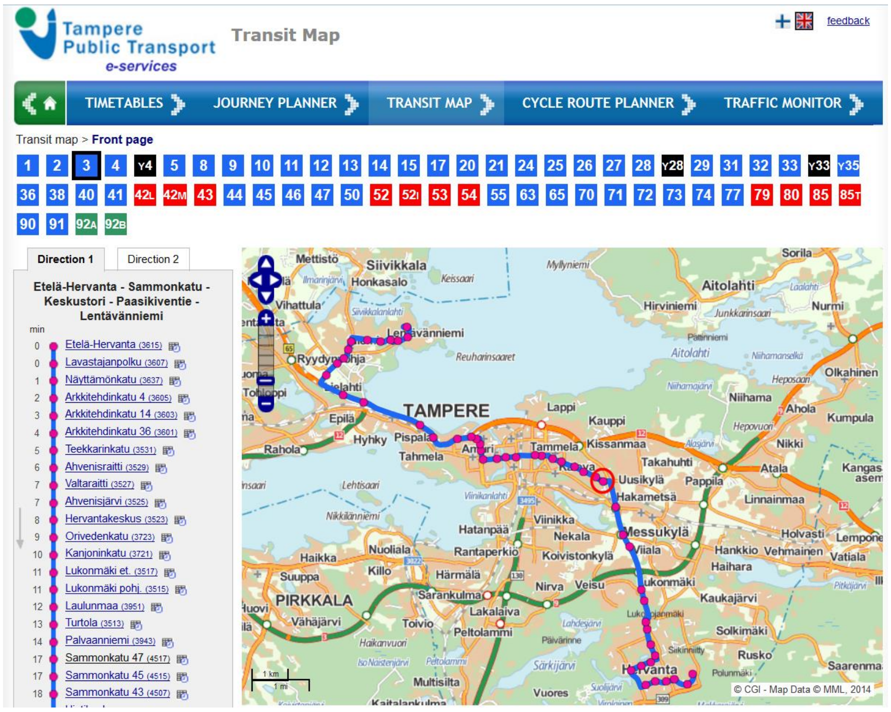


Figure 19: Tampere public transport REPA Transit Map [78].

Cycle route planner as well as the journey planner the users should enter the starting and destination point, it is also possible to choose a prefer cycle path. The suggested route is displayed in the map with information about the maximum altitude and length of the route. Additionally users can modify displacement speed so in that way the route planner calculates the time in a more accurate way (see Figure 20).

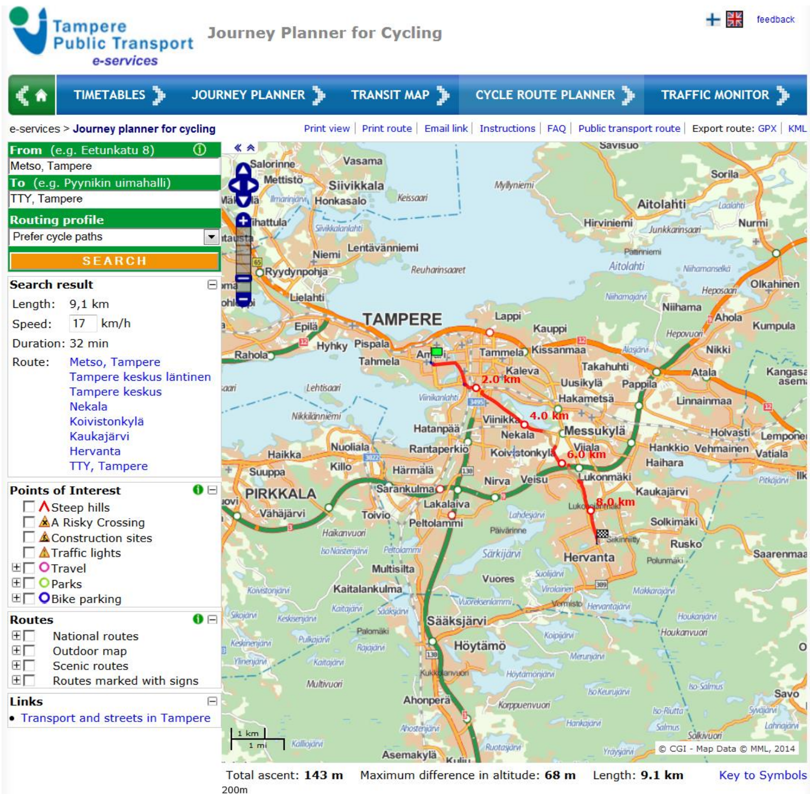


Figure 20: Tampere public transport REPA Cycle Route Planner [78].

Finally the traffic monitoring shows in real time the buses that are covering a specific route, the route could be selected by the users from the menu on the top, also it is possible to enter the stop name so the system will show only the buses that stop on that station (see Figure 21).

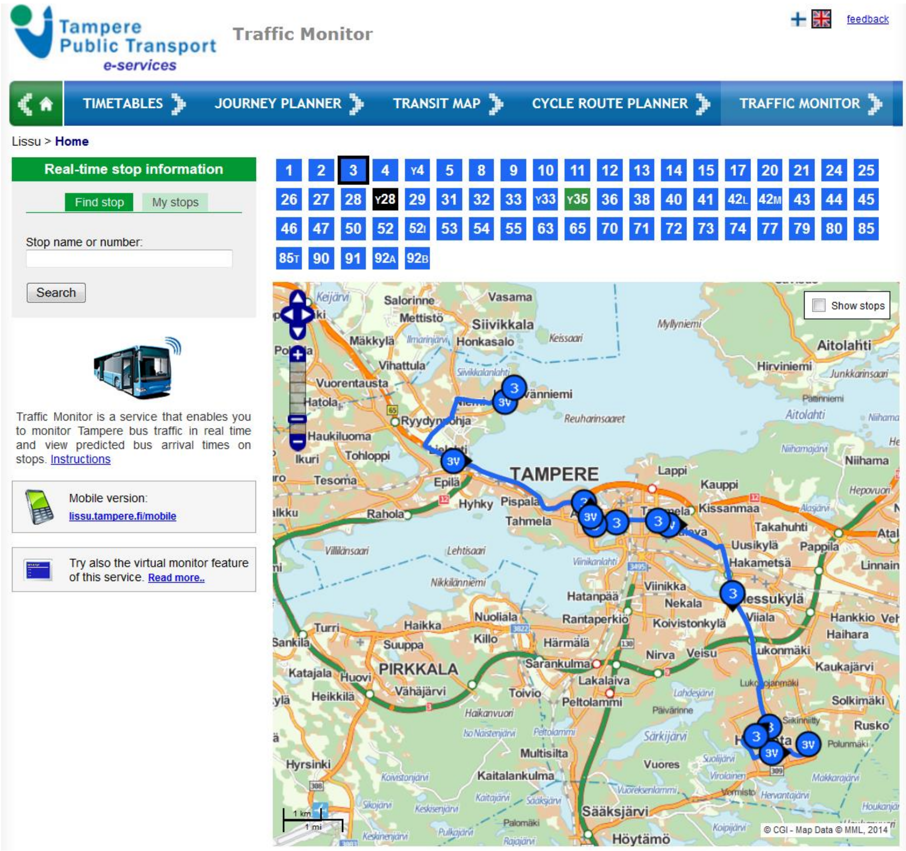


Figure 21: Tampere public transport REPA Traffic Monitor [78].

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 in terms of energy efficiency/emissions were selected (see Table 7) as well a set of factors that affect in the system (see Table 16).

The follow graphs show the behaviour of the KPIs for Tampere City in the recent years:

The following Figure 22 shows the density of passengers in public transport in Tampere city had change from 2011 to 2013, it can be seen that from 2011 to 2012 the density rise, however from this last to 2013 the value declined until 2.39 passengers per kilometre.

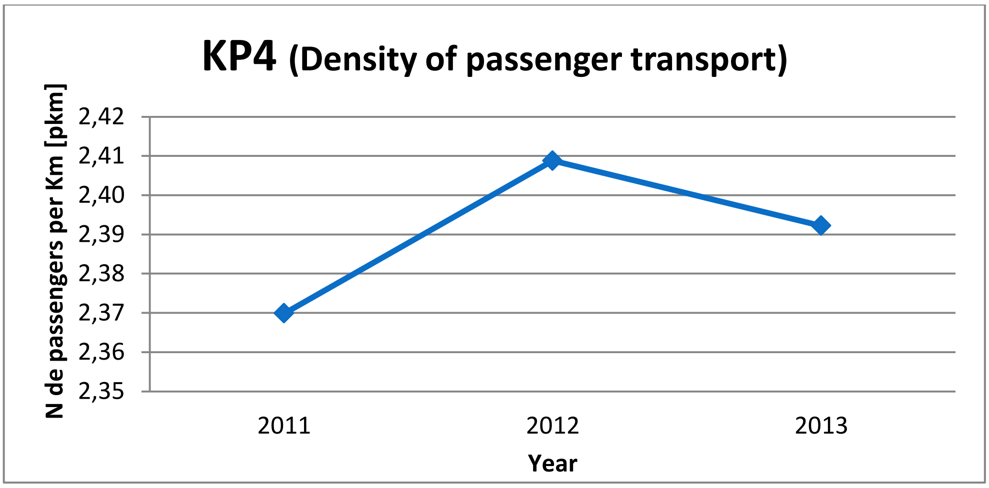


Figure 22: KP4 Density of passenger transport for Tampere city.

In contrast with the KP4 the KP5 shows that the number of passengers per fuel unit has been growing almost linearly. There are two causes for this behaviour, one is that the density of passenger has also grown, the another cause is that the buses consumption is more efficient, so they consume less fuel per kilometre (see Figure 23).

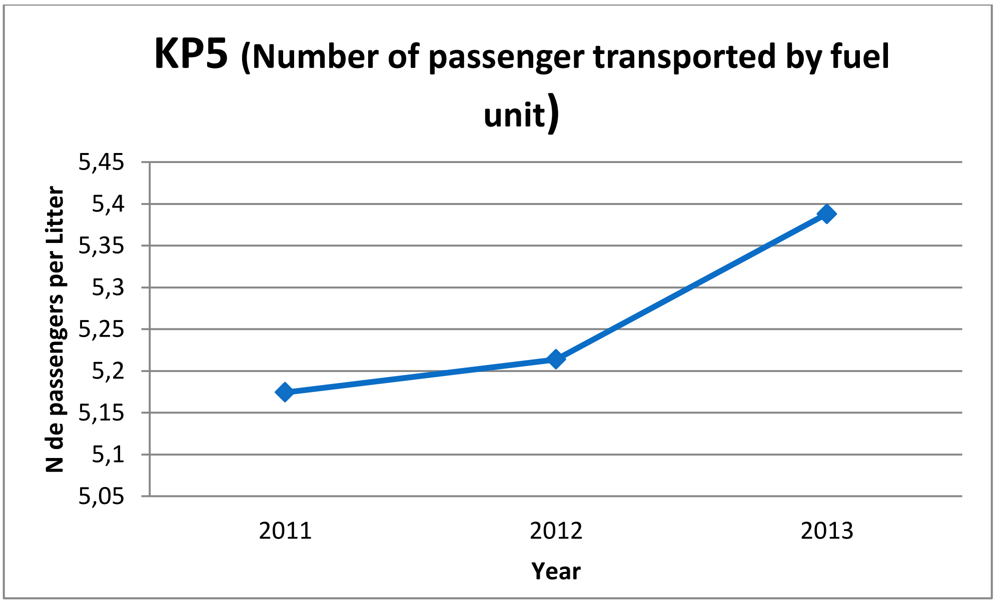


Figure 23: KP5 Number of passenger transported by fuel unit for Tampere city.

As KP6 is a reflection of KP5, it has similar behaviour, showing that the fuel units per passenger are less in 2013 compared with previous years (see Figure 24).

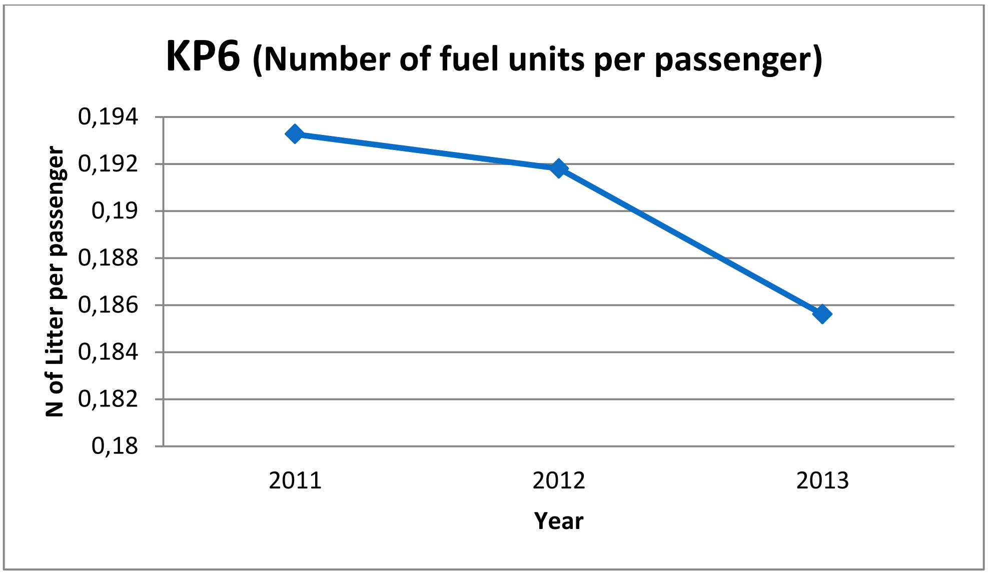


Figure 24: KP6 Number of fuel units per passenger for Tampere city.

KP8 shows the composition of the emissions in the transport sector, as it can be seen it in the following Figure 25 Tampere has a high modal share percentage for private car over the years (2005 to 2012), next is PT.

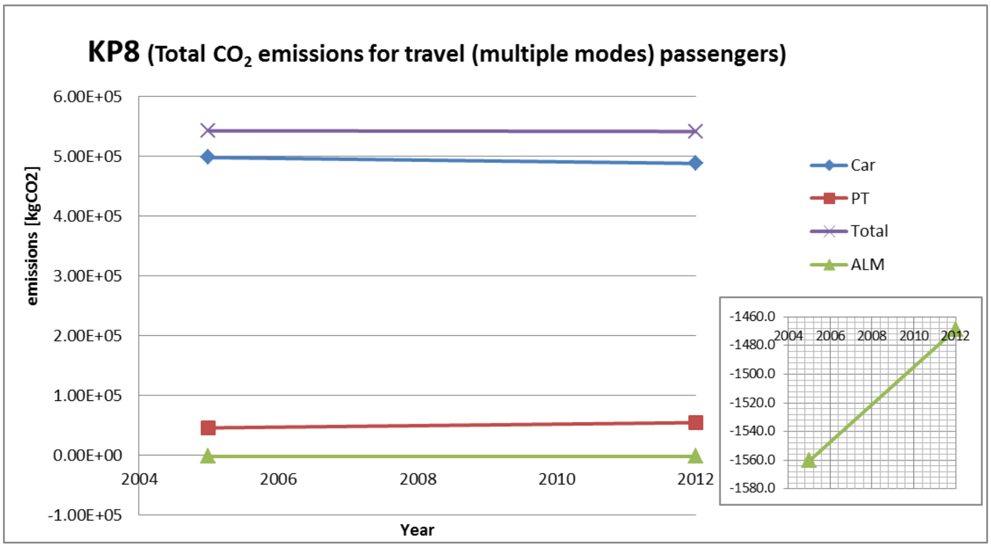


Figure 25: KP8 Total CO_2 emissions for travel (multiple modes) passengers by mode for Tampere city.

Figure 26 shows in more detail the total CO2 emissions for an average Finn per year, which had decreased from 2005 to 2012 as it is observed in the figure. This change is a consequence of the decline in the share percentage for private car and the rise in the PT percentage.

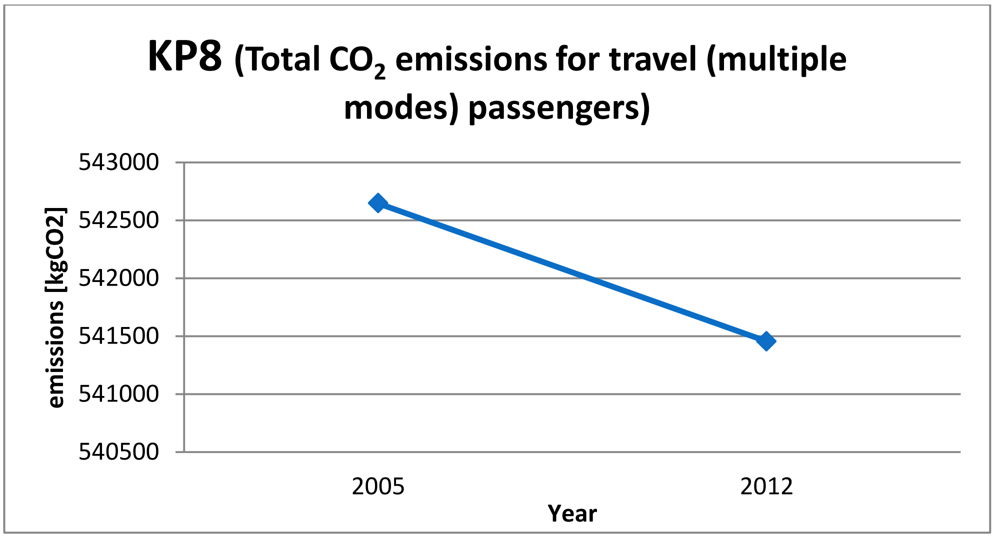


Figure 26: KP8 Total CO_2 emissions for travel (multiple modes) passengers for Tampere city.

KP10 has a similar performance as KP8, from the Figure 27 it is possible to observe that the number of vehicles per 1000 habitants has drop from 2012 to 2013, meaning that the car availability is less and as a result less people is willing to choose to drive over PT or ALM.

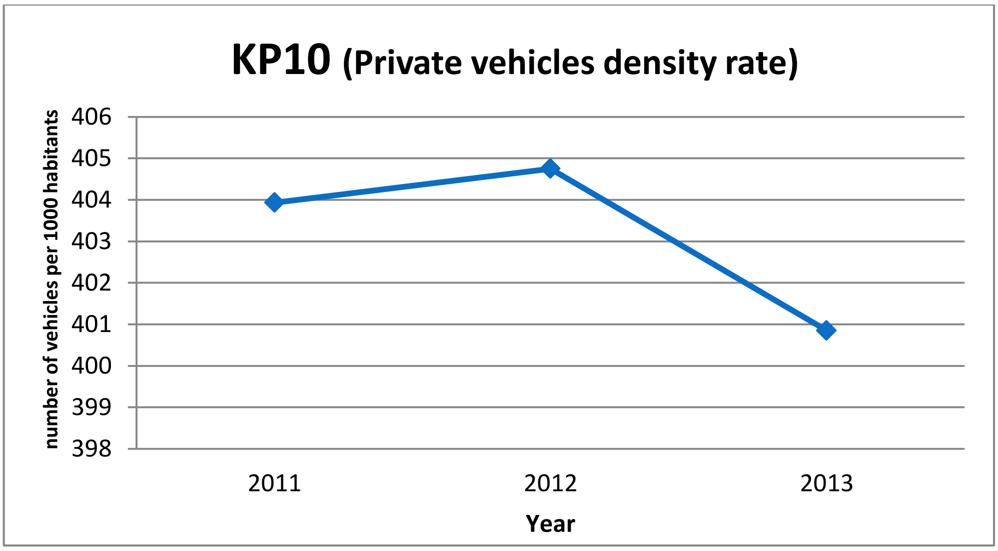


Figure 27: KP10 Private vehicles density rate for Tampere city.

This car availability affects the other transport modes. As can be seen it in the KP13 the share of public transport has increased from 16% to 19% in 2005 to 2012 respectively (see Figure 28).

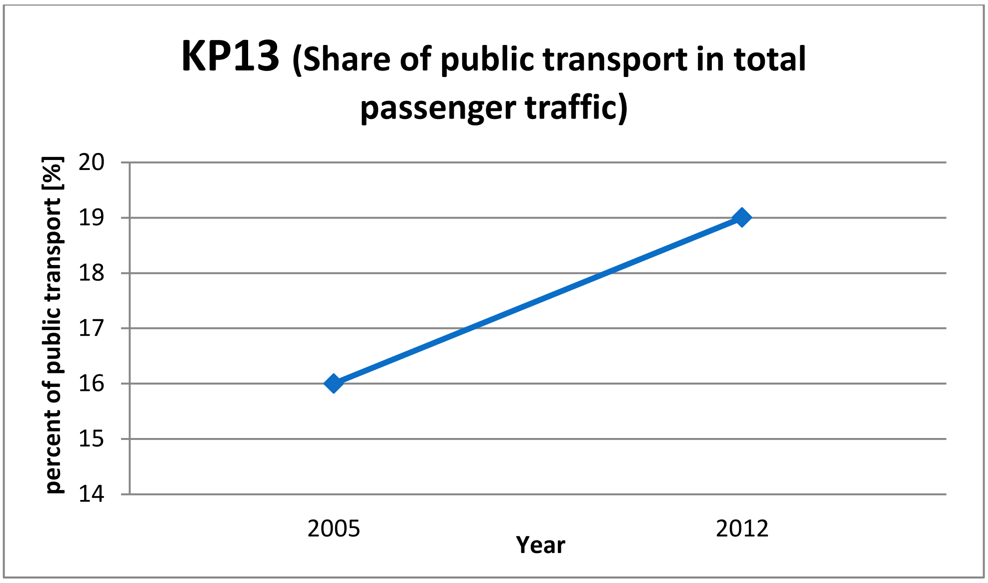


Figure 28: KP13 Share of public transport in total passenger traffic for Tampere city.

The chart KP16 (Figure 29) shows how a new plug-in electric cars and hybrids have been added to the Finnish vehicle fleet from 2011 to 2014, we assume that similar growing has been happening in Tampere.

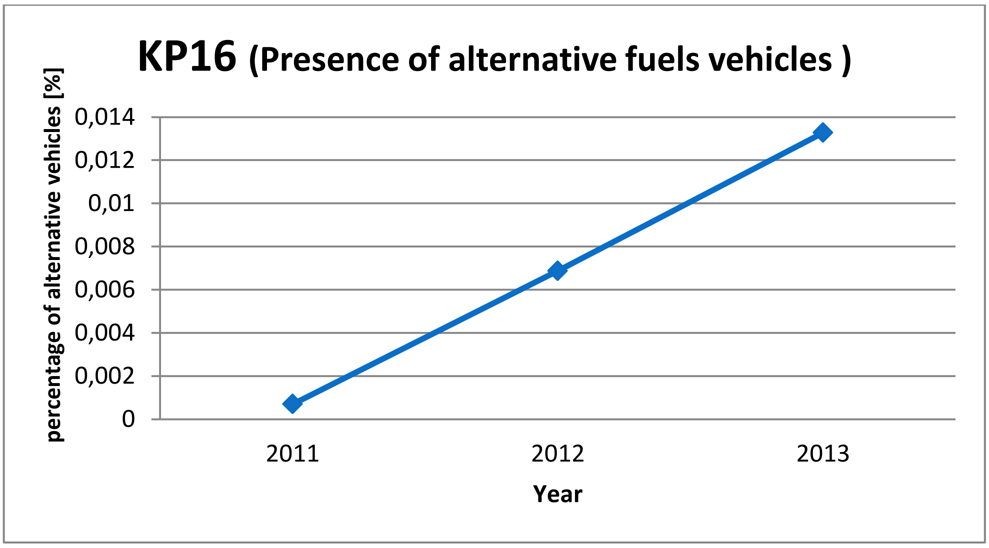


Figure 29: KP16 Presence of alternative fuels vehicles for Tampere city.

ALM modes are represented also by the kilometres of TF and OR routes, which has been constantly growing from 2004 to 2011. In that sense Tampere offers an alternative to the car and PT use by building more of these roads that also lend in increments on ALM selection (see Figure 30).

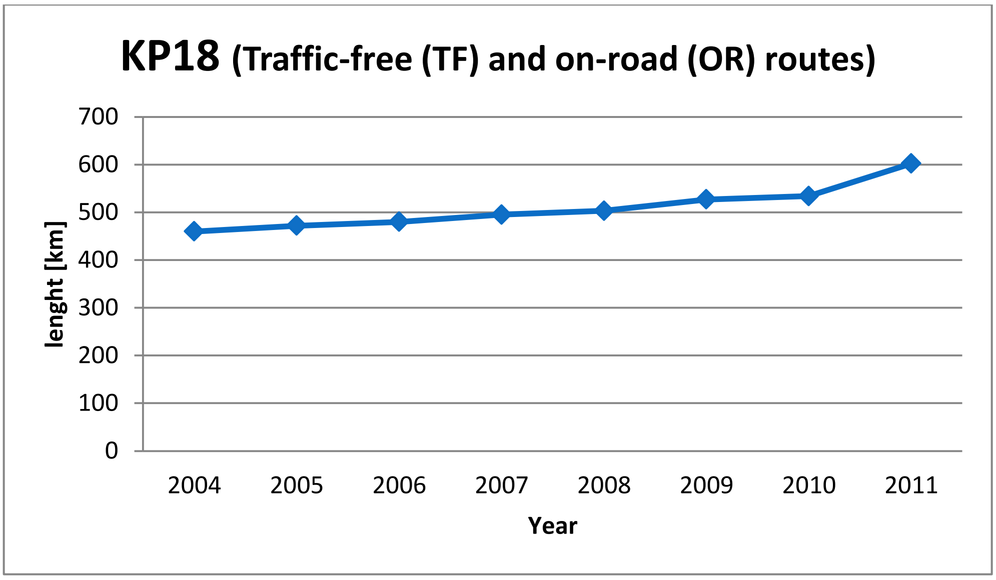


Figure 30: KP18 Traffic-free (TF) and on-road (OR) routes for Tampere city.

However the number of users has declined from 2005 to 2012. The amount of user shown in the following Figure 31 are those counted in a couple of points in the Tampere city and are cyclist, so in consequence the number of user is quite low compared with the whole Tampere population, however for the purpose of to knowing the performance of usability this number is used as a reference.

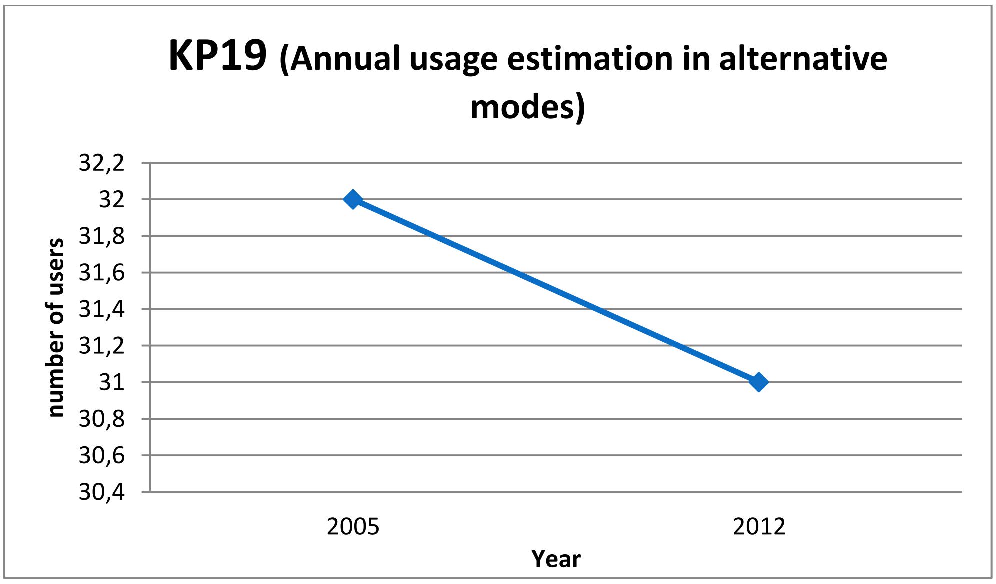


Figure 31: KPI 19 Annual usage estimation in alternative modes for Tampere city[40].

Base line and Targets

According with the section 3.1.3 (General KPIs conversions) the KPIs were transformed to carbon units in order to get the base line equation for each of them. The following information was used for conversion process:

[40] The number of users per year of alternative modes in Tampere only includes the cyclist on specific point in the city.

The latest study on passenger traffic, an average Finn makes three journeys per day, which take 66 minutes in total. The average length of these journeys is 15 kilometres. The average mileage per person is 41 kilometres per day[79].

Average gasoline car Carbon conversion factor (CCF) is $217\frac{gCO_2}{km}$

Average Diesel Bus Public transport CCF_{PT} is 63 $\frac{gCO_2}{pkm}$

Gasoline: $\text{Specific weight } 0.75\frac{\text{kg}_{\text{fuel}}}{\text{litre}} * \text{ Carbon dioxide } 3133\frac{\text{gCO}_2}{\text{kg}_{\text{fuel}}} = 2349.7\frac{\text{gCO}_2}{\text{litre}}$

Diesel: $\text{Specific weight } 0.845\frac{\text{kg}_{\text{fuel}}}{\text{litre}} * \text{ Carbon dioxide } 3148\frac{\text{gCO}_2}{\text{kg}_{\text{fuel}}} = 2660\frac{\text{gCO}_2}{\text{litre}}$

Additionally to the base line, the figures show target values for each of the KPIs for 2016.

For KP4e conversion was necessary to make a projection to be able to get a base line and 2011 data was not included for the regression, but it was used in the projection. As a result the base line value for 2016 is 148.51 gCO_2 the target was set as 1% of reduction (1.485) so the value for 2016 is 147.02 gCO_2. These values show that Tampere is reducing the emissions per passenger in PT gradually year per year, meaning that Tampere's PT system is moving toward a more efficient use of the energy.

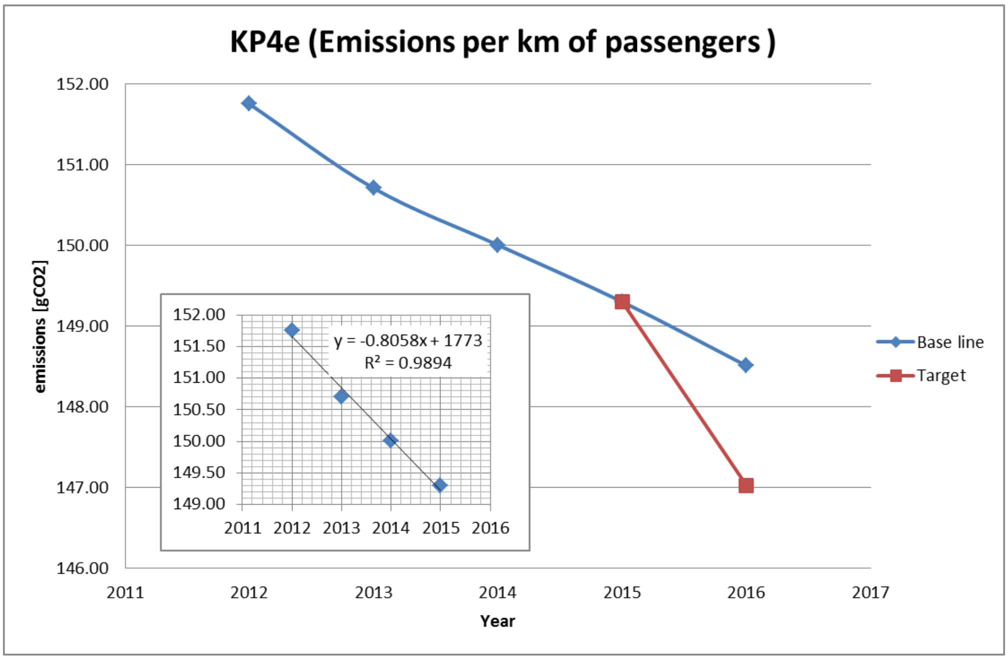


Figure 32: KP4e Emissions per km of passengers for Tampere city.

On the emissions saved in the KP4s was also used the same projection method as a result the values for 2016 are: Base line 362.88 gCO_2 , the set target is 1% (3.63 gCO_2) of savings increasing from the baseline value to 366.51 gCO_2. This KPI conversion shows that the use of PT in Tampere is contributing to saving considerable amounts of CO2 per passenger, that otherwise will use private car.

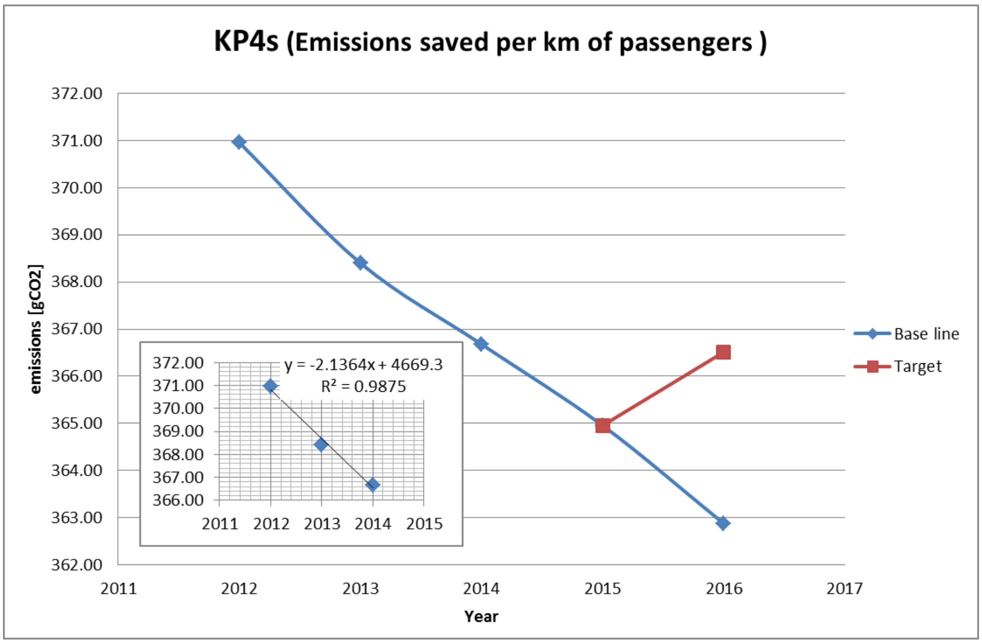


Figure 33: KP4$_s$ Emissions saved per km of passengers for Tampere city.

In the KP5e the base line was found by applying a linear regression, for 2016 its value is 0.00209 $\frac{\text{passengers}}{\text{gCO}_2}$. For the set target, the city should increase the number of passengers per unit of emission, which means an increment of 4.1752E-05 $\frac{\text{passengers}}{\text{gCO}_2}$ so by 2016 the target value is 0.00213 $\frac{\text{passengers}}{\text{gCO}_2}$. According to the KP4 s and e the city of Tampere is also looking for increasing the efficiency of the PT system by increasing the number of passengers per fuel emission, as it can be seen in the Figure 34.

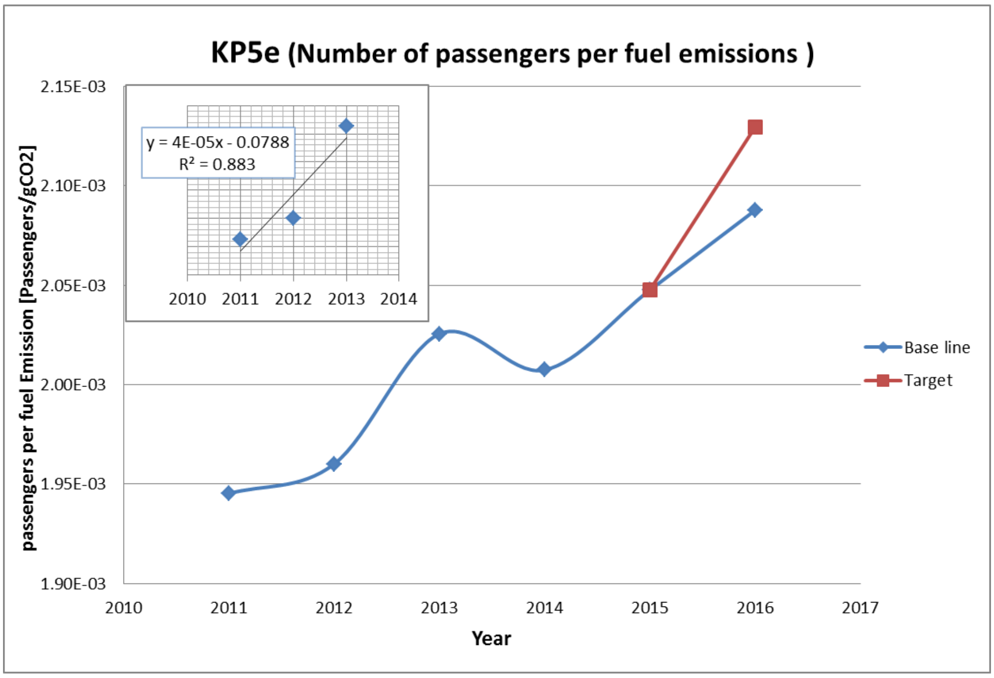


Figure 34: KP5e Number of passengers per fuel emissions for Tampere city.

For KP6e the base line value for 2016 is 464.05 $\frac{gCO_2}{passengers}$ and the target value is 454.77$\frac{gCO_2}{passengers}$ that means a reduction of 2% (9.28$\frac{gCO_2}{passengers}$). Figure 35 shows how the emissions per passenger had been declined constantly. Additionally Tampere by increasing the number of PT passengers and the efficiency of the vehicles pretends to decrease even more this value in order to achieve a more sustainable system.

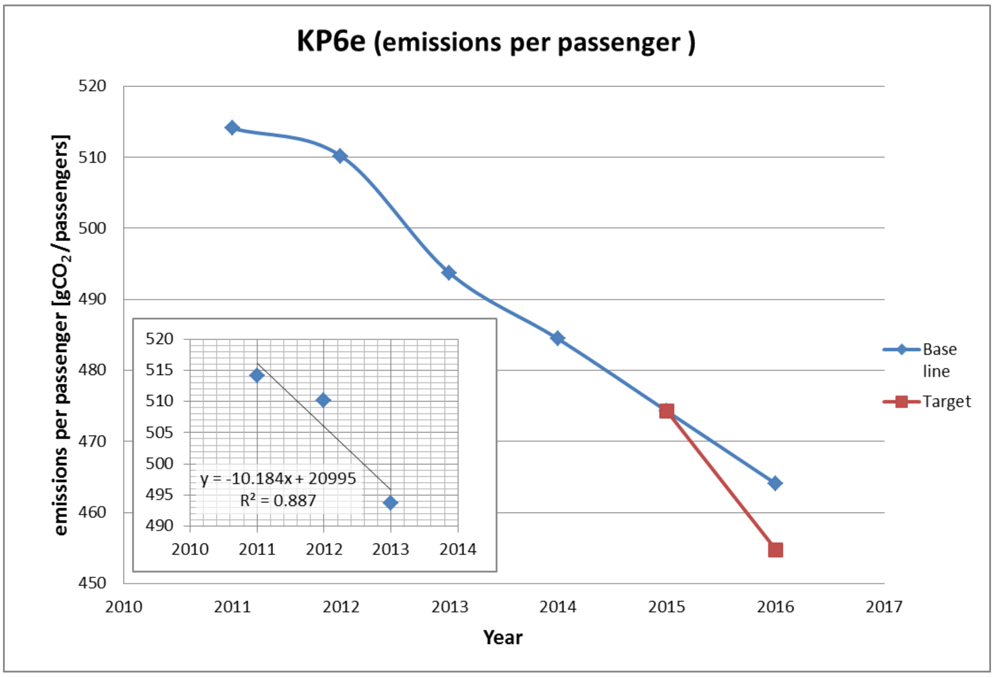


Figure 35: KP6e emissions per passenger for Tampere city.

KP8 do not require a conversion, the base line value is 540777.64 $kgCO_2$ and the target value was found using the objectives that Tampere has for 2016 (see Figure 12) so the emission target for 2016 is 490237.14 $kgCO_2$. The objectives of Tampere are to increase the PT share percentage and to decrease the use of private car. By making those changes Tampere will decrease their total emission value considerably with the respect to the projection explained below.

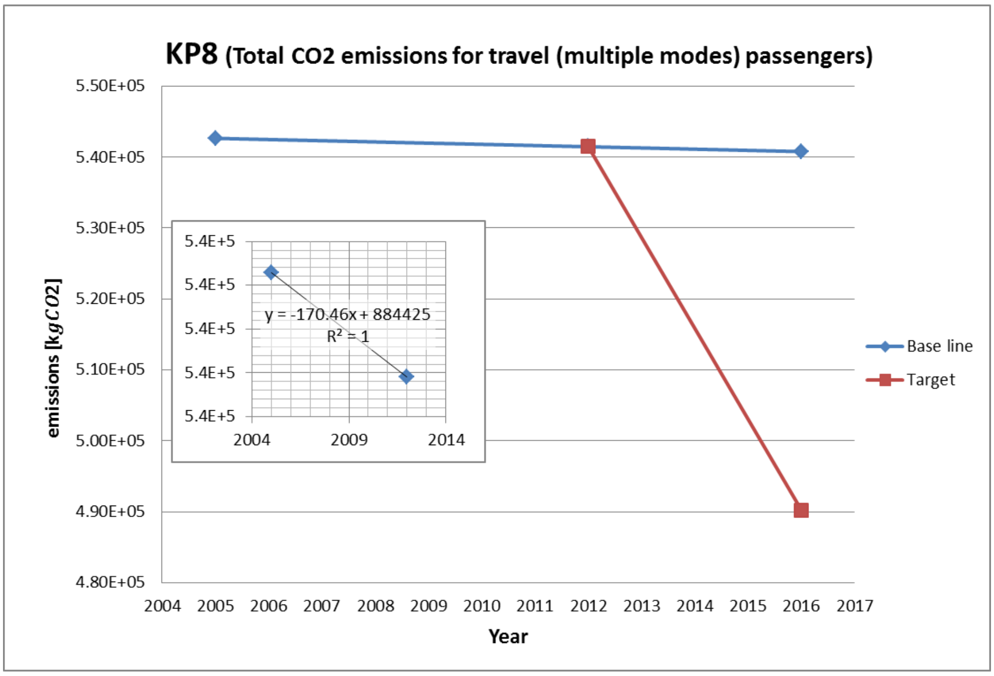


Figure 36: KP8 Total CO2 emissions for travel (multiple modes) passengers for Tampere city

Part of the objectives of Tampere is to reduce the number of private cars available, so in that sense the use of PT and ALM will increase, based on this idea the KP10e figure shows that the base line value is 3531.78 $kgCO_2$, however Tampere wants to make this number even lower, in consequence the target value is 3496.46 $kgCO_2$ the reduction is 1% or 35.32 $kgCO_2$.

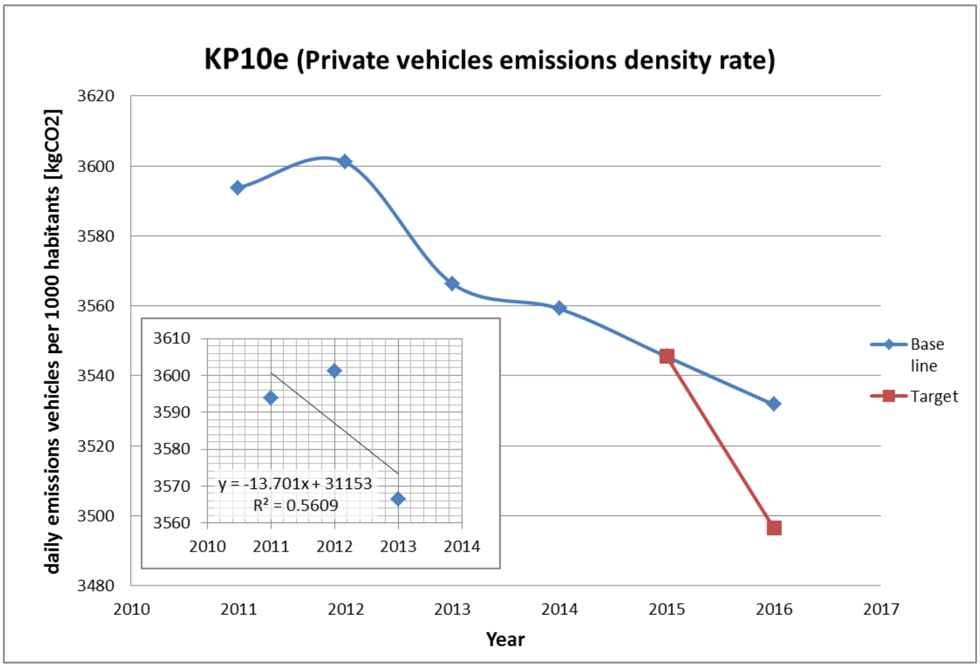


Figure 37: KP10e Private vehicles emissions density rate for Tampere city.

In contrast Tampere wants to increase the use of PT that will extend the current emission saved, for 2016. KP13s Base line value is 150000 $kgCO_2$, which by increasing the modal share the savings target value will be 155488.06 $kgCO_2$ that represents a 22% modal share for 2016 coming from 19% on 2012

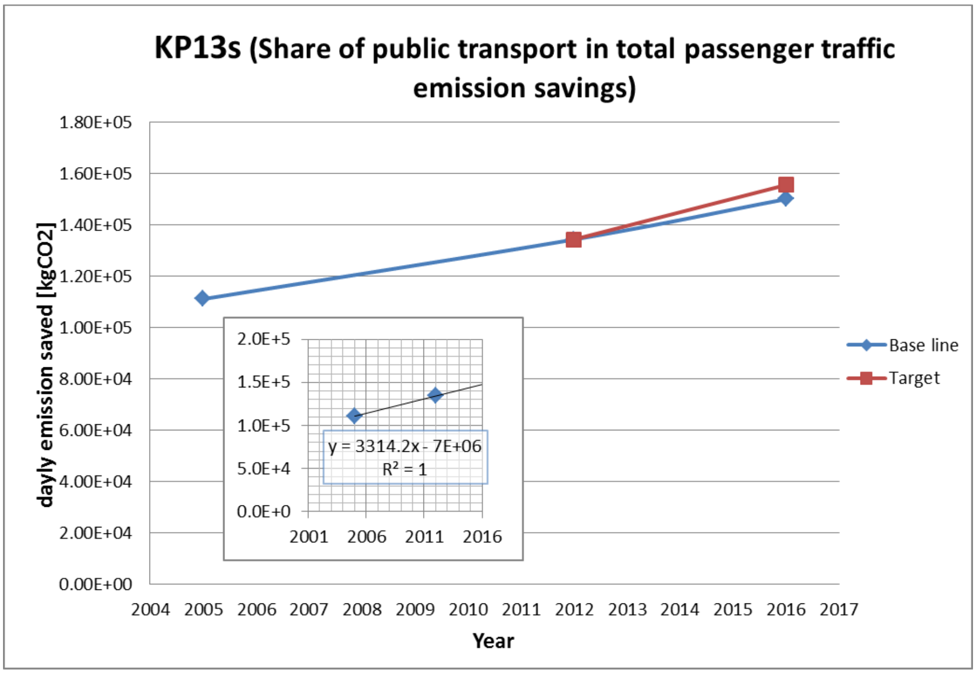


Figure 38: KP13s Share of public transport in total passenger traffic emission savings for Tampere city.

It is assumed that all the alternative vehicles are electrical cars, for that reason emissions in the case of Tampere are considered as zero. So as they are zero emission by using them there are only savings in emissions, because they replace conventional cars. In consequence Tampere savings for 2016 is 2,6E+04 $kgCO_2$, however by increasing the amount of alternative cars the Target value will be 2,86E+04 $kgCO_2$ that represents an increment of 10%.

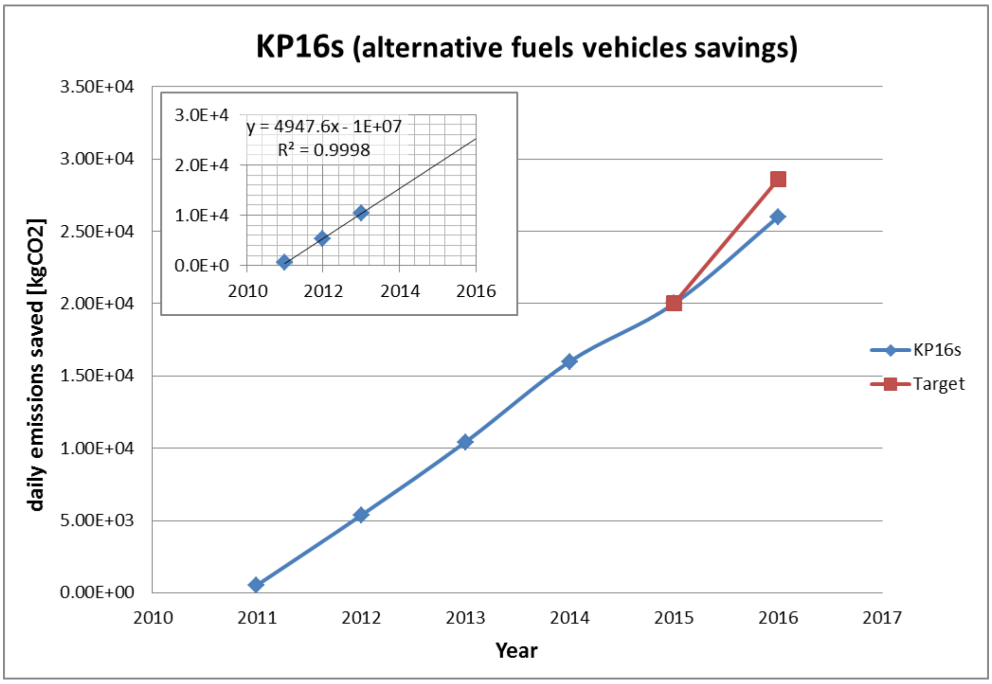


Figure 39: KP16s alternative fuels vehicles savings for Tampere city.

The opportunity in KP18s is to increase the kilometres of TF and OR routes because without opportunity implementation the saving value is 142.4576 $kgCO_2$, so a target value can increase the saving on 5% compared with the base line, that is 7.12288 $kgCO_2$ or 149.58048 $kgCO_2$ by 2016.

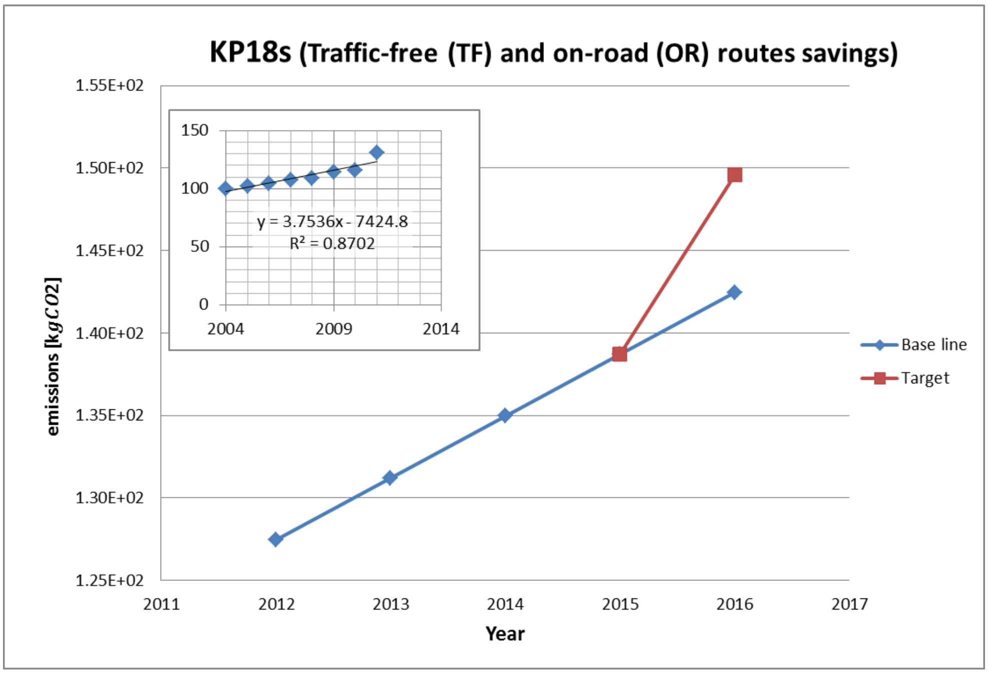


Figure 40: KP18s Traffic-free (TF) and on-road (OR) routes savings for Tampere city.

Finally as it has been mentioned several times previously, Tampere wants to increment the usability of those TF and OR paths, design for ALM, with that the saving will increase also from a Base line value of 4.33 $kgCO_2$, to a Target value 4.84 $kgCO_2$ that represent 34 uses for 2016.

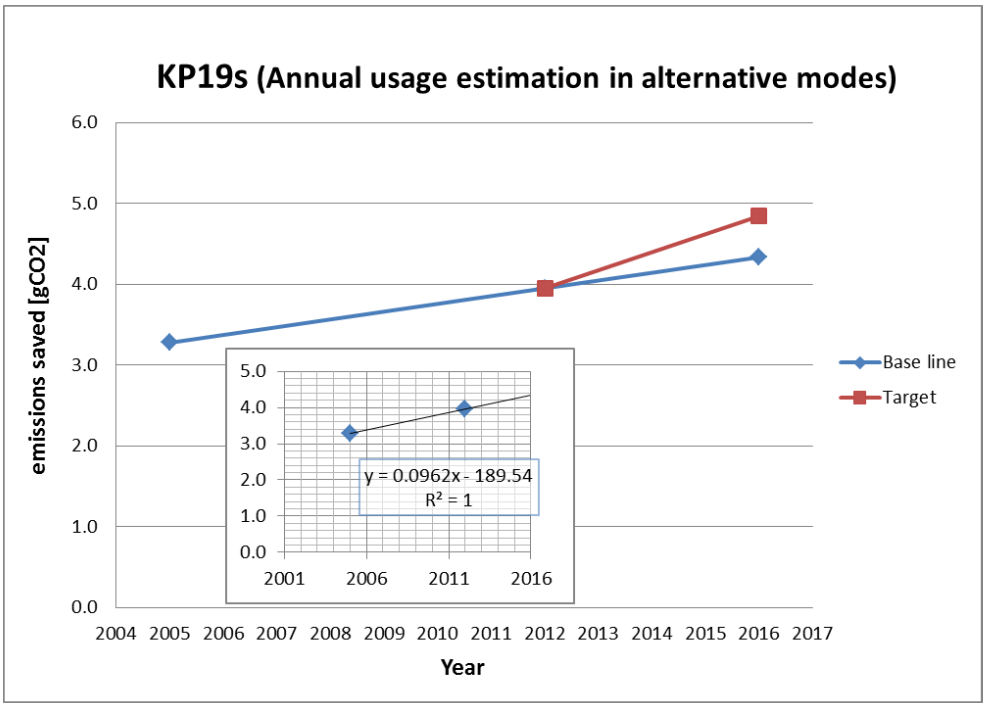


Figure 41: KP19 Annual usage estimation in alternative modes for Tampere city.

The forward Table 23 resumes the KPIs' Base line and Target values for Tampere MoveUs pilot.

ID	Name	Base line value	Target value
KP4e	Emissions per km of passengers	148.51 gCO_2	147.02 gCO_2
KP4s	Emissions saved per km of passengers	362.88 gCO_2	366.51 gCO_2.
KP5e	Number of passengers per fuel emissions	0.00209 $\frac{\text{passengers}}{gCO_2}$	0.00213 $\frac{\text{passengers}}{gCO_2}$.
KP6e	emissions per passenger	464.05 $\frac{gCO_2}{\text{passengers}}$	454.77 $\frac{gCO_2}{\text{passengers}}$
KP8	Total CO2 emissions for travel (multiple modes) passengers	540777.64 $kgCO_2$	490237.14 $kgCO_2$
KP10e	Private vehicles emissions density rate	3531.78 $kgCO_2$	3496.46 $kgCO_2$
KP13s	Share of public transport in total passenger traffic emission savings	150000 $kgCO_2$	155488.06 $kgCO_2$
KP16s	alternative fuels vehicles savings	2,6E+04 $kgCO_2$	2,86E+04 $kgCO_2$
KP18s	Traffic-free (TF) and on-road (OR) routes savings	142.4576 $kgCO_2$	149.58048 $kgCO_2$
KP19s	Annual usage estimation in alternative modes	4.33 $kgCO_2$	4.84 $kgCO_2$

Table 23: List of KPIs' Base line and Target values for Tampere city.

5.2.2 Madrid pilot

Main goal

The main goal of Madrid pilot is to contribute to Madrid's sustainable mobility goals by fostering the use of greener transport modes (public bus, bike-hiring, walking) enhancing different and personalized mobility information.

Objectives

1. Increase the use of public bus.
2. Increase the use of bike-hiring.
3. Enhance the ease for walking.
4. Reduce the use of private car

Question	Objectives			
	1	2	3	4
Who	EMT (Metropolitan Transport Corporation) Madrid City Council	Madrid City Council	Madrid City Council	Madrid City Council EMT (Metropolitan Transport Corporation)
What	Reduce the use of private car. Promote use of public bus.	Reduce the use of private car. Promote use of bike-hiring.	Reduce the use of private car	Increase modal share of alternative modes
Where	In city urban	In city urban	In city urban	In city urban

	area	area	area	area
When	Long term	Medium term	Long term	Short term
Why	- Less congestion and traffic jams due to reduced number of cars. - Increase social conscience. - Increase the energy efficiency and reduce carbon emissions. - Less pollution= Better air quality - Lower number of/ less need for car parks and parking lots - Increase environmental awareness. - Environmental protection (reducing pollution) - Faster and more reliable public transport - Increase knowledge about energy efficiency	- Increase social awareness. - Sporty & Healthy citizens - No carbon emissions. - No emissions of greenhouse gases - Reduce motor noise - Less pollution= Better air quality - Increase environmental awareness. - Environmental protection (reducing pollution and noise)	- Increase social awareness. - Sporty & Healthy citizens - No carbon emissions. - No emissions of greenhouse gases - Reduce motor noise - Less pollution= Better air quality - Increase environmental awareness. - Environmental protection (reducing pollution and noise) - Improve of a safe and lively urban area	- Reduce congestion and traffic jams - Increase social conscience. - Reduction on greenhouse gases' and carbon emissions. - Less pollution= Better air quality - Lower number of/ less need for car parks and parking lots - Increase environmental awareness. - Environmental protection (reducing pollution) - Increase alternative transport modal share

Table 24: Objectives and "Wh" questions for Madrid City.

The city urban area is the area with the biggest population density and the closest to the city centre. The following map (Figure 42) shows the main districts covered by the public bus service:

Figure 42: Madrid city map.

Target group

The main target groups considered for Madrid pilot are: private car users, commuters and citizens. It might be taken in account that a user can fit into all these groups, although not at the same time. Visitors can be classified in any group if it is the case or necessary.

Madrid had 3,207,247 inhabitants by 2013, which represents a population density of 5,294.5 inhabitants per square kilometre. The number of private cars registered in Madrid in 2013 was 1,671,890, which is equal to a rate of 0.51 vehicles per inhabitant.

Identified variables

Variable	Objectives
Energy consumption per vehicle	1,2,4
Fuel consumption per vehicle	1,4
Calories consumption in alternative modes	2,3
Public Bus fleet	1
Bike-hiring fleet	2
Modal share percent in each mode	1,2,3,4
Number of public transport passengers	1
Number of cyclists	2
Number of drivers	4

Table 25: Identified variables for Madrid City.

Energy Evaluation

Energy Revision

Road transport in Madrid city consumes one third of the energy of the city, generates one fifth of the total emission of greenhouse gases (GHG) and is the mayor responsible of the pollutant emissions emitted to the atmosphere: 56.3% of NOx emissions and 67.9% of the particulate matters (PM) in suspension.

With the objective of progressing towards a more sustainable mobility energy model and improving the city air quality, the mobility strategy included in the Energy and Climate change –Horizon 2020 Plan of the city sets the following objectives:

- To progress towards low carbon mobility, increasing the contribution to the pedestrian and cyclist mobility, and the use of public transport in the transport modal share.
- To reduce 20% the emission of GHGs associated to road transport.
- To develop infrastructures for alternative fuels supply including electric charging for e-transport.
- To reduce 50% of the carbon footprint of the municipal's vehicle fleet.

The Energy Agency of Madrid City Council is carrying out the following projects, directly addressing the fulfilment of those objectives:

- Alternative fuels for vehicles

In Madrid, as in the majority of European cities, the road transport is the main source of pollution into the atmosphere. Among those pollutants the dioxide nitrogen (NO2), has the greatest impact in the city air quality.

Madrid City Council is developing measures to promote the use of less polluting vehicles in the municipal fleet and increase the non-conventional fuels distribution network like Compressed Natural Gas (CNG) and Liquefied Petroleum Gas (LPG).

- Electric charging points

The Energy Agency promotes, in collaboration with other municipal entities, the deployment of an electric charging infrastructure for public access, which it is going to fill the electric vehicles users' need. The charging points will mainly be located in the streets and municipal parking facilities.

- Less polluting municipal vehicle fleet

The penetration of such vehicles is facilitated by the implementation of environmental clauses to the different contracting modes that impose limits to NOx and CO_2 emissions to new vehicles. Such requirements apply for the integral and renting contracts managed by different municipal areas and companies.

By the end of 2013, the less polluting municipal vehicle fleet was composed of:

  - 1.245 CNG propelled vehicles, mainly public buses from EMT and environmental services vehicles, street litter collection and cleaning.
  - 91 LPG propelled vehicles for the surveying of environmental services in the street.
  - 178 hybrid vehicles, used by the police and for municipal internal transportation.
  - 153 electric or hybrid vehicles, most of them used by municipal contacting companies related to environmental services in urban parks and gardens.

Along with the aforementioned alternative technologies, conventional gasoline class A and Euro V vehicles are consider as less polluting, summing up 598 vehicles used by different municipal services.

- Urban freight distribution with electric vehicles

It is estimated that 33.000 uploading and downloading operations are carried out daily in the centre of Madrid City by the industrial sector. This sector is responsible for 14% of NOx emissions and more than 25% of illegal parking operations.

Madrid City Council takes part in the European project FREUVE, it aims to promote the use of commercial vehicles using less polluting technologies; this project is a demonstrator pilot for urban freight distribution that considers the use of electric vehicles and uploading consolidation platforms. The pilot is focused in a specific part of the city that includes the Old City's Central Market of Vegetables and Fruits. Results of this initiative will enable the design of an electric mobility strategy at larger scale for the urban freight distribution sector in the city.

Energy sources:

All conventional fuels and electricity are available and currently in use in Madrid transport sector. According to international specifications, gasoline is blended with bio-ethanol (less than 10%) and diesel is blended with bio-diesel (less than 7%). As an exception, there are buses that are propelled with a blend of diesel and biodiesel with a proportion of 70:30.

It is expected at 2020 Madrid will achieve a 10% of bio-share (biofuels share percentage) in all the fuels used by the transportation sector. This rise in the bio-share will lead into emissions savings, because CO2 emissions from bio components are consider as zero emissions.

Electricity
Conventional fuels: **Gasoline** **Diesel** **Compressed Natural Gas**

Table 26: Energy sources in Madrid

Currently, the proportion between people and vehicles in Madrid is 507 cars per thousand inhabitants (2013). It implies a decrease of nearly 3% with respect to the previous year, which continue dropping in the last few years. In contrast the electrical vehicles enrolment had been increasing in 5.6% during the first three months of 2014, with respect to the same period in 2013.

Emissions:

Green House Gases (GHG) are compose by direct and indirect emissions, direct emissions in Madrid decreased 15.8% in 2012 in comparison to 1990, while, indirect emission increased 9.9%. In global terms, GHG emissions had decrease by 6.5% from 1990 to 2012. The highest sources of GHG emissions are residential-commercial and freight sectors, which in 2012 contributed in 55.3 % and 18.7 % respectively to total GHG emissions even when their total emission evolution is going down.

The table 26 shows the GHG emissions registered from 1990 to 2012 in Madrid City.

Emissions (ktons CO_2 eq)	1990	1999	2000	2001	2002	2003	2004

Direct	8138	8474	8542	8393	8426	8574	8519
Indirect	4670	5917	5968	6173	6426	5925	6320
TOTAL	**12808**	**14391**	**14510**	**14566**	**14853**	**14499**	**14839**

Emissions (ktons CO_2 eq)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Direct	8627	8536	8430	8286	7844	7433	6844	5849
Indirect	6760	6359	6661	5844	5211	4148	4846	5131
TOTAL	**15387**	**14895**	**15092**	**14130**	**13055**	**11581**	**11690**	**11980**

Table 27: GHC emissions in Madrid[41].

Transportation modes:

The use of the public transportation services in Madrid has significantly grown during the last year. As can be seen in the next **Error! Reference source not found.**, in 2012, the percentage of inhabitants using public transport was about 65%.

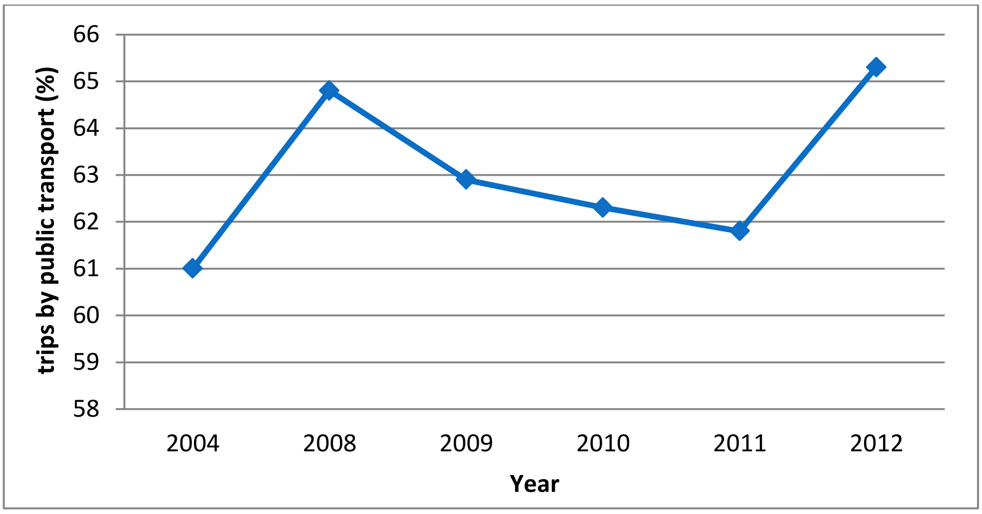


Figure 43: Public transport use evolution from 2004 to 2012.

Madrid's public transport is mainly compose by the bus service, which is supporting by an information system and a journey planner online platform, deployed by a transport company (Empresa Municipal de Transportes de Madrid **EMT**) providing one of the most advance transport system in the city. Public bus information can be consulted in shelter's panels on bus stops, showing relevant information such as bus line, itinerary, timetable and minutes left to next bus arrival (see Figure 44).

[41] GHC emissions in Madrid. Source: Energy Agency of Madrid City. Government Area of Environment and Mobility.

Figure 44: Madrid bus shelter with information panel.

Bus information is also available EMT website (http://www.emtmadrid.es/), where the user can find different options like:

- Waiting time search engine, obtained by line or by shelter number.
- Waiting time can also be request by SMS message through mobile phone.
- Relevant information is also provided to impaired users through an accessible web portal called "Accessible mode" (http://accesible.emtmadrid.es/)
- Journey planner service for public bus users called "Navega Madrid" (http://www.emtmadrid.es/mapaweb/emt.html). The user can look for the necessary information to reach the destination and get it on a map, by providing the starting and destination points. The available information includes: bus routes by line, bus lines that go through a specific place, recommended journey option, touristic journeys using EMT lines, waiting time at a bus stop, interest points (monuments, museums, restaurants, hospitals,…), line by date/hour, etc. (See Figure 45).

Figure 45: Navega Madrid web page, the public bus journey planner from EMT.

Figure 46: Navega Madrid viewer.

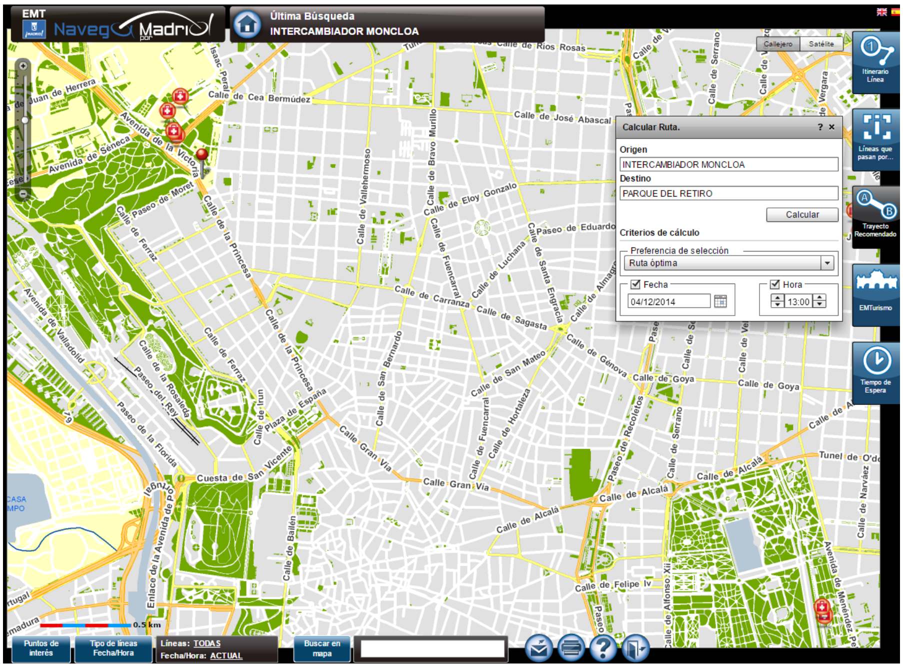


Figure 47: Departure/Destination points selection - Journey planner.

In the particular case of departure/destination points, the resulting view shows the walking route to the bus stop from origin and from the bus stop to the destination, route, line/s, travel time, stops and their situation in the map, and the option to ask for the waiting time (Figure 46 and Figure 47).

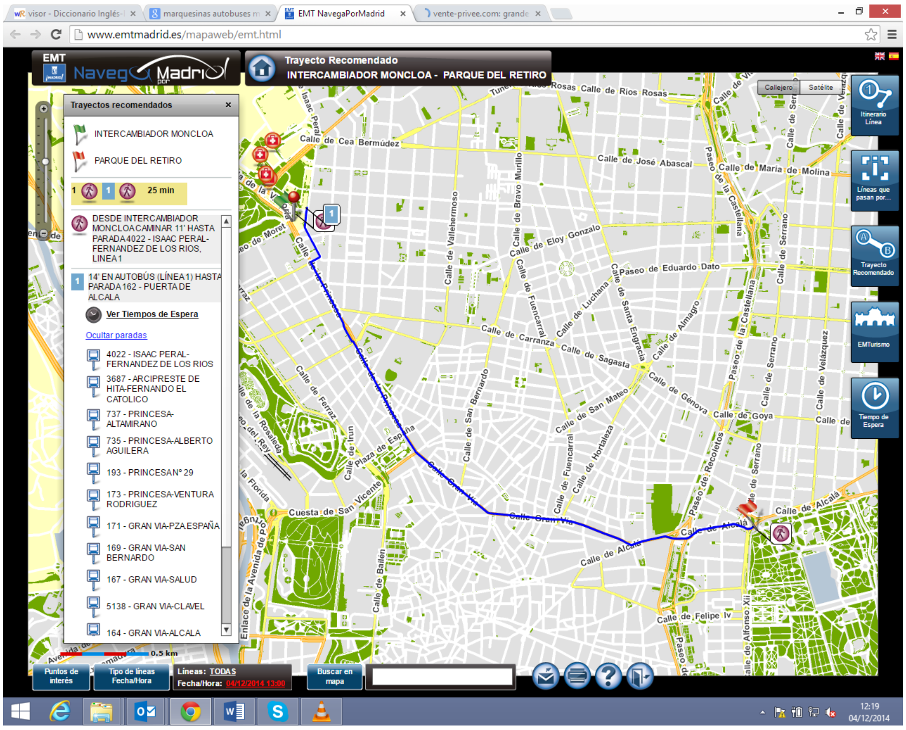


Figure 48: Departure/Destination point – Results View.

With respect to alternative modes of transportation, it is to highlight the implementation of a new public electric bike-hiring service in Madrid in 2014. At a first stage, this service is formed by 1560 electric bikes, 123 stations and 3126 moorings. In addition to that, it is relevant to note that the bicycle path network length tendency is to grow, as can be seen in the following Figure 49 although in a reduced proportion during the last years. At the end of 2012, Madrid had nearly 300km of cycle paths and a green ring for bike riders with some space kept for pedestrians and resting areas. Currently, nearly 70 km of bike-friendly streets and lanes among the service area and adjacent streets have been marked.

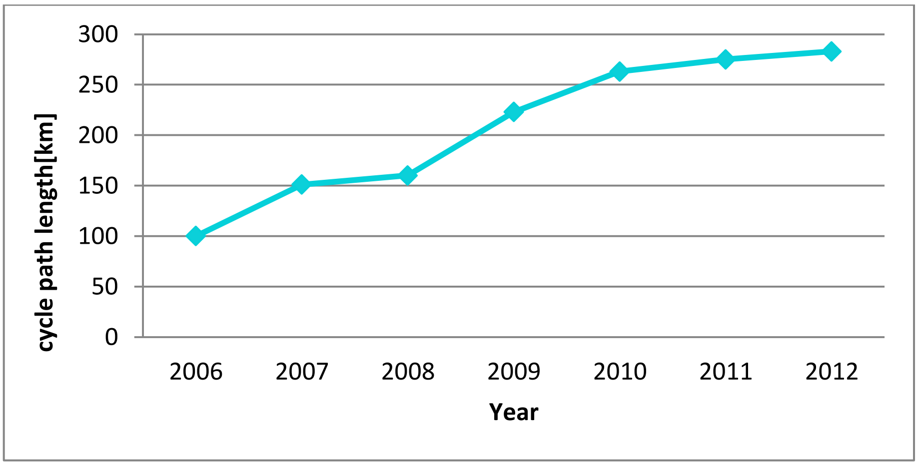


Figure 49: Madrid cycle path length per year.

The information is available to the user on public electric bike-hiring service shelters and in BiciMad web site (http://www.bicimad.com/index.html) show in the

Figure 50: the information includes maps, number and position of shelters, fares, user area, etc.

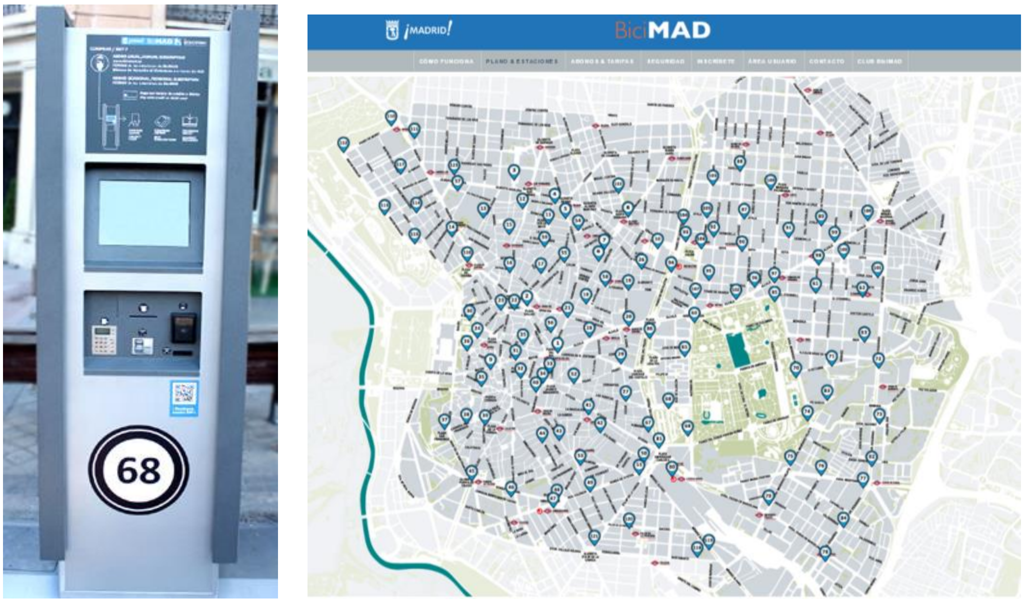


Figure 50: BiciMad shelter on the left and shelter situation map on the right.

Madrid City council owns a website (http://www.infobicimadrid.es/gis_bicis.htm) where the user can consult information about cycling network routes, recommended cycling streets, bike parking, and even touristic information offices (see Figure 51).

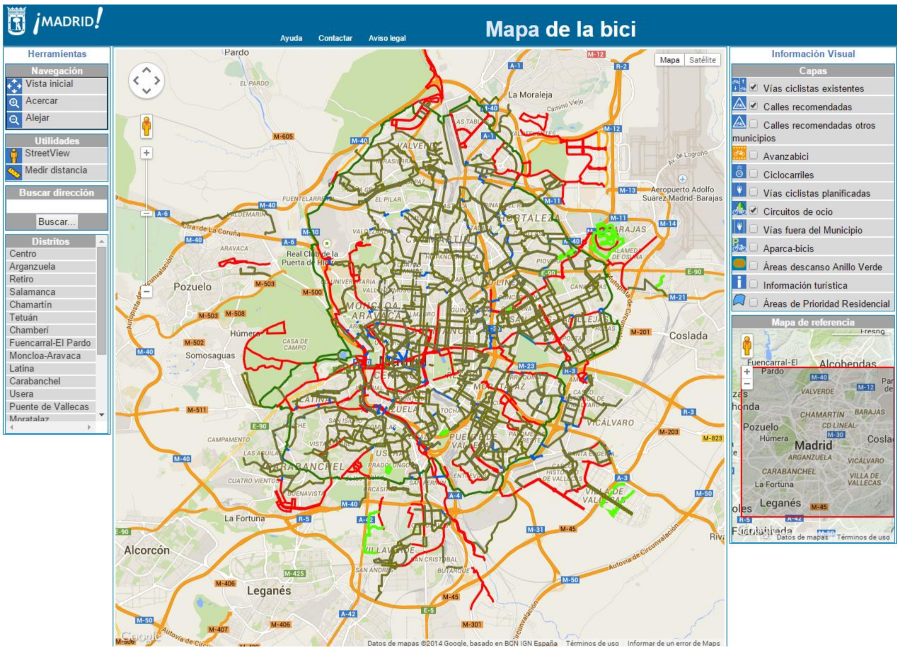


Figure 51 Map of the bicycle on Madrid web site

In general, the city of Madrid has several projects in the alternative transportation modes to encourage their selection. Some of them are:

- Online mobility portal in Madrid (Muevete por Madrid, http://www.mueveteporMadrid.es/) with relevant and interesting information about each transport mode available in Madrid, including walking, bike, public bus, metro, train, taxi, motorcycle and private car. Recommended routes, points of interest, parking, policies and other relevant information is offered in all transport modes through this portal. It also includes links to specific mobility Apps to be downloaded either to Android smartphones or iPhones.

- Cycling and walking:
  - Bike on-line office with access to all information needed to travel by bike in Madrid, including maps, bike facilities, access to public bike hiring services, and bike use promotion campaigns like Pedestrian-Bike-Vehicle cohabitation campaign, STARS project to encourage and promote biking to school, etc.
  - Public Bike-hiring service extension
  - Walking and cycling facilities improvement.
- Public transport:
  - Public transport card external benefits (tickets discounts,…)
  - Campaigns for increasing sustainable mobility awareness of citizens.
  - Increase on moorings facilities: Thermometer + Clock, battery recycling container, free Wi-Fi, real-time information panels.
  - New Public transport card renewal (2013-2014).
- Other projects:
  - Collaboration with sporting events (Worldwide Basket Championship (2014), Mutua Madrid Open Tennis (2014)), for the promotion of the use of public transport.
  - Private vehicle pollution reduction campaigns.

Performance Indicators

Based on the previous information and the objectives that Madrid city has defined, a number of KPIs that reflect the performance of the system in terms of energy efficiency/emissions were selected (see Table 9) as well a set of factors that affect in the system (see Table 17).

The follow graphs show the behaviour of the KPIs for Madrid City:

The next Figure 52 is related to the public bus transport, showing the relation between passengers and distance travelled per vehicle unit, in two different bus lines of Madrid City. The general tendency in both bus lines is to grow in 2013 with respect to 2012, reaching the levels of the year 2011, which are the maximum levels of the last few years.

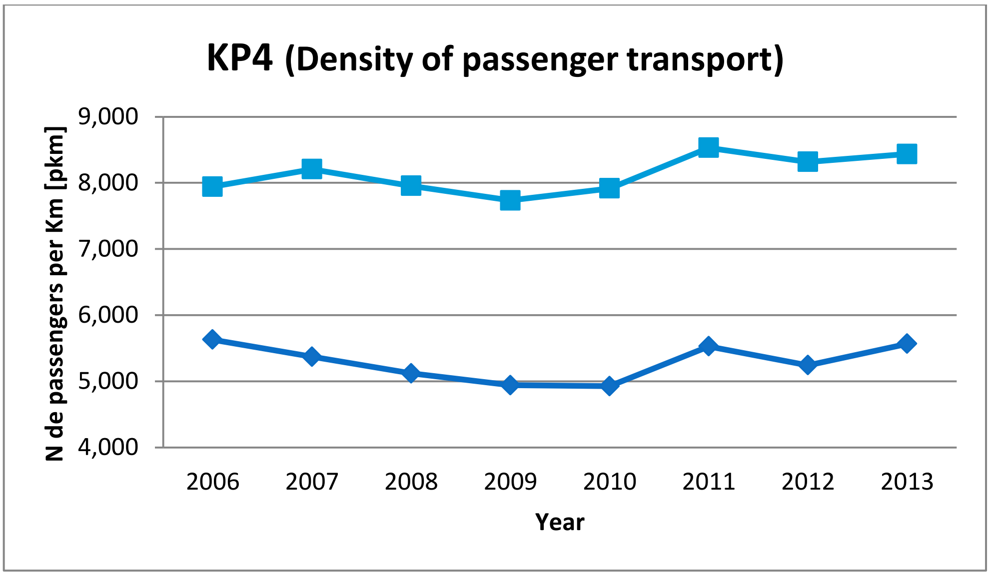


Figure 52: KPI4 Density of passenger transport for Madrid City.

The following chart relates the previous KPI4 with the unit of fuel consumed (see Figure 53), showing the number of passengers transported by a unit of fuel (litre). The most passengers per unit of fuel the most efficient transport system is.

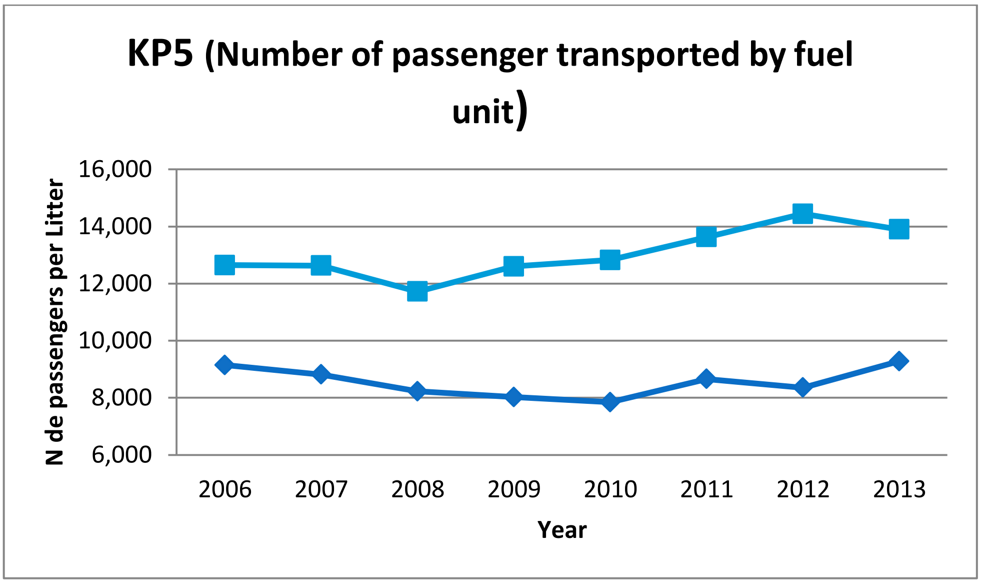


Figure 53: KP5 Number of passenger transported by fuel unit for Madrid City.

The same two bus lines mentioned before have been analysed in the next chart (Figure 54) so as to obtain the number of fuel units consumed per passenger. The lowest quantity of units, the more efficient the transport system is.

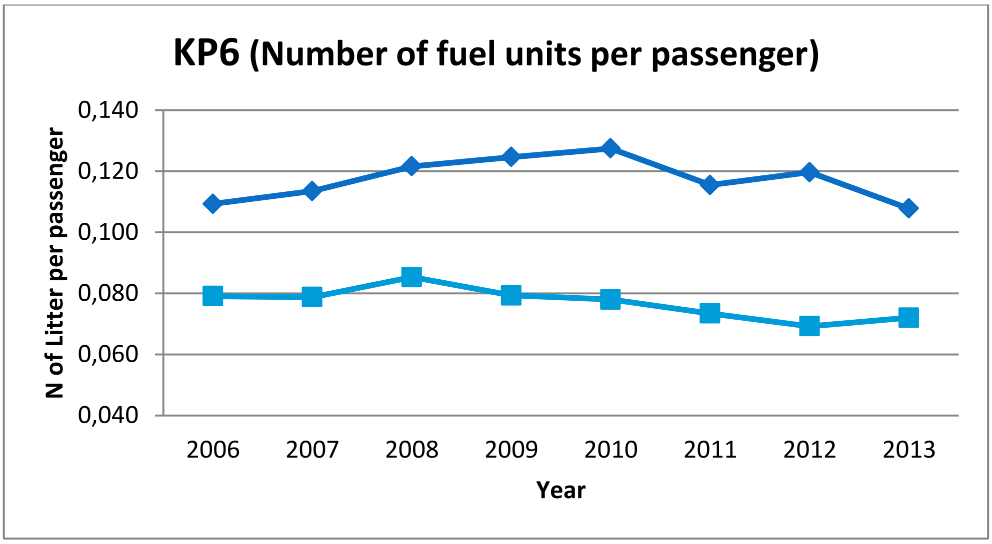


Figure 54: KP6 Number of fuel units per passenger for Madrid City.

The following chart (Figure 55) shows the relation between the travelled distance by those specific bus lines and a considered area of 8,4km2 where fleet units of those lines travel.

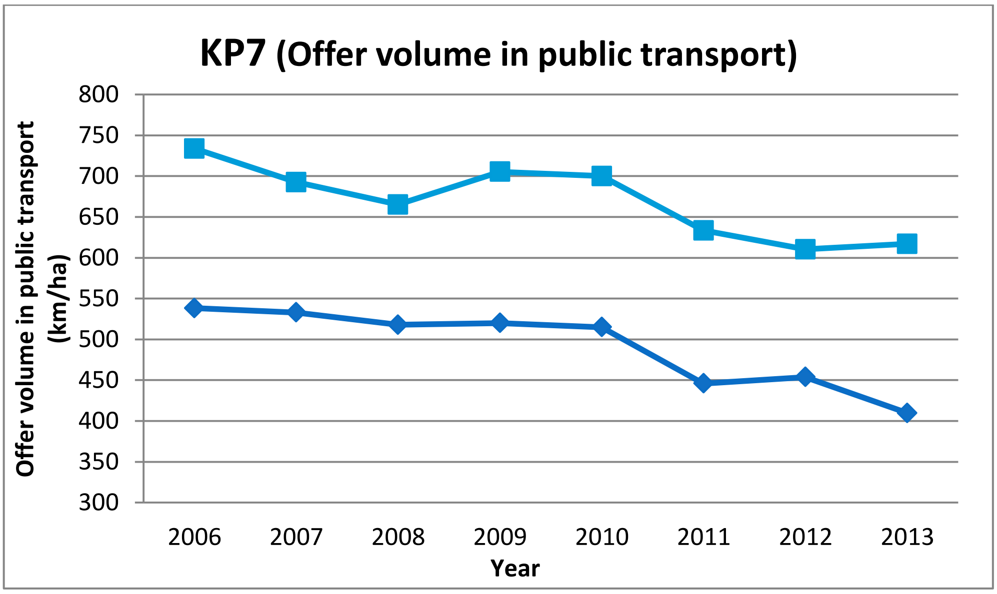


Figure 55: KP7 Offer volume in public transport for Madrid City.

The following picture shows the values of the number of private vehicles per 1000 inhabitants (see Figure 56). It is observed that the KPI value is decreasing in the last few years.

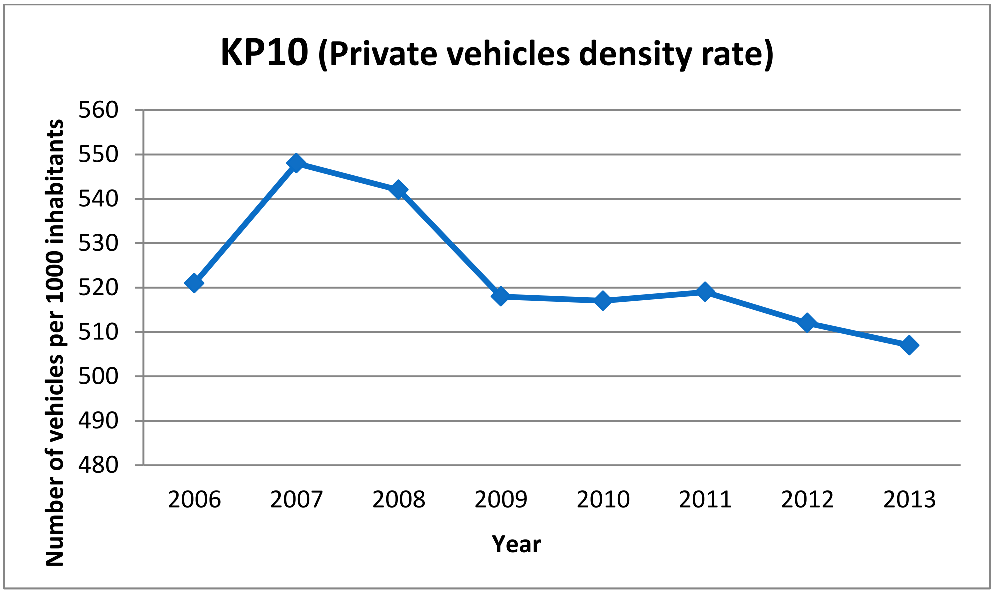


Figure 56: KP10 Private vehicles density rate.

The next chart shows the number of private diesel vehicles from the rest of fuels including gasoline (see Figure 57), from the total fleet. Market tendency is to buy diesel vehicles. This KPI is not applicable to public bus transport because the public buses fleet are not gasoline propelled vehicles, and the comparative should be done between diesel and CNG, and not between diesel and gasoline.

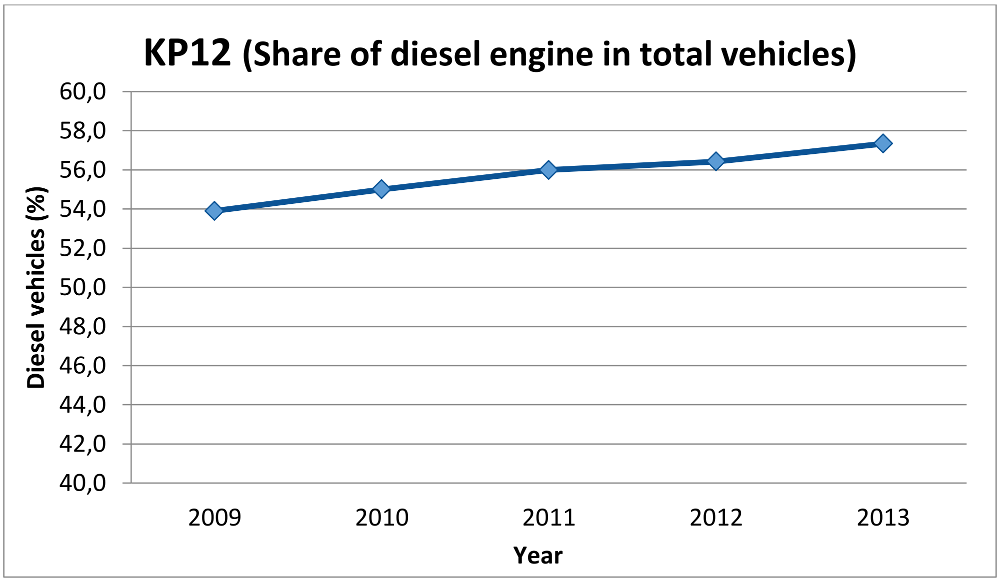


Figure 57: KP12 Share of diesel engine in total private vehicles for Madrid City.

The following chart shows the relation between new technology vehicles (newer than 2010) and total fleet, applied both to private vehicles (PV) and public transport (PT). Available data of public fleet in 2013, only from January to April (43 units) see Figure 58.

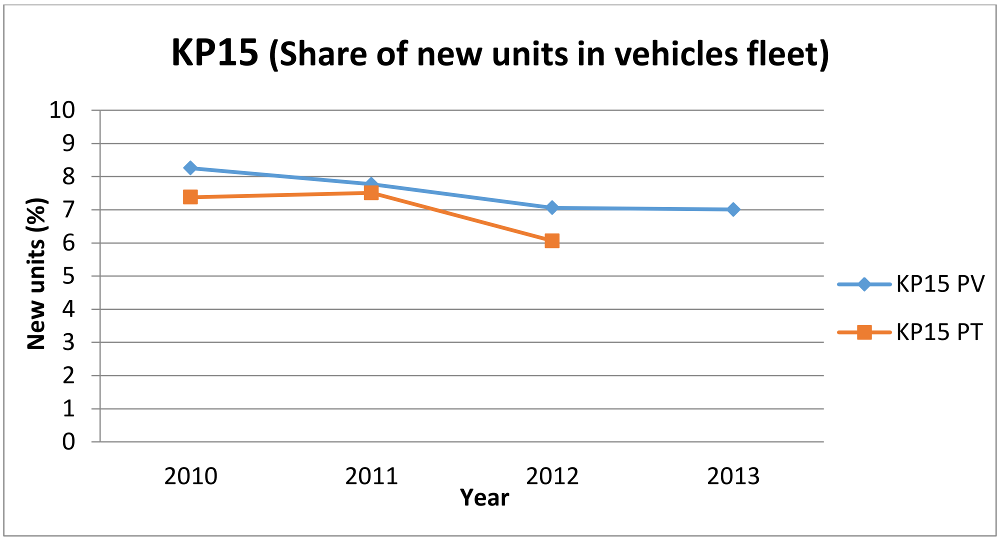


Figure 58: KPI15 Share of new units in vehicles fleet for Madrid City.

The following two charts show the growth of alternative fuel vehicles respect to the total vehicles fleet, for public transport (PT) and private vehicles (PV), considering those newer than 2010 (see Figure 59 and Figure 60).

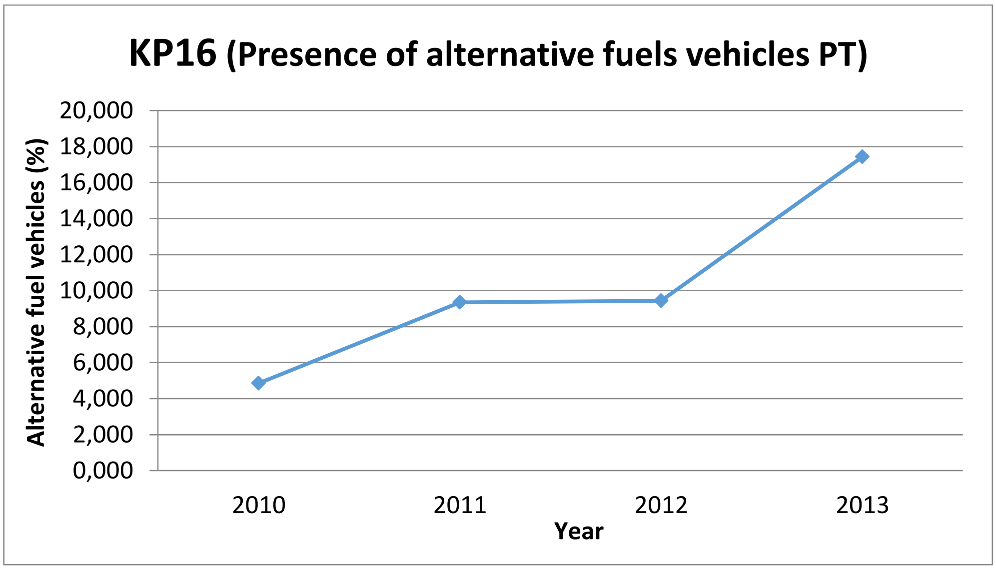


Figure 59: KP16 Presence of alternative fuels newer 2010 vehicles in Public Transport in Madrid City.

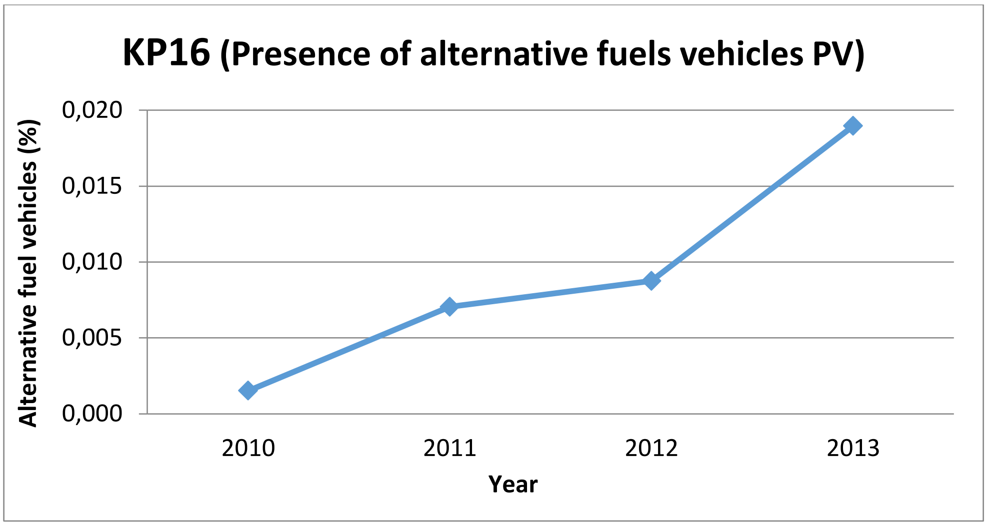


Figure 60: KP16 Presence of alternative newer than 2010 fuels vehicles in Private Transport in Madrid City.

The following two charts show traffic-free (TF) and on-road (OR) routes in Madrid. It has been distinguished between pedestrian walkways in the city centre and cycling network (Figure 61and Figure 62).

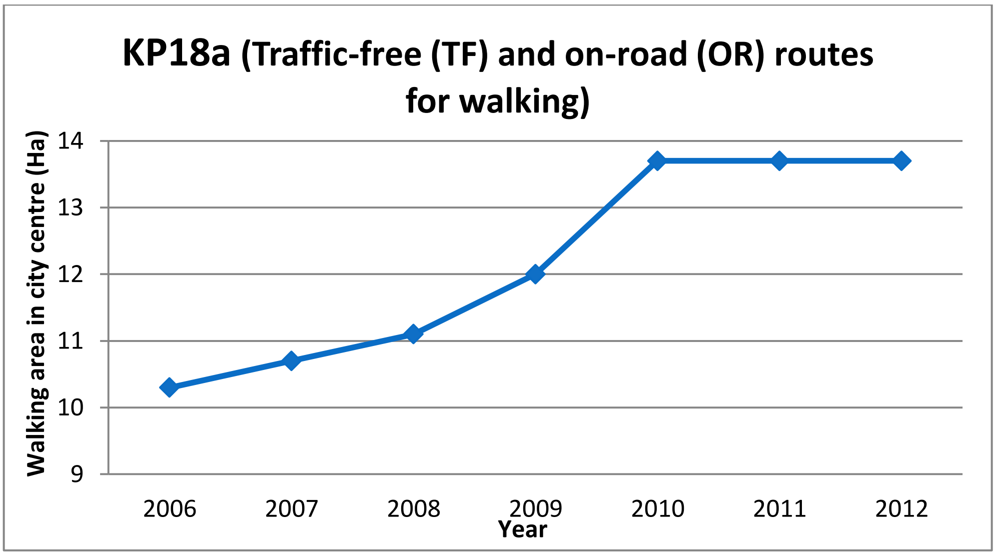


Figure 61: KP18a Traffic-free (TF) and on-road (OR) routes for walking in Madrid City.

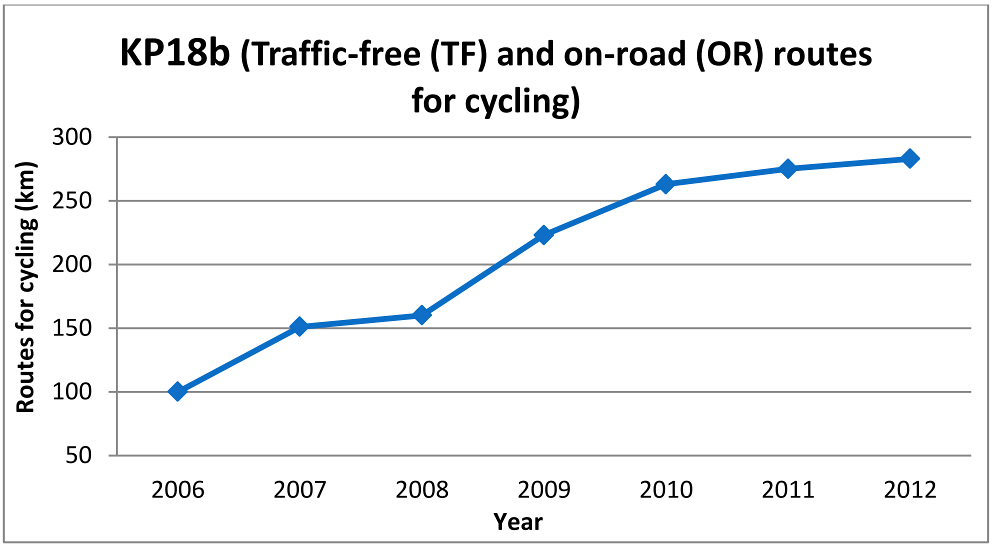


Figure 62: KP18b Traffic-free (TF) and on-road (OR) routes for cycling in Madrid City.

The next figure shows the number of public bike moorings included in the cycling network. Bike-hiring service has been implemented in 2014, so there are no further data up to the moment (see Figure 63).

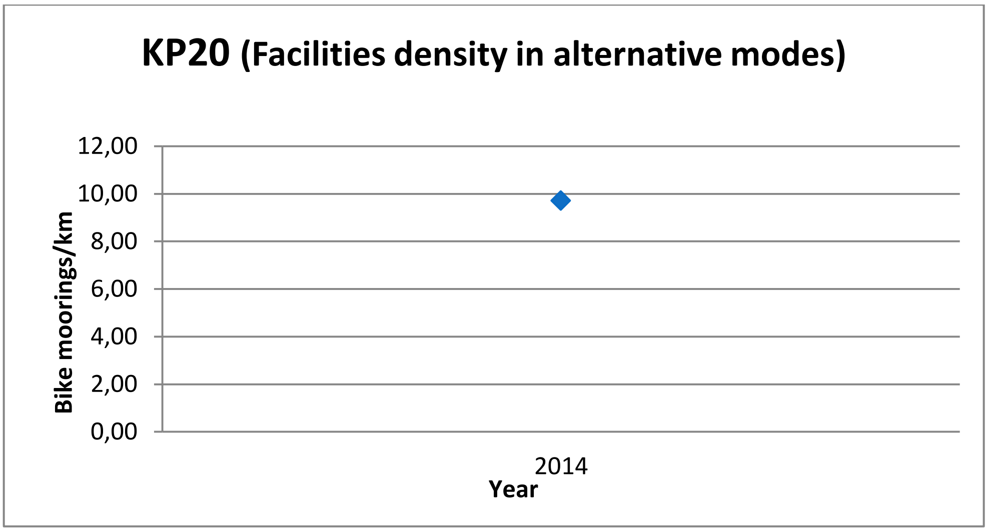


Figure 63: KP20 Facilities density in alternative modes for Madrid City.

The figure below shows the media value of trip cost by both public transport (PT) and private vehicles (PV) Figure 64.

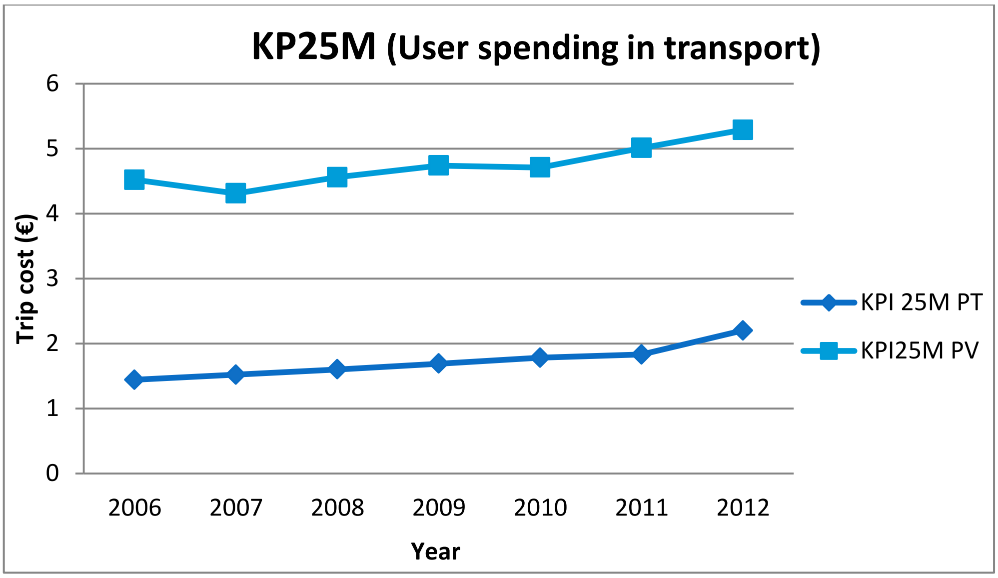


Figure 64: KP25M User spending in transport for Madrid City.

The following chart shows the percentage of trips done by public bus, which keep within the established frequency (see Figure 65). This KPI is aimed at showing the reliability (punctuality) of the public transport.

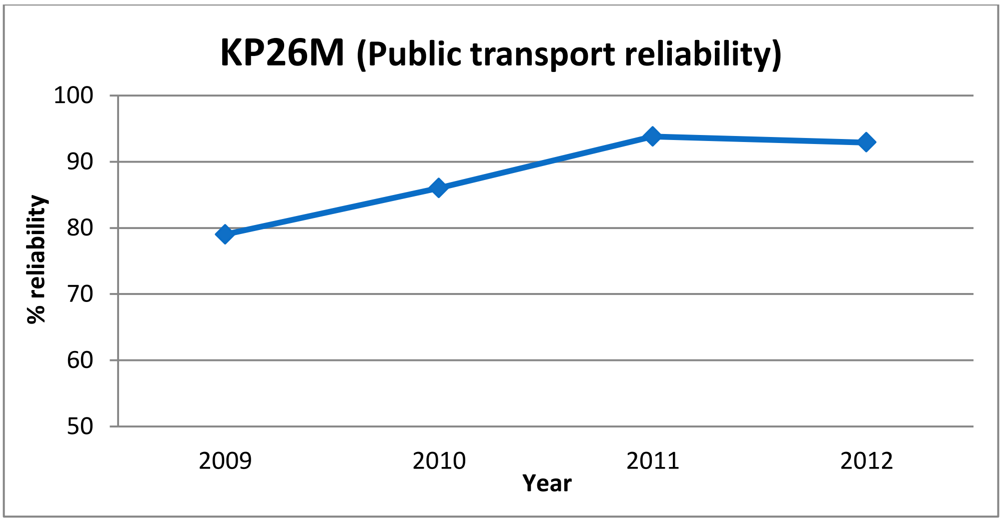


Figure 65: KP26M Public transport reliability in Madrid City.

As mentioned before, bike-hiring service has been implemented along 2014, so there are no further not previous data up to the moment. Information about the use of private bikes is not measured (Figure 66).

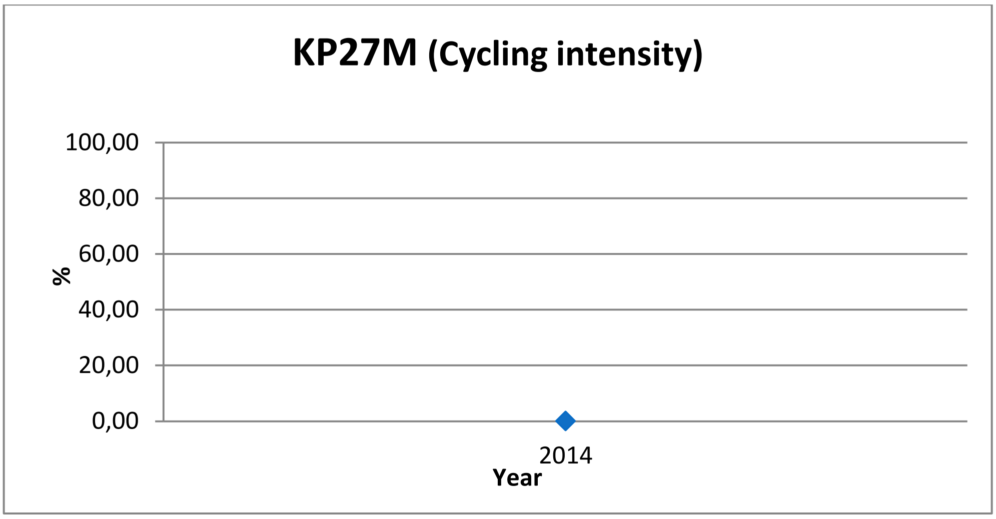


Figure 66: KP27M Cycling intensity for Madrid City.

The figure below shows the daily media concentration of NO2 and PM10, which are local pollutants measured and registered in Madrid City that can be related with traffic conditions (Figure 67).

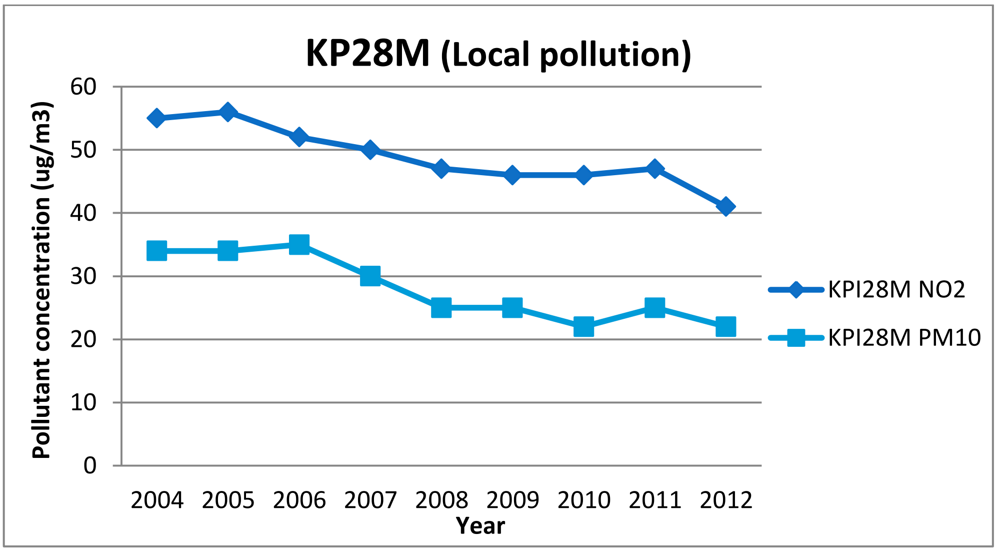


Figure 67: KP28M Local pollution for Madrid City.

The next chart shows the evolution of different cubic capacity vehicles; the cubic capacities considered are: CC <1199; CC (1200-1499); CC (1500-1999); CC >2000 (see Figure 68).

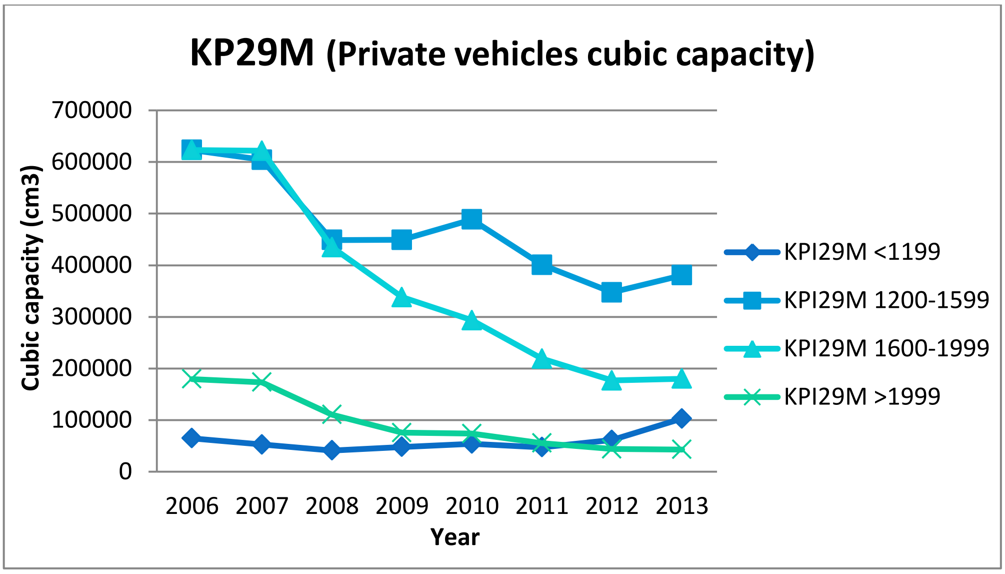


Figure 68: KP29M Private vehicles cubic capacity for Madrid City.

The chart below shows the percentage of public buses with CNG-propelled engine, from the total bus fleet. Public transport's manager company aims to invest in greener technologies like CNG instead of in diesel engine buses, as can be seen in the Figure 69.

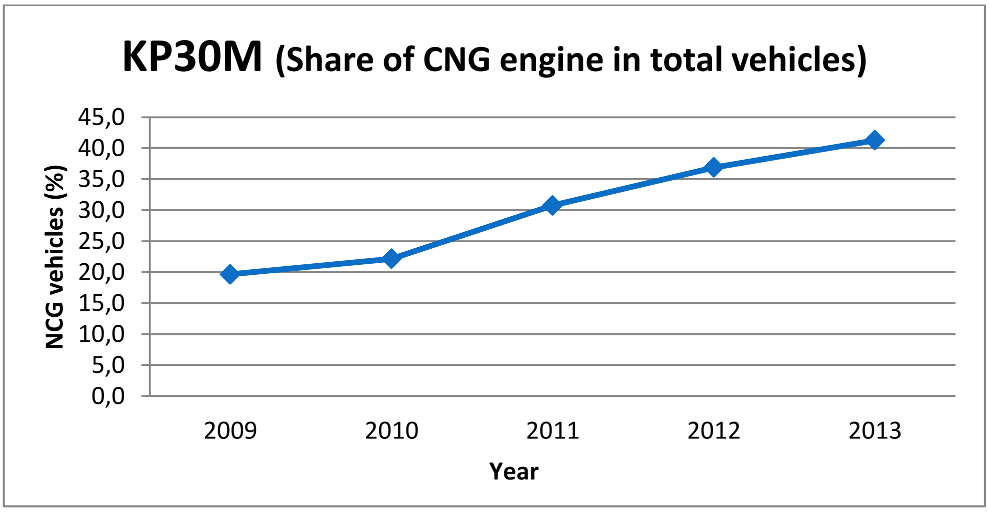


Figure 69: KP30M Share of CNG engine in total public buses fleet in Madrid City.

Base line and Targets

According with the section 3.1.3 (General KPIs conversions) the KPIs expressions were transformed into carbon units in order to get the base line equation for each of them. The following information was used for the conversion processes:

- Considering two journeys per day, of less than 20 minutes each, and median speed of 30km/h, the average mileage per person is 4400km per year.
- Average gasoline car Carbon Conversion Factor (CCF) is 0,21$\frac{kgCO_2}{km}$
- Average gasoline car Carbon Conversion Factor (CCF) is 0,179$\frac{kgCO_2}{km}$ for cars newer than 2010.
- Average diesel car Carbon Conversion Factor (CCF) is 0,18$\frac{kgCO_2}{km}$

- Average Diesel Bus Public transport CCF_{PT} is 63 $\frac{gCO_2}{pkm}$
- Average Diesel Bus Public transport CCF_{PT} is 30 $\frac{gCO_2}{pkm}$ for vehicles newer than 2010.
- Average CNG Bus Public transport CCF_{PT} is 52 $\frac{gCO_2}{pkm}$
- Diesel: $Specific\ weight\ 0.845 \frac{kg_{fuel}}{litre} * Carbon\ dioxide\ 3148 \frac{gCO_2}{kg_{fuel}} = 2660 \frac{gCO_2}{litre}$

Additionally to the base line, the following figures in this section show the target values set for each of the KPIs for 2016. It is to note that KPIs related to public transport are related specifically to bus lines 12 and 61. It is also to highlight that an average gasoline car is considered as the most common one, in order to cover the worst and most contaminating scenario.

For the conversion of KPI4 into KPI4e it was necessary to make a projection of values for 2014 and 2015, to be able to get a base line. Data related to 2011 were not included for the regression calculation but it was used in the projection process. These values show that Madrid attempts to reduce the emissions per passenger in public transport, which involves the bus system to move towards a more efficient use of the energy (see Figure 70 and Figure 71).

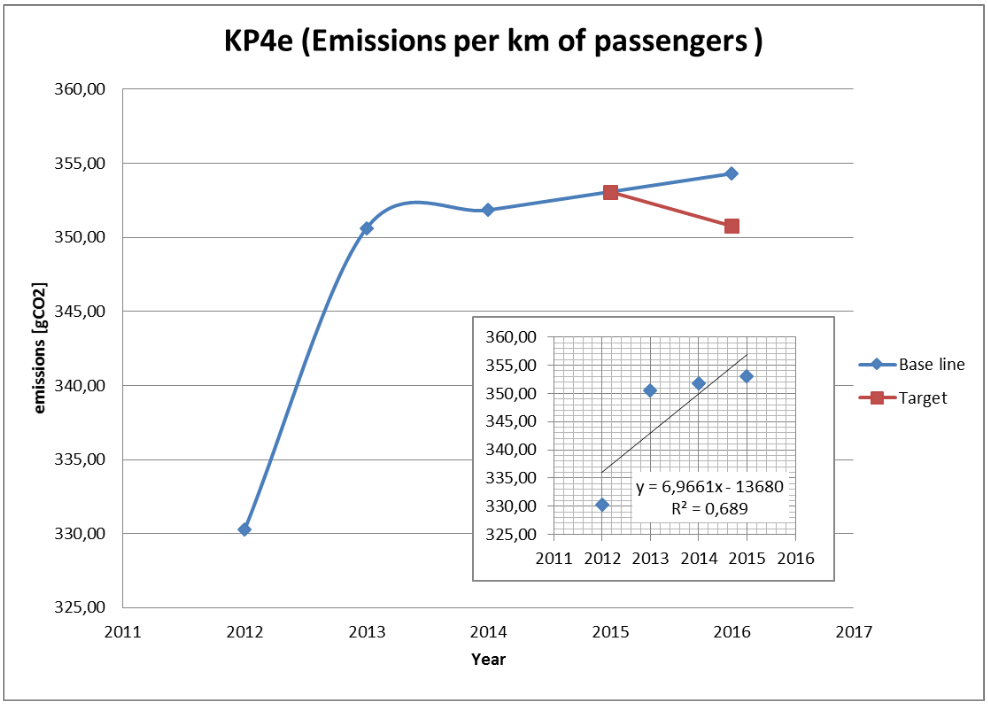


Figure 70: KP4e emissions per km of passengers in Bus line 12 in Madrid City.

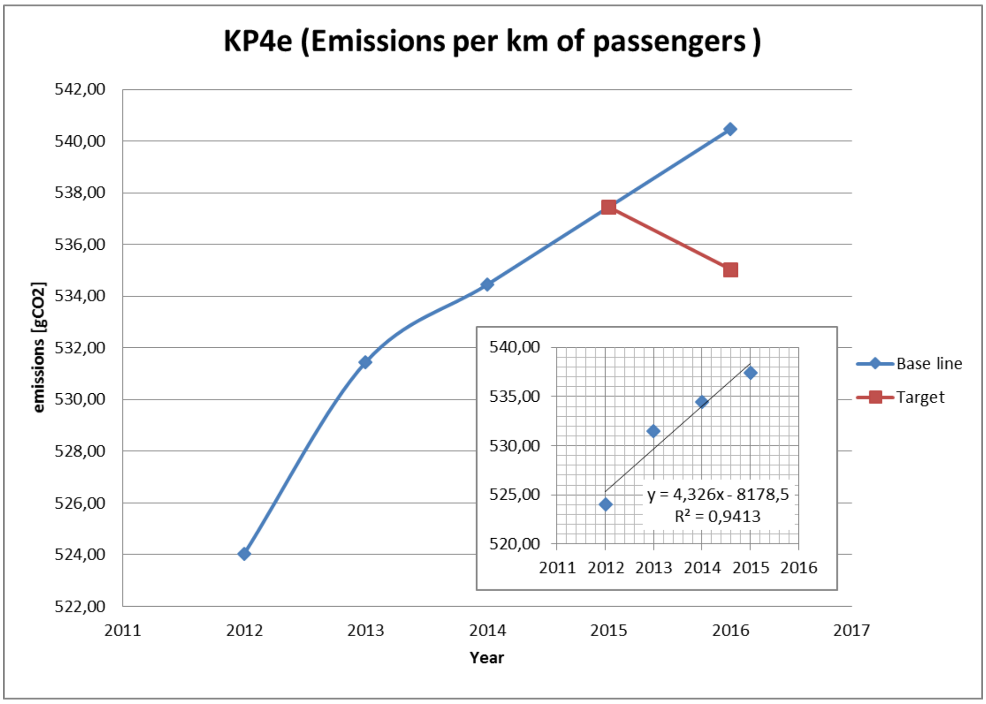


Figure 71: KP4e emissions per km of passengers in Bus line 61 in Madrid City.

On the emissions saved in the KP4s the same projection method was also used. As a result, the values of KP4s for 2016 are shown in Figure 72 and Figure 73. This KPI conversion value shows that the use of public bus as transport, contributes to saving a certain amount of CO2 per passenger, in comparison to using a private car.

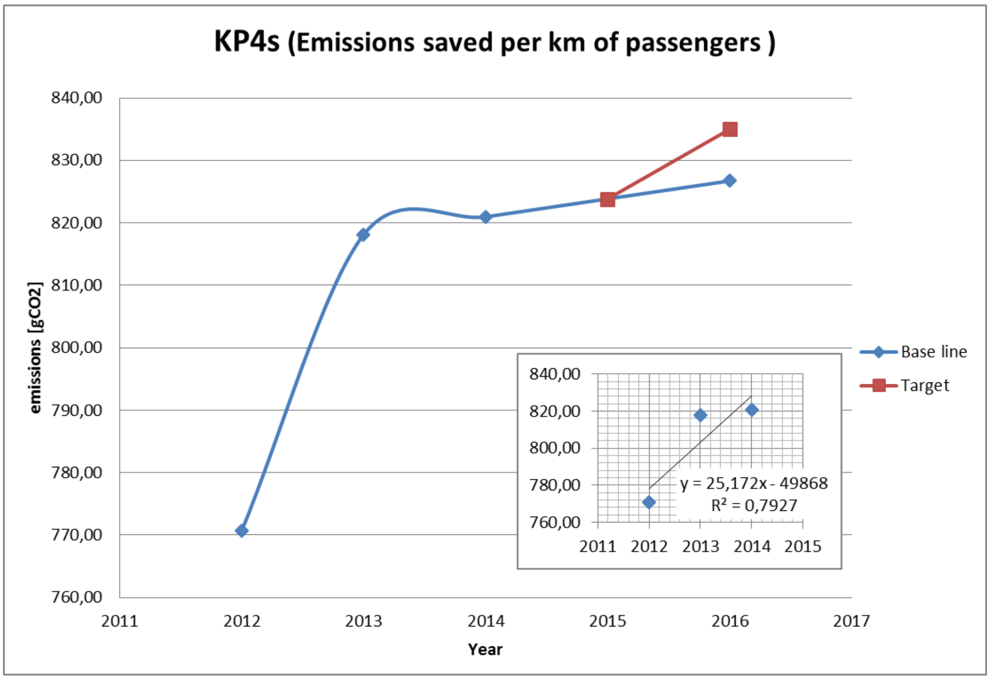


Figure 72: KP4s emissions saved per km of passengers in Bus line 12 in Madrid City.

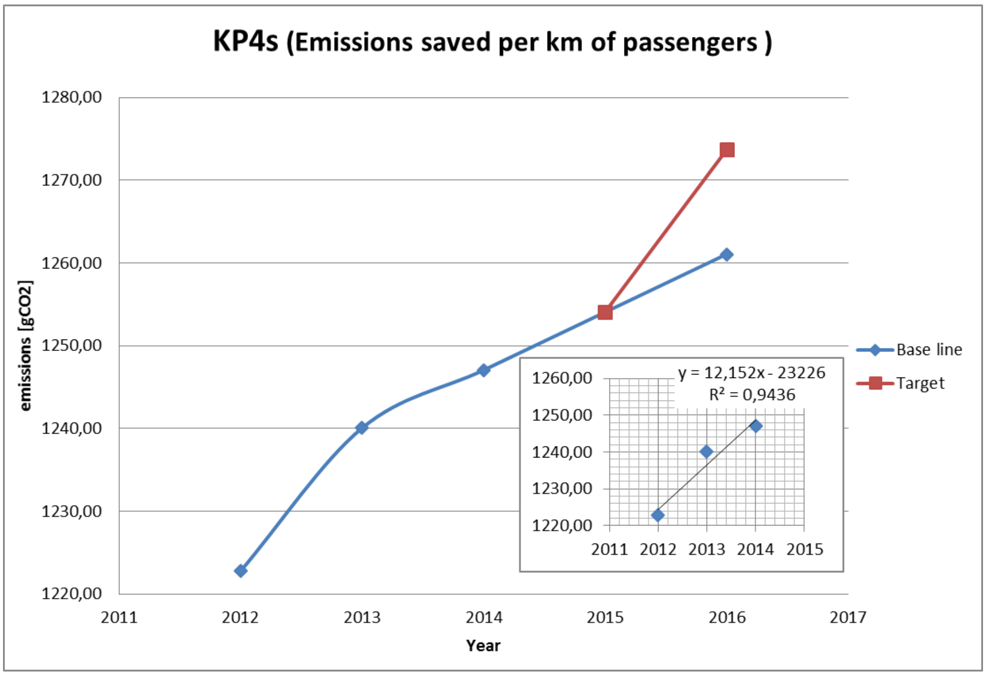


Figure 73: KP4s emissions saved per km of passengers in Bus line 61 in Madrid City.

For the conversion of KPI5 into KPI5e it was necessary to make a projection for 2014 and 2015, to be able to get a base line for those years. 2011 data were not included for the regression but they were used in the projection process (Figure 74 and Figure 75). These values show that even when not all the studied lines are as efficient as the most efficient one, Madrid is aimed at promoting public transport and at increasing the number of public transport users, what would involve the reduction of fuel emissions per passenger and thus moving the bus system towards a more efficient use of the energy model.

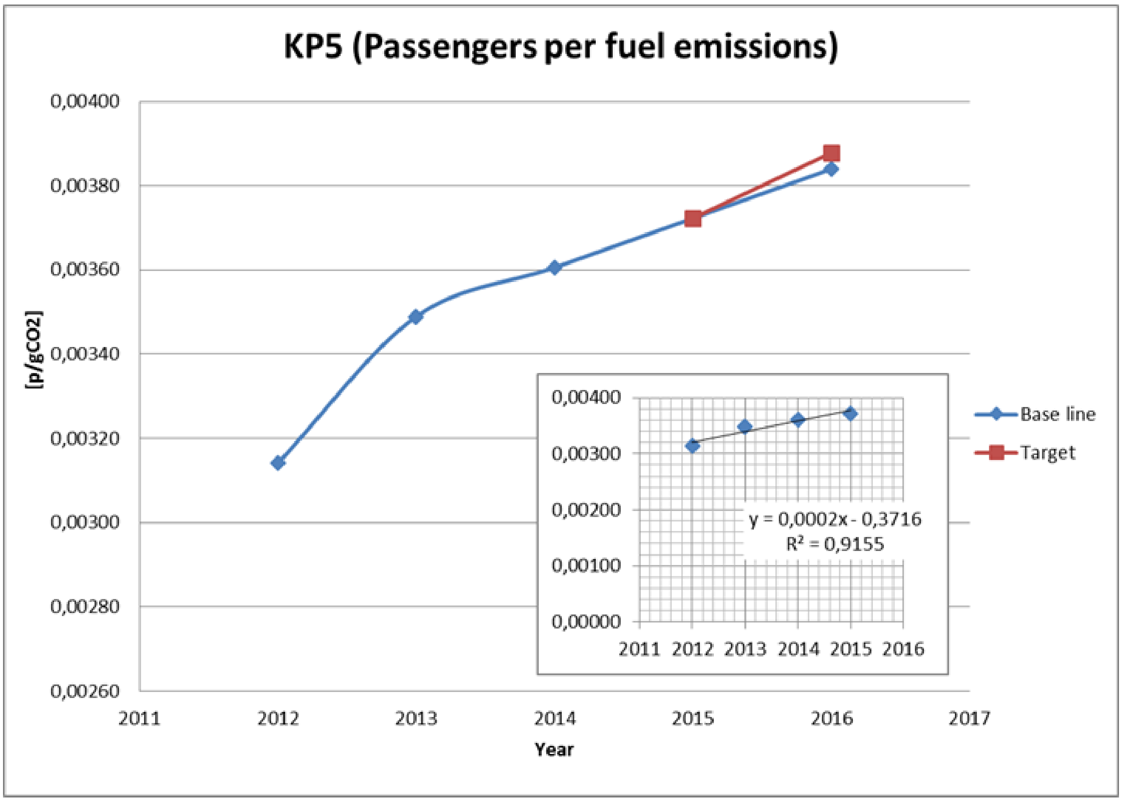


Figure 74: KP5e passengers per fuel emissions in Bus line 12 in Madrid City.

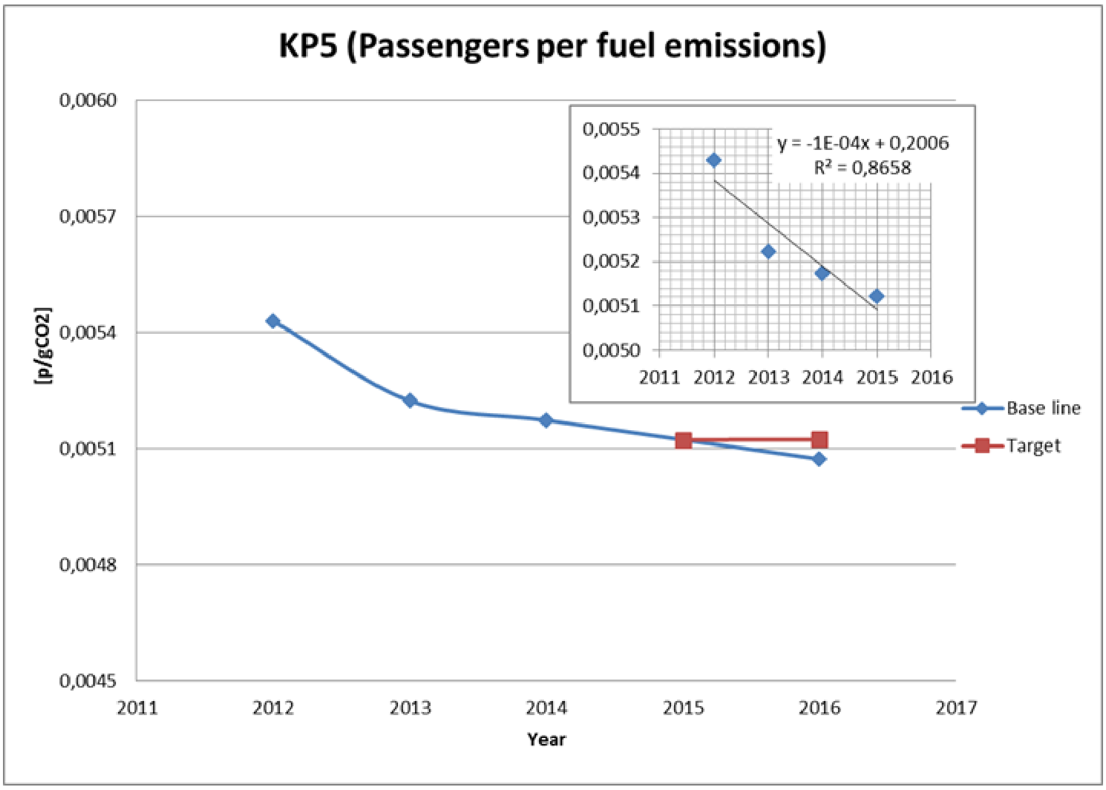


Figure 75: KP5e passengers per fuel emissions in Bus line 61 in Madrid City.

For the conversion of KP6 into KP6e it was necessary to make a projection for 2014 and 2015, to be able to get a base line. 2011 data were not included for the regression but they were used in the projection (Figure 76 and Figure 77). Those values show, as in the case of KP5, that even when not all the studied lines are as efficient as the most efficient one, Madrid will attempt to reduce emissions per passengers in public transport, moving bus system towards a more efficient use of the energy.

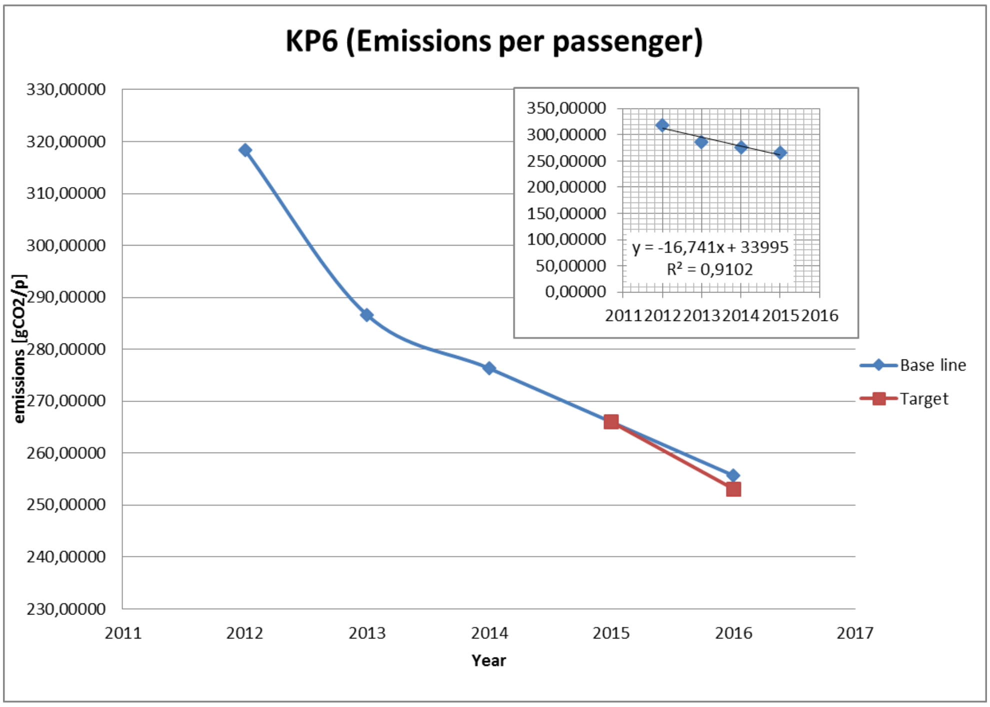


Figure 76: KP6e emissions per passengers in Bus line 12 in Madrid City.

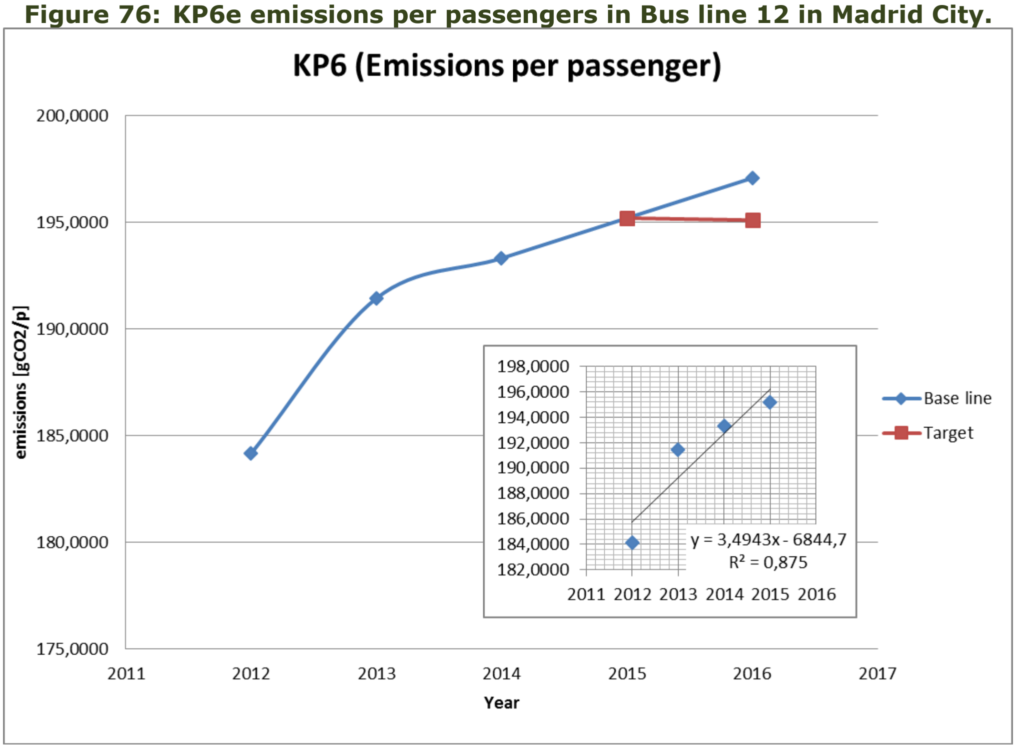


Figure 77: KP6e emissions per passengers in Bus line 61 in Madrid City.

For KP7e conversion it was necessary to make a projection for 2014 and 2015, to be able to get a complete base line (see Figure 78 and Figure 79). 2011 data was not included for the regression but it was used in the projection process. Those values show that Madrid is aimed at reducing the overall emissions generated by public transport, despite the cases where the use of the bus line is not that efficient and the emissions tendency is to grow. It is intended to improve energy efficiency in public transport, considering the percentage of use.

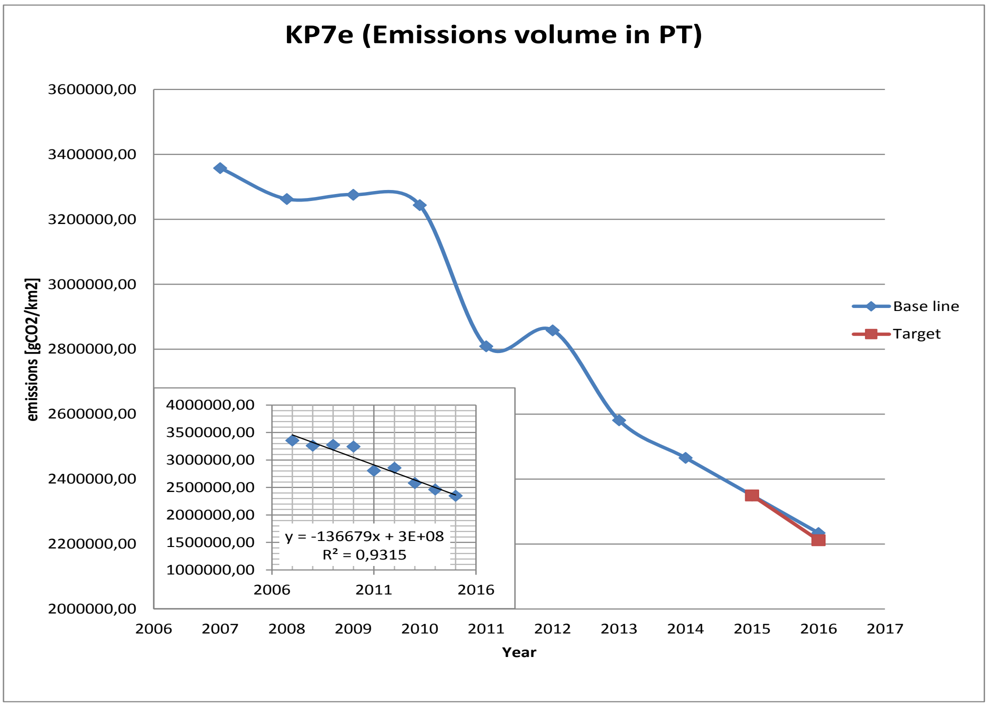


Figure 78: KP7e emissions volume in Bus line 12 in Madrid City.

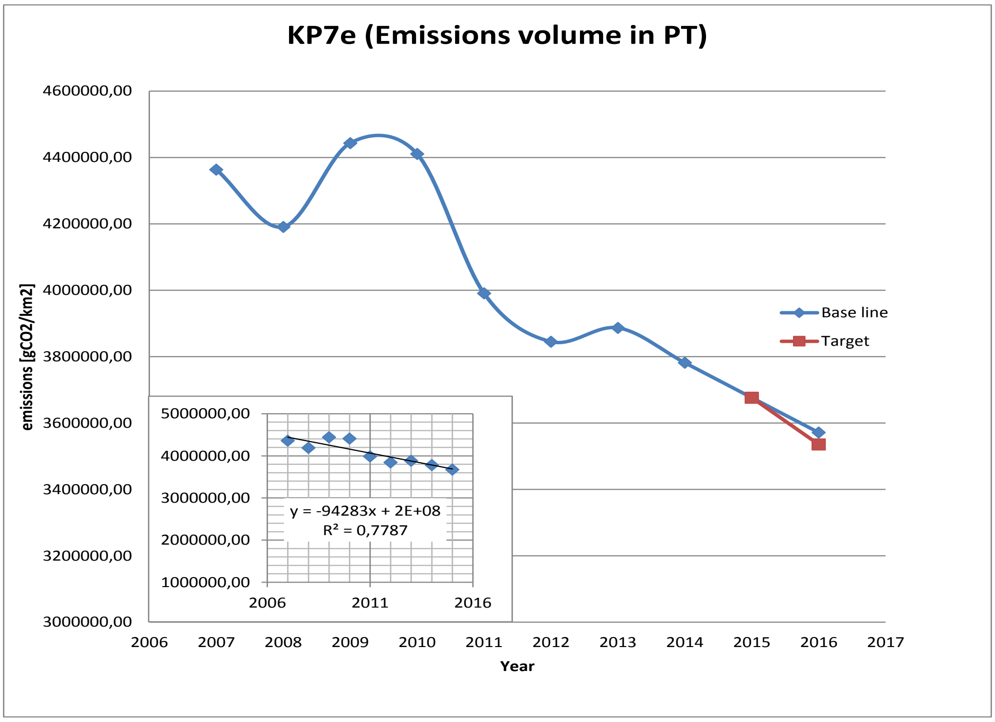


Figure 79: KP7e emissions volume in Bus line 61 in Madrid City.

On the emissions saved in the KP7s it was also used same projection method as in the previous cases and the result of the values for 2016 are included in the Figure 80 and Figure 81. This KPI7 conversion shows that even when the tendency of the saving values is to grow, the target is to increase the savings related to emissions volume of the public transport.

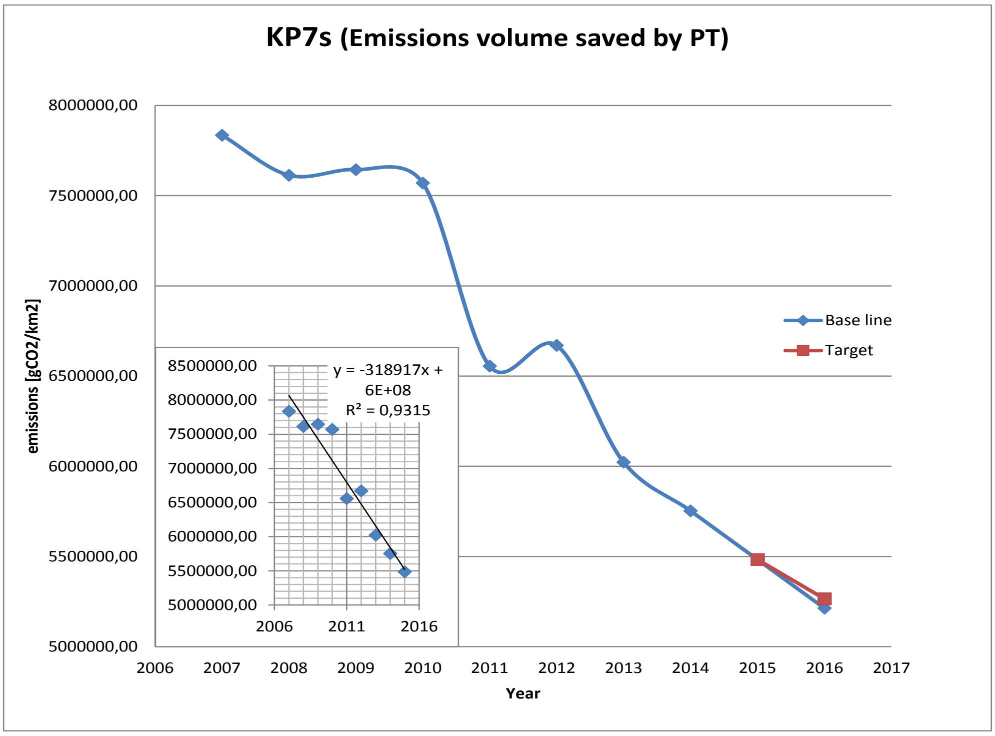


Figure 80: KP7s emissions volume saved in Bus line 12 in Madrid City.

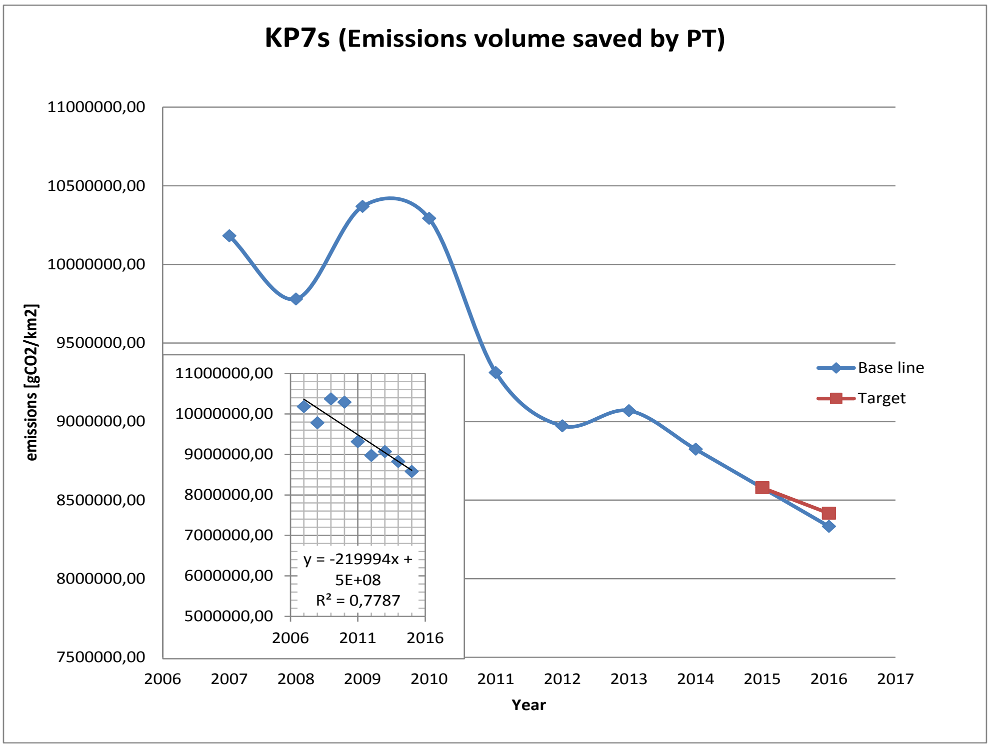


Figure 81: KP7s emissions volume saved in Bus line 61 in Madrid City.

Private vehicles density rate can be transformed into energy or emission units by using the worst scenario as reference scenario, meaning the use of a private car with lowest occupancy level. Car Carbon Conversion Factor (CCF) has therefore been considered for the conversion process of KP10. KP10 base line Figure 82 results as following:

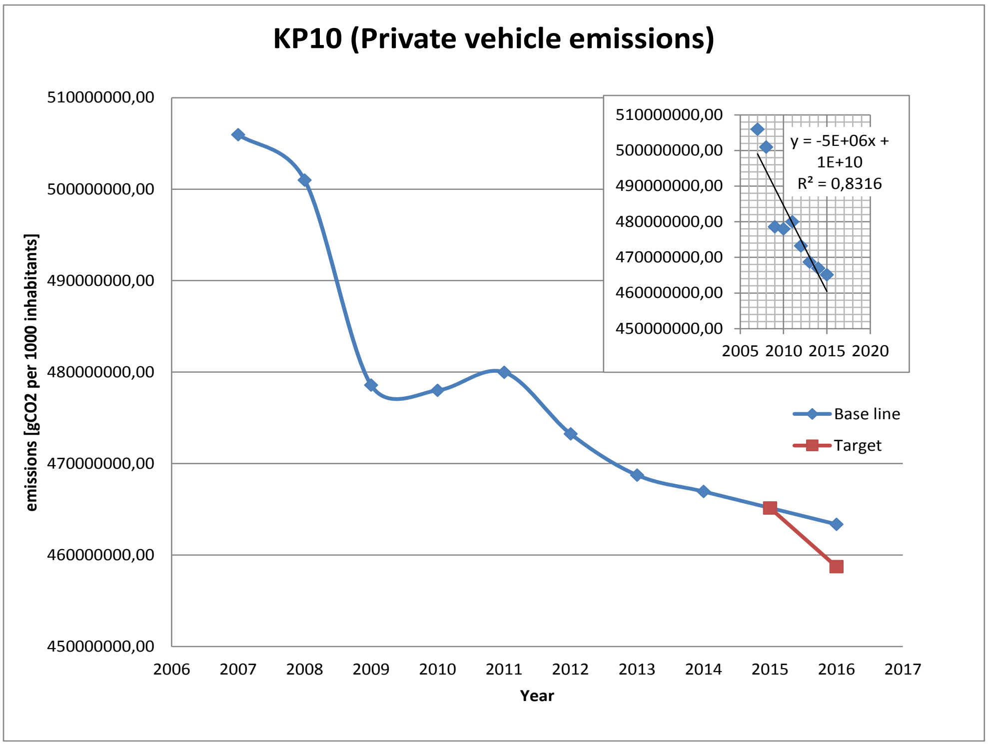


Figure 82: KP10e Private vehicles emissions density rate for Madrid City.

The opportunity in this KPI is to decrease the emissions caused by private vehicles, because without opportunity implementation the emission value estimated for 2016 is 463364587.92 gr CO2 per 1000 inhabitants. Considering the emissions tendency measured during the last years (2012-2013), the target is set to reduce the emissions in 1% compared with the base line, that is, the target is to reduce emissions to 4633645.87 gCO2 per 1000 inhabitants or 458730942.04 gCO2 per 1000 inhabitants by 2016.

Share of diesel engine in total private vehicles, can be transformed into energy or emission units by using a reference scenario, which is the worst scenario, considering a private car with the lowest occupancy level. Car Carbon Conversion Factor (CCF) is also to be considered, making a difference between gasoline and diesel. KPI12 base line Figure 83 results as following:

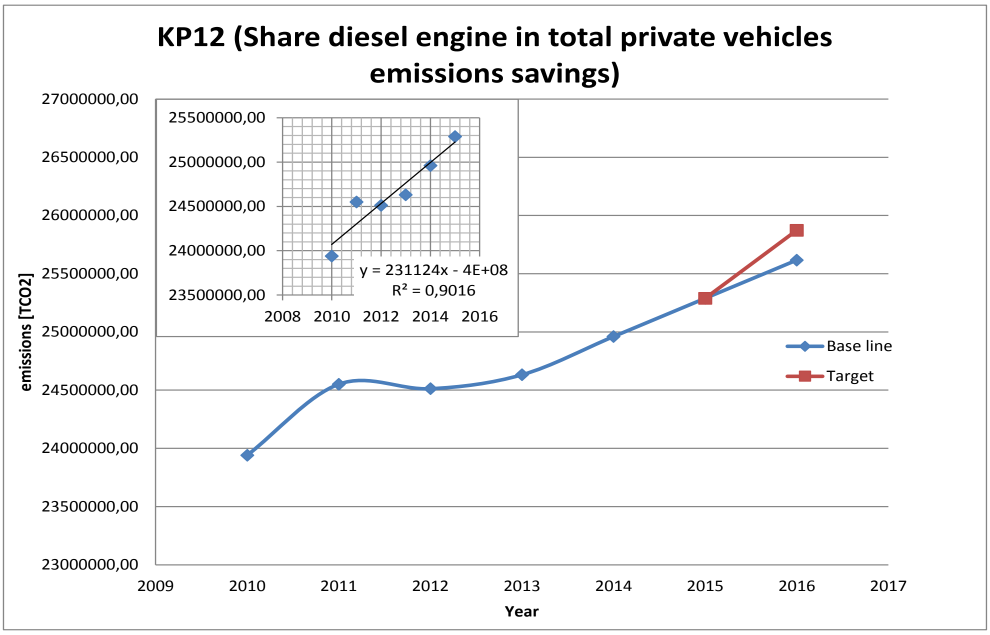


Figure 83: KP12s Share of diesel engine in total private vehicles emissions for Madrid City.

The opportunity in this KPI is to decrease the emissions caused by the increasing use of diesel private vehicle in opposition to gasoline ones, because without opportunity implementation the emission value estimated for 2016 would be 25617005.7 Tons of CO2. Considering the emissions tendency measured during the last years the target is set to increase the emissions saving in 1% compared with the base line, that is to save 256170 Tons of CO2 or to measure 25873175,75 Tons of CO2 by 2016.

The share of new units in private vehicles fleet can be transformed into energy or emission units by using the worst scenario as a reference, as explained in previous cases. Taking into account the evolution of the average gasoline car Carbon Conversion Factor (CCF), the KPI15 Figure 84 and Figure 85 are:

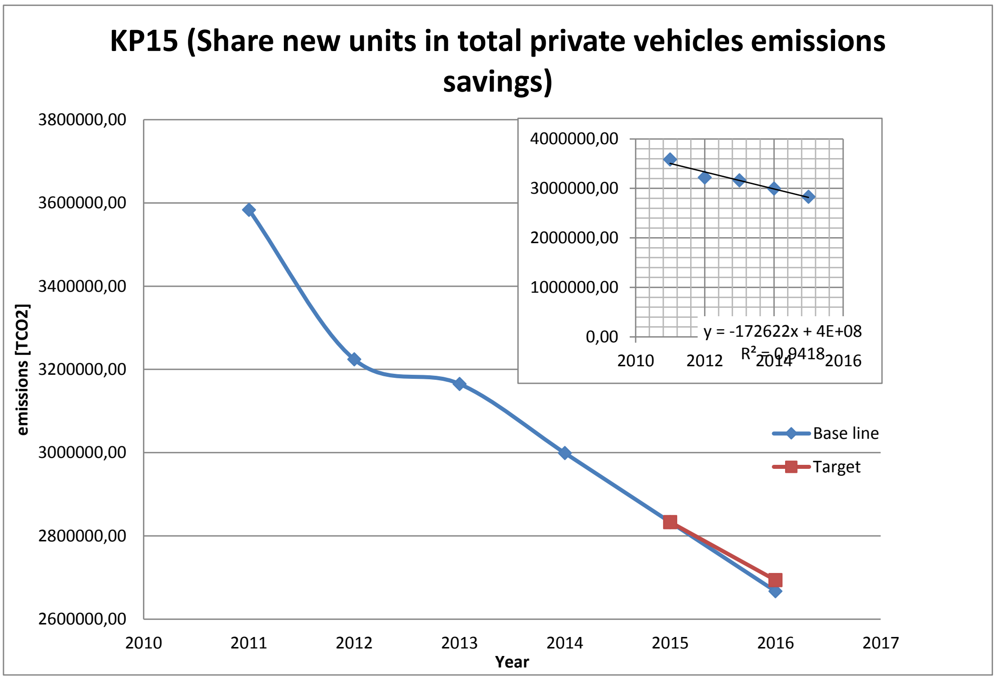


Figure 84: KP15s Share of new units in total private vehicles emissions savings for Madrid City.

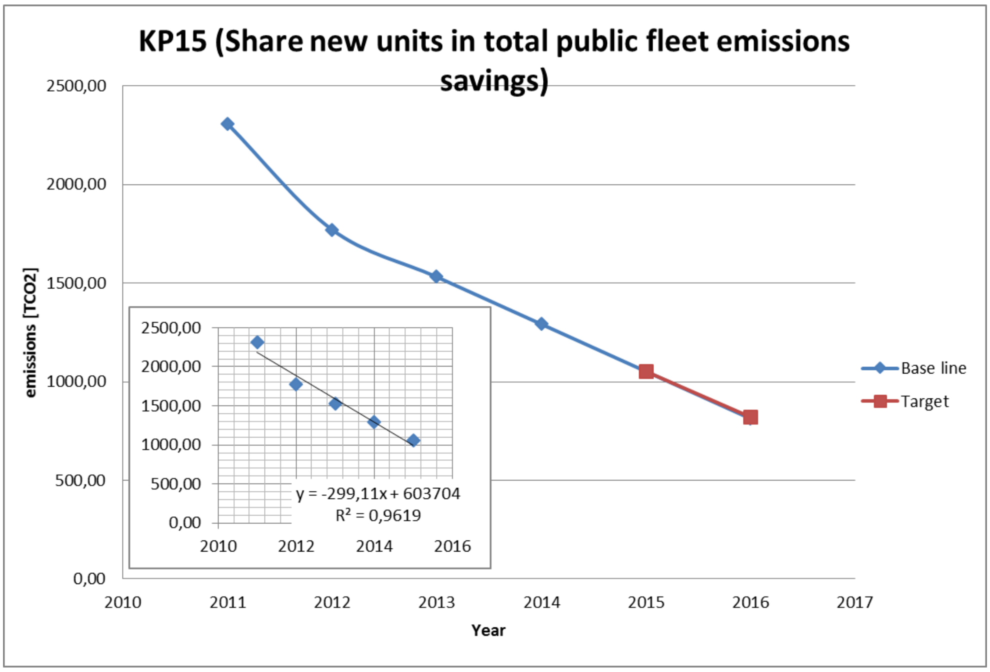


Figure 85: KP15s Share of new units in total public fleet emissions savings for Madrid City.

The opportunity in this KPI is to decrease the emissions caused by vehicles, increasing the savings by the new vehicle units launched to market from 2010 onwards. To calculate the emissions saved in KP16 it was necessary for the conversion to make a projection for 2014 and 2015, to be able to get a base line. 2010 data were not included for the regression calculation but it was used in the projection process (Figure 86 and Figure 87). Alternative fuels vehicles (private and public) are increasing in the last years in Madrid City. That means a reduction in emissions generated by transport, and an improvement of the energy efficiency.

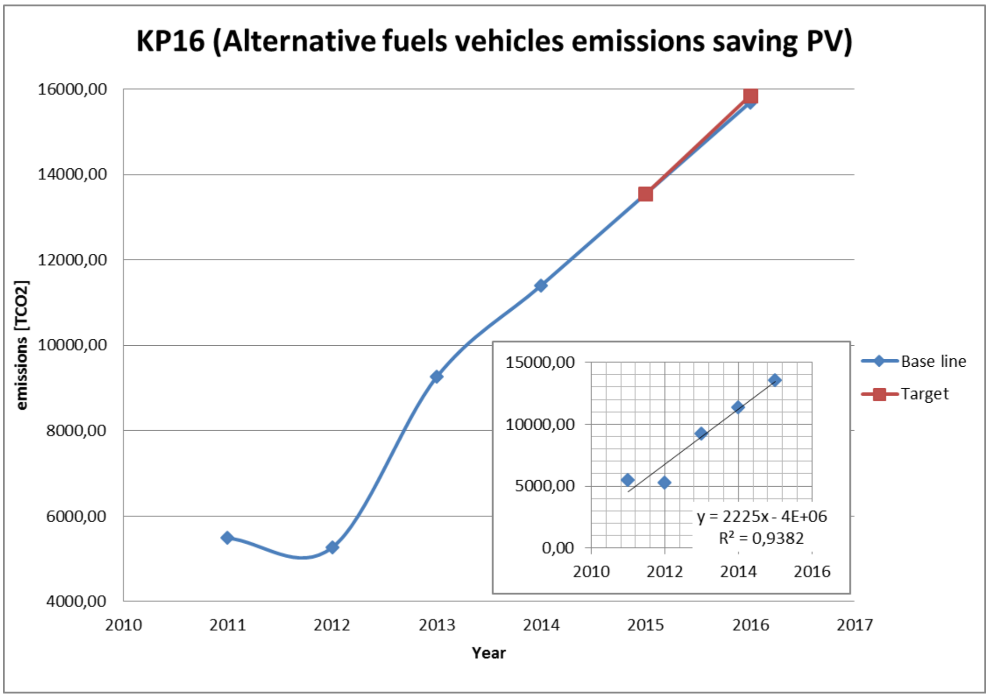


Figure 86: KP16 Private alternative fuel vehicles emissions saving in Madrid City.

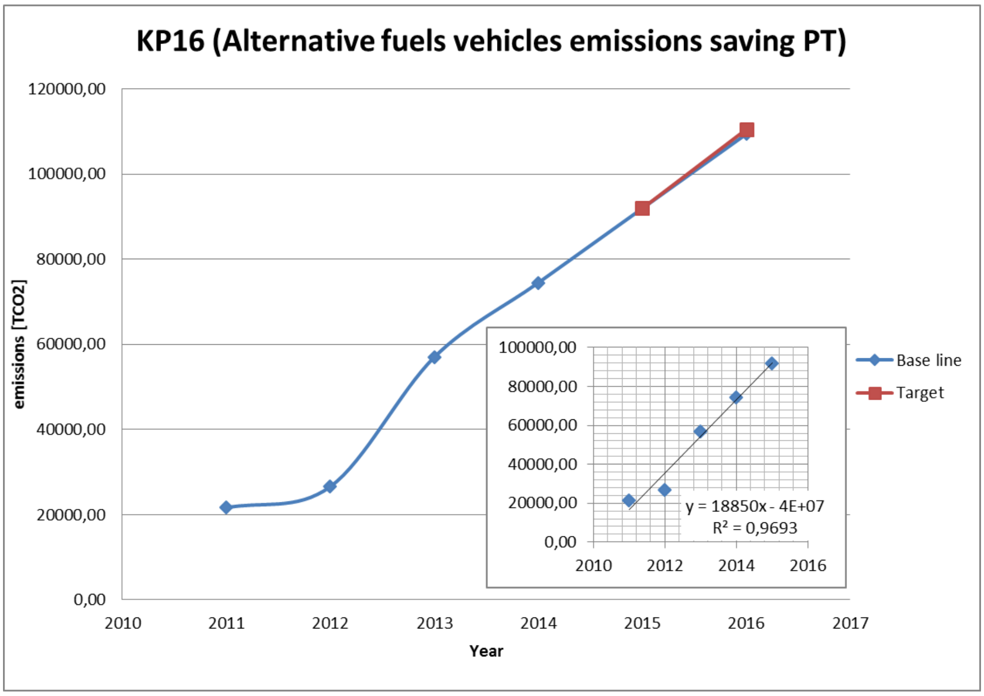


Figure 87: KP16 Public transport alternative fuel vehicles emissions saving in Madrid City.

In KPI18, TF and OR cycling routes can be transformed into energy or emission units by using a reference scenario, which is the worst scenario (a private car with the lowest occupancy level). The KPI18 Figure 88 and Figure 89 are related to emissions saved by either walking or cycling:

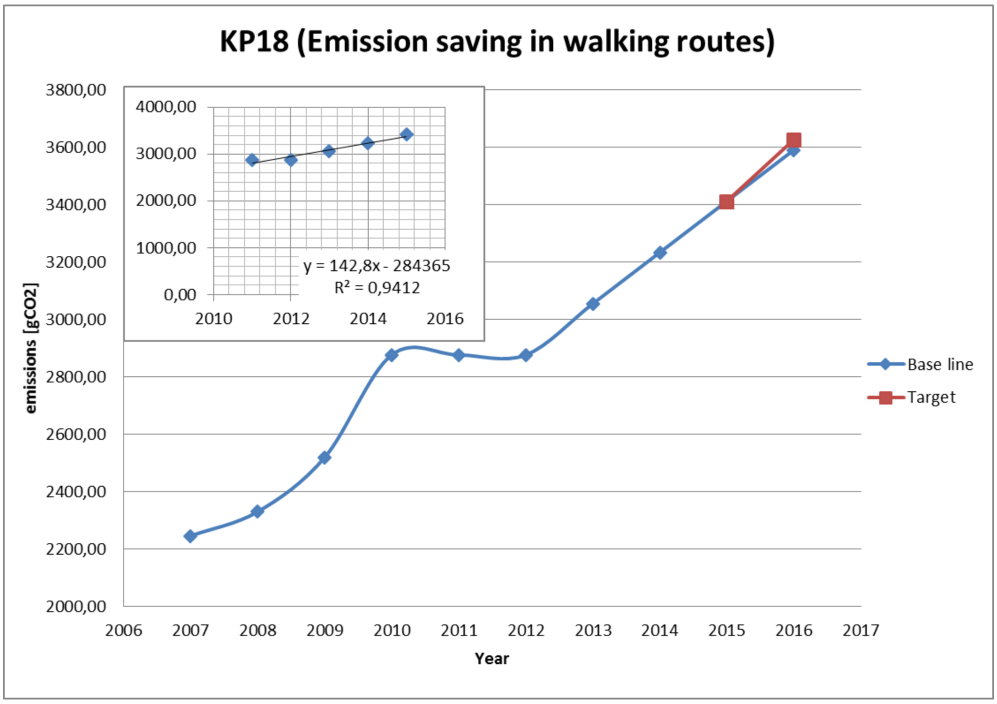


Figure 88: KP18s emission saved in walking routes in Madrid City.

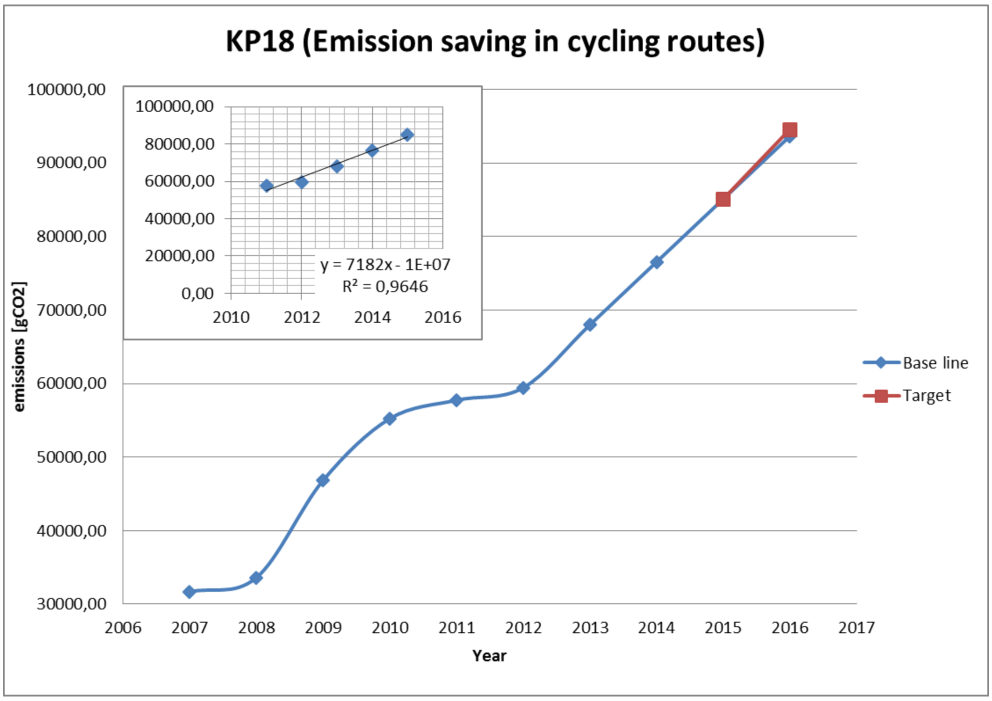


Figure 89: KP18s emission saved in cycling routes in Madrid City.

To calculate the emissions saved in KP18, the necessary conversion involves making a projection for 2014 and 2015, so as to be able to get a base line. 2006 data were not included for the regression calculation but they were used in the projection process. The opportunity in this KPI is to save emissions caused by private and public vehicles, by promoting walking and cycling, and increasing their routes.

To calculate the average emission equivalent from vehicle cubic capacity, an average engine of 1600-1999 cc has been considered. For the conversion it was necessary to make a projection for the years 2014 and 2015, in order to be able to get a base line (Figure 90). 2006 data were not included for the regression calculation but they were used in the projection process.

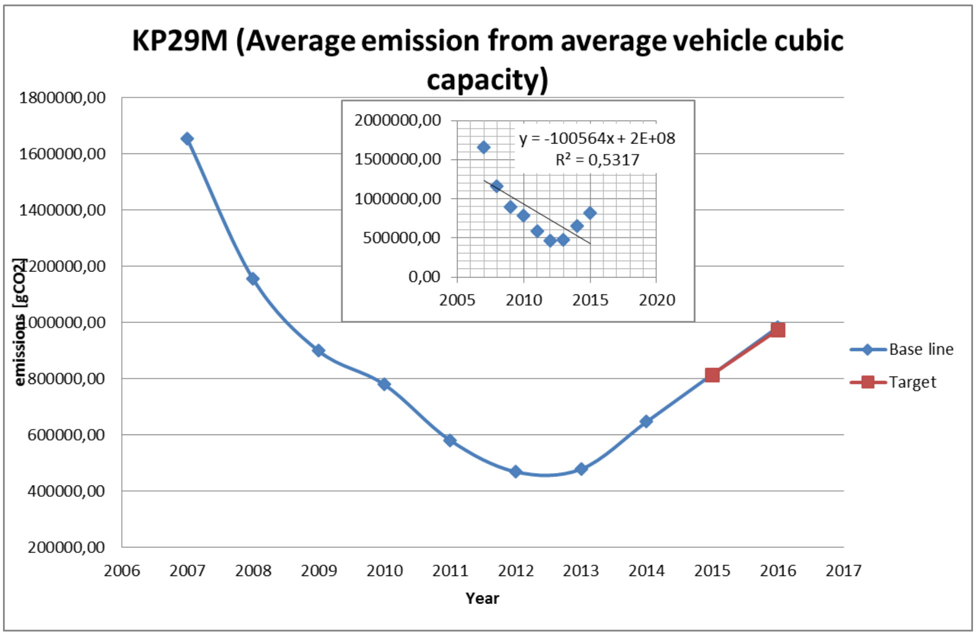


Figure 90: KP29M Average emission from average vehicle cubic capacity in Madrid City.

The opportunity in this KPI is to decrease the emissions caused by private vehicles, based on their cubic capacity, because without opportunity implementation the emission value is 984135.02 gCO2. Considering the tendency measured during the last years the target is set to increase the emissions saving in 1% compared with the base line that is 9841.4 gCO2 or 974293.67 gCO2 by 2016. For KP30M conversion it was necessary to make a projection for 2014 and 2015, to be able to get a base line. 2009 data was not included for the regression but it was used in the projection Figure 91.

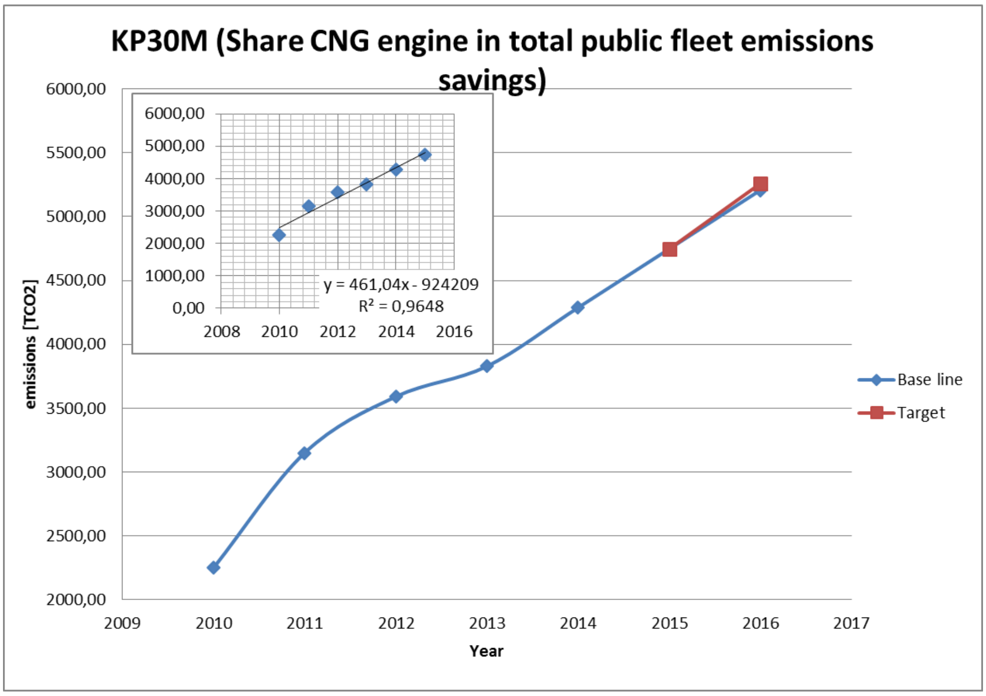


Figure 91: KP30M Share CNG engine in total public fleet emissions savings in Madrid City.

These values show that Madrid is aimed at increasing the savings of public transport with CNG engines. The use of this kind of alternative fuels is intended to improve the energy efficiency in public transport, considering the percentage of use. Without opportunity the saving value of this KPI would be 5207.84 Tons of CO2. Considering the tendency measured during the last years the target is set to increase the emissions savings in 1% compared with the base line, which is 52.078 Tons of CO2 or 5259.92 Tons of CO2 by 2016.

The forward Table 28 resumes the KPIs' Base line and Target values for Madrid pilot in MoveUs project.

ID	Name	Base line value	Target value
KP4e	Emissions per km of passengers	L12: 354.31 gCO_2	L12: 350.77 gCO_2
		L61: 540.45 gCO_2	L61: 535.05 gCO_2
KP4s	Emissions saved per km of passengers	L12: 826.73 gCO_2	L12: 834.99 gCO_2
		L61: 1261.06 gCO_2	L61: 1273.67 gCO_2
KP5e	Number of passengers per fuel emissions	L12: 0.00384 p/gCO_2	L12: 0.00388 p/gCO_2
		L61: 0.0051 p/gCO_2	L61: 0.005124 p/gCO_2
KP6e	Emissions per passenger	L12: 255.73 gCO_2/p	L12: 253.17 gCO_2/p
		L61: 197.07 gCO_2/p	L61: 195.1 gCO_2/p
KPI7e	Offer volume in public transport	L12: 2234234.46 gCO_2/km^2	L12: 2211892.12 gCO_2/km^2
		L61: 3571343.66 gCO_2/km^2	L61: 3535630.2 gCO_2/km^2
KPI7s	Offer volume in public transport	L12: 5213213.75 gCO_2/km^2	L12: 5265345.89 gCO_2/km^2
		L61: 8333135.2 gCO_2/km^2	L61: 8416466.552 gCO_2/km^2
KP10e	Private vehicles emissions density rate	463364587.9 $gCO_2/1000inh$	458730942.04 $gCO_2/1000inh$
KPI12	Share of diesel engine in total vehicles	25617005.7 TCO_2	25873175.76 TCO_2
KPI15	Share of new units in vehicles fleet	PV: 2667033.6 TCO_2	PV: 2693703.94 TCO_2
		PT: 813.12 TCO_2	PT: 821.25 TCO_2
KP16s	Alternative fuels vehicles savings	PV: 109401.6 TCO_2	PV: 110495.62 TCO_2
		PT: 15689.52 TCO_2	PT: 15846.42 TCO_2
KP18s	Traffic-free (TF) and on-road (OR) routes savings	W: 3591.00 gCO_2	W: 3626.91 gCO_2
		C: 93660 gCO_2	C: 94596.6 gCO_2
KP29	Private vehicles cubic capacity average	984135.02 gCO_2	974293.67 gCO_2
KP30M	CNG engine in public fleet	5207.84 TCO_2	5259.92 TCO_2

Table 28: List of KPIs' Base line and Target values for Madrid City.

5.2.3 Genoa pilot

Main goal

The main goal of Genoa pilot is to improve the urban mobility sustainability having a good level of air quality indexes (AQIs). The goal is reached by fostering the use of greener transport modes (ex. increasing public bus and car-sharing users) enhancing different and personalized mobility information.

Objectives

1. Makes the user aware of the impact of his choice in terms of energy consumption and pollutants emission.
2. Increase the use of public transport.
3. Increase the use of multimodal transport modes.
4. Reduce the use of private cars.

Question	Objectives			
	1	2	3	4
Who	CDG	CDG	CDG	CDG
What	Make the user aware of the impact of his choice in terms of energy consumption and pollutants emission	Increase the use of public transport;	Increase the use of multimodal transport modes;	Reduce the use of private cars.
Where	Central and peripheral area	Central and peripheral area	Central and peripheral area	Central and peripheral area
When	Short term	Medium Term	Medium Term	Medium Term
Why	Increase knowledge about energy efficiency Raise awareness	Reduce Traffic Level Improve Air Quality Indexes	Reduce Traffic Level Improve Air Quality Indexes Increase knowledge about sustainable mobility	Reduce Traffic Level Improve Air Quality Indexes Reduce the use of Carbon fuel

Table 29: Objectives and "Wh" questions for Genoa City.

The objectives are related to Genoa urban area (central and peripheral area). Genoa[42] is the capital of the Ligurian Region in north-west of Italy and is the sixth most populated Italian city. The urban area is placed in a narrow strip between the Apennines Mountains and the Ligurian Sea, along a seaside of about 30 km from the western to the eastern part, and in two main valleys, Bisagno and Polcevera, see Figure 92.

[42] For more information about the Genoa city go to the website www.comune.genova.

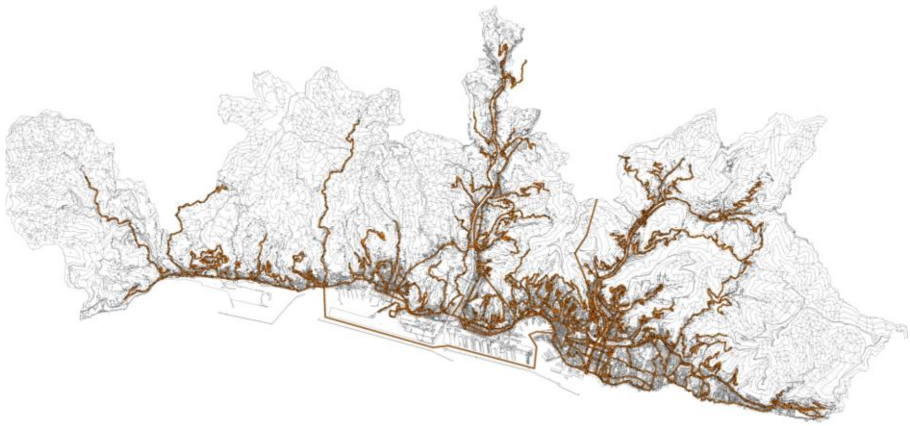


Figure 92: Genoa orography and main road net.

The Genoa territory is divided into 9 administrative areas, as can be seen in the Figure 93 below.

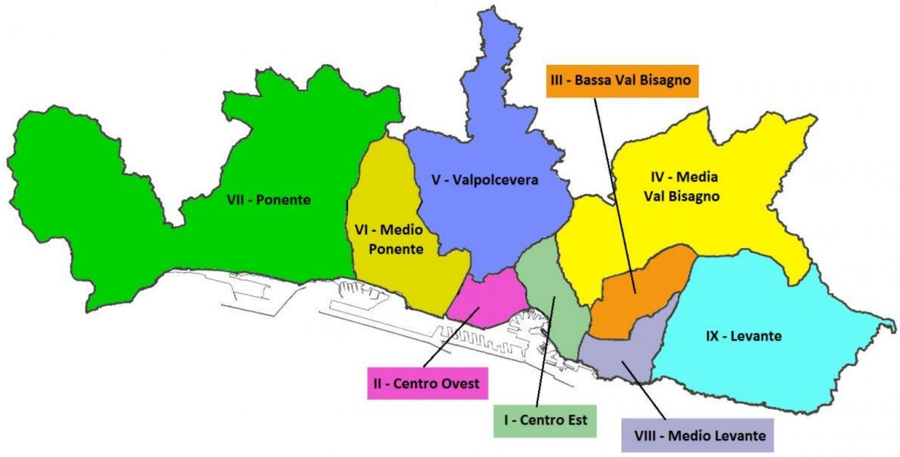


Figure 93: Administrative areas in Genoa pilot.

The Genoa Historic Center (Figure 94) is one of the largest in Europe. It unwinds in an intricate maze of alleyways (caruggi) that open into small squares.

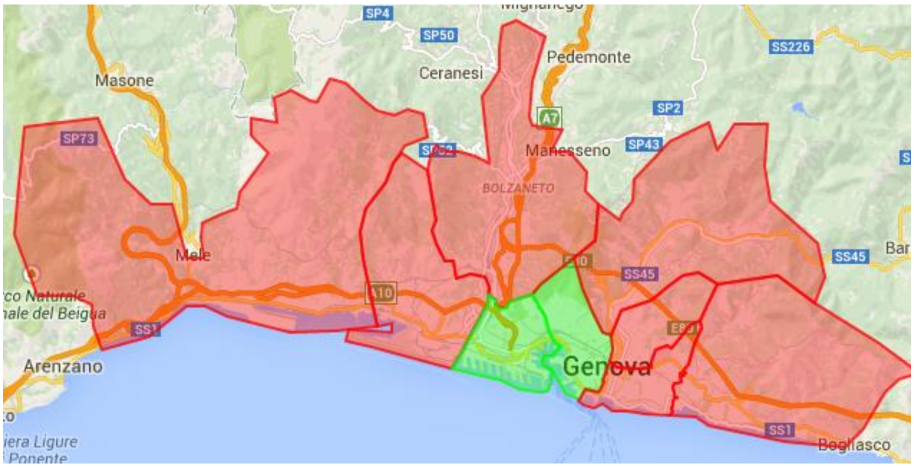


Figure 94: Genoa Historic Center (green area in the map).

Genoa has one of the main ports in the Mediterranean Sea. Redesigned by Renzo Piano in 1992, Genoa's Old Port area has become a "mecca" for tourists.

Figure 95: Genoa – Old Port area.

Genoa's urban traffic consist mainly in private cars 290.000, following by 140.000 2-wheels vehicles and 25.000 Light duty vehicles, in a limited urban road network of 1.400 km, due to, limited space for new transport infrastructure and lack of alternative routes. Additionally public transport system covers 913 km with 154 Million of passengers per year, which constitute 43% of the modal share, followed by 42% of private vehicles and 15% of others.

Target group

The target group is composed mainly by Citizens and Visitors. Using the MoveUs services Citizens and visitors will be provided with efficient routes according to environmental parameters, as well as to the suitability of the mean of transport to be used. For citizens, parameters like their scheduled routines could be also considered in order to calculate the most convenient route for a determined user. It is clear that optimizing the transportation has a huge impact on improving the users' perception of the city.

Genoa is the sixth largest city in Italy with a population of 610.000 within its administrative limits on a land area of 240 km^2, including 276.000 inhabitants in 28 Km^2 in the central area. The urban area of Genoa extends beyond the administrative city limits with a population of 720.000; Genoa is one of Europe's largest cities on the Mediterranean Sea and the largest seaport in Italy.

Identified variables

Variable	Objectives
Energy consumption per vehicle	1,2,3,4
Pollutants Emission per vehicle	1,2,3,4
Number of public transport passengers	1,2,3,4

Table 30: Identified variables for Genoa city.

Energy Evaluation

Energy Revision

The Municipality of Genoa is one of the first cities in Italy to submit its Sustainable Energy Action Plan (SEAP) in accordance the Mayors' Covenant initiative of the European Commission, whereby each city makes a voluntary and unilateral commitment to reduce its CO2 emissions beyond the target of 20% by 2020.

Emission reductions will be achieved by implementing a system of urban mobility based on alternative transport modes that will create an easier access to and around the city. Policies favouring surface and underground local public transport, cycle paths, pedestrian precincts, intermodal use of public elevators and funiculars and the introduction of more water-based transport are part of the new system.

The SEAP, in mobility field, foresees a series of planning actions, through the local Urban Mobility Plan, including energy efficiency requirements in the urban mobility system. Some of the actions are:

- Protected road axes: establishment of dedicated public transport priority lanes.
- Parking policy: expansion of the Blue Areas (resident permit parking program and priced parking for non-residents).
- Elevators and funiculars: creation of vertical lift systems consisting of elevators and funiculars for the densely populated hillside areas and/or intermodal hubs within the system of urban mobility.
- Environmental islands: a combination design to penalize private vehicle traffic, favoring the public transport and guaranteeing road safety, also for cyclists and pedestrians.
- Extension of the subway line: extension of the existing metro line.
- Eco-friendly fleet transition plan: the local bus company made plans to introduce new eco-friendly vehicles replacing the highly polluting buses.
- Interchanging hubs: in the network system interchangers are crucial in terms of guaranteeing efficient service.
- Goods Transport: areas off limits for non-commercial private vehicles in order to rationalize traffic generated by the commercial vehicles around the old town.
- Expansion of the car sharing service: in order to discourage the use of private vehicles it is planned to expand the car sharing fleet to suburbs where it is not yet offered and upgrade the online systems services.
- Soft mobility: new models of soft mobility in order to reduce traffic congestion, noise, air pollution and improve the quality of life for citizens by cycle paths (bike and e-scooter sharing service).
- Wireless city network: this action intends to implement a wireless city network allowing Internet access to all citizens and visitors of the city through their own portable notebook, laptop computer, tablet-PC, and smart-phone.

According to SEAP studies, in 2005 Genoa had an energy consumption of 1.853.292,9 MWh and CO_2 emissions of 495.533,4 ton[43]. The following Table 31 resume the consumption and emissions for several categories.

Categories	Fleets	Energy consumption [MWh/2005]	Total per categories [MWh/2005]	CO_2 emissions [ton/2005]	Total per categories [ton/2005]	TOTAL TRANSPORT [ton/2005]
Municipal Fleet	Cars	**4452**	**37293**	**1129**	**9830,8**	**495533,4**
	2-Wheels	**1580**		**393,3**		
	AMIU[44]	**31261**		**8308,5**		
Public transport	Buses (diesel, oil and hybrid)	**96902**	**111271,9**	**25856,8**	**33234,6**	
	Electric systems	**14223**		**7338,6**		
	Car sharing	**146,9**		**39,2**		
Private and commercial	Cars and commercial vehicles	**1380184**	**17047**	**364462**	**452468**	
	2-wheels	**324544**		**88006**		

Table 31: Energy consumptions and CO2 emissions for transport categories in Genoa (2005 data).

The following Figure 96 shows the CO_2 Genoa emissions composition, which is composed mainly by the private and commercial category, representing 91%.

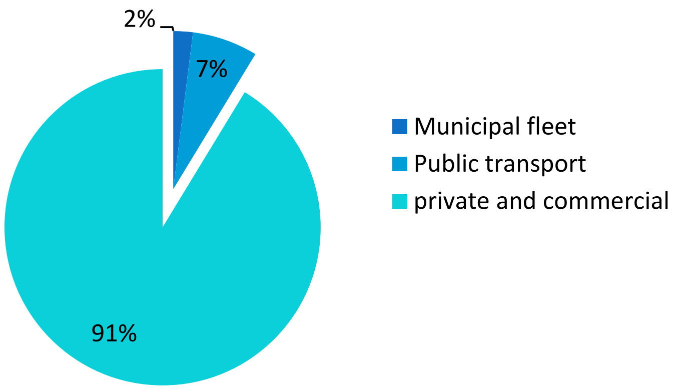


Figure 96: Diagram of CO2 emissions [%] per transport categories in Genoa (2005 year).

Energy sources:

All conventional fuels and electricity are available and currently used in Genoa's transport sector. The following Table 32 resumes the Genoa's energy sources and the energy consumption per transport category.

Category	Electricity	Conventional fuels			Total
		Natural Gas	Diesel	Gasoline	
Municipal fleet	-	-	30.676	6.618	37.294
Public transport	14.222	179	96.603	269	111.273
Private and commercial	-	-	200.000	1.505.628	1.705.628

[43] ton= tonnes of CO2 equivalent.

[44] AMIU= Waste collection trucks

transport					
Subtotal transport	**14.222**	**179**	**327.279**	**1.512.515**	**1.854195**

Table 32: Energy sources and consumption [MWh] per transport category in Genoa (2005 data).

The actions proposed by SEAP will allow a reduction of 22,8% in CO_2 emissions within 2020 that means more than 113.000 ton per year. This reduction has as the following components: 0,05% from municipal fleet, 3,6% from public transport, and 16,2% from private and commercial transport. The Mobility Department is involved in several European and National projects with the aim to improve the local transport system and energy efficiency in general:

- The MATTM (Ministry of Environment) initiative is a national project for the development of new and innovative infomobility services in the city of Genoa. The initiative operates especially in relation to the developments obtained with the S.I.MO.NE project (the traffic supervisor) and the information systems available for public transport.

- 3iPLUS is an EU project financed with the European Regional Development Fund aimed at the realization of a data processing structure able to gather information on transportation and real-time traffic and to make it accessible in a uniformed way using Wi-Fi Network.

- Electric City Transport (Ele.C.Tra.). The overall objective of this project is to promote a new urban mobility model, characterized by a standard structure with common characteristics to all the project cities, suitable to transfer to other cities or regions and to develop in the future enhancing other means of transport such as electric bikes or buses or cars and specific characteristics, suitable for every cities involved, highlighting demand mobility flows, local buses and metros networks, particular citizens and tourists needs.

MoveUs aim is to improve the citizen and tourists behavior underling the impact of a certain mobility choice in terms of energy consumption and pollutants emission, based on this objective Genoa city has an online tool named "Mobilitypoint". Mobilitypoint is a web site where users can consult several aspects of the public transport service and private system. This web site also includes a Journey Planner containing timetables, travel planner, and transit maps, see Figure 97.

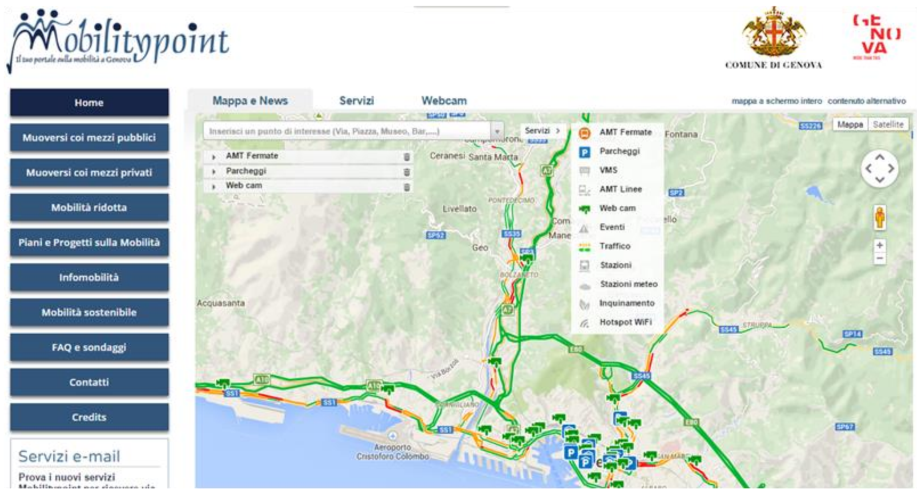


Figure 97: www.mobilitypoint.it - Home section.

The journey planner consists in a route search that allows users to enter the departure and destination as well as the time and date. After a user enters that information the system calculates the route and gives to the user several suggestions, which include the number of bus, its time in departure and destination place, and the meters that the user should walk to get to his/her final destination. This information is complemented by a map that shows the suggested route.

Data for Energy Evaluation are provided by the "***Statistics Department***" of the Municipality. The Department is a centre for the collection, analysis and research aimed at development and dissemination of statistical information. The different collections of data is disseminated on line using different tools with the aim to inform and make available the data on the real demographic situation and socio-economic of the municipality, in its various contexts (population, labour market, economic activities, tourism, culture and education, transport, prices), proposing also interesting comparisons, regionally and nationally.

Data regarding the CO_2 emission and power consumption per Km are provided by EEA (European Environment Agency). This agency provides independent information on the environment. Nowadays EEA is a major information source for project regarding environmental policy. Currently, the EEA has 33 member countries. The EEA's mandate is to help the member to make informed decisions about improving the environment, integrating environmental considerations into economic policies and moving towards sustainability.

For the Energy Evaluation Genoa'team has evaluated several datasets provided by EEA. The most suitable for MoveUS project was "Monitoring of CO_2 emissions from passenger cars" database. This database contains information about manufacturer name, type approval number, type, variant, version, make and commercial name, specific emissions of CO_2, mass of the vehicle, wheel base, track width, engine capacity, fuel type and fuel mode. Additional information, such as engine power, are also present.

Genoa's bus service works on conventional roads (no priority lines) carrying passengers on shorter journeys. Buses operate with low/middle capacity, under inexpensive price, with several stops. The main local transport company is AMT

S.p.A., abbreviation of Enterprise Mobility and Transport. The forward Figure 98 shows a typical bus line.

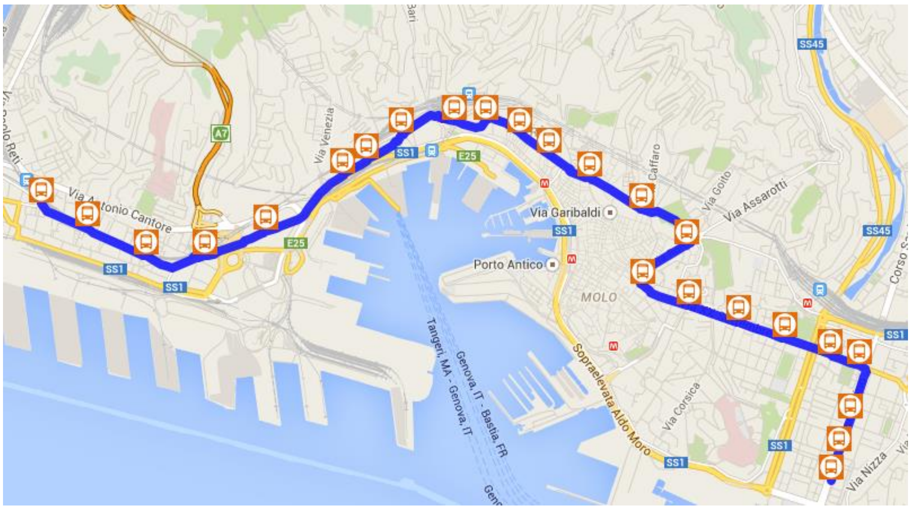


Figure 98: Bus Line SS1 in Genoa city.

Bus service is the hearth of Genoa's public transport system, transporting annually more than 15 million passengers per year; the Figure 99 shows the evolution of passengers per year from 1996 to 2013, as can be see it the number is constantly decreasing in the last four years, and is expected it will keep growing. At the same time the trips had become shorter year by year, Figure 100 shows how the annual mileage has been reduce.

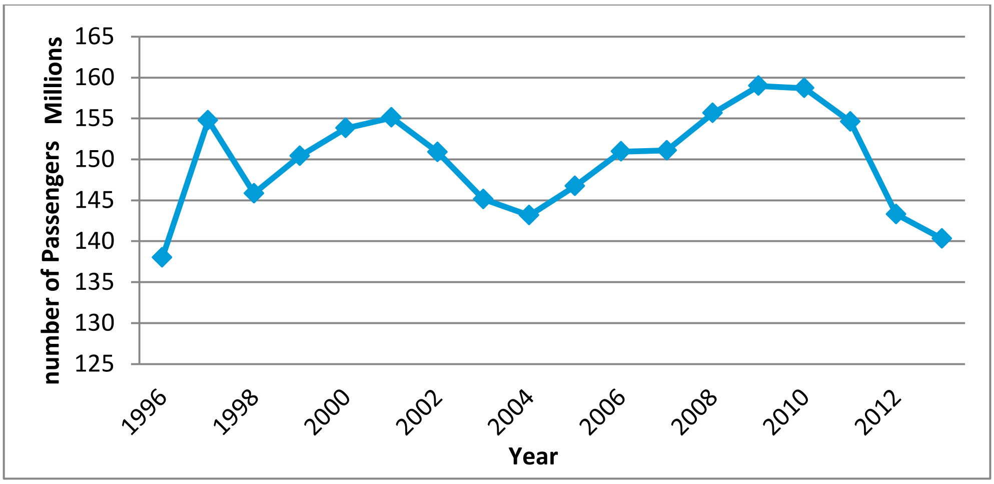


Figure 99: Total passengers transported by AMT Annually in Genoa City.

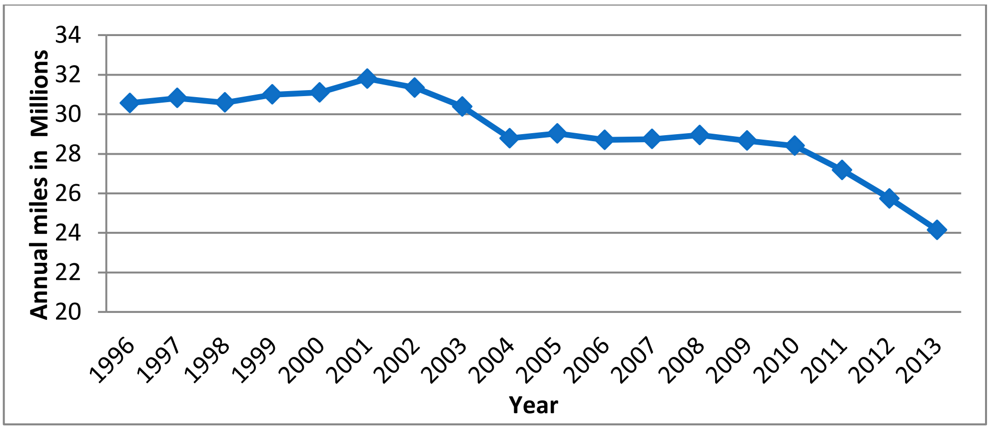


Figure 100: Annual mileage corded by AMT users in Genoa City.

Another variable that shows a constant growing is the number of private vehicles in Genoa, as can be seen it in the Figure 101 the number of cars has grown from 340 to more than 400 thousands representing an increment of 18% in 13 years. In contrast the city inhabitants have decrease 610 to less than 600 thousand from 2001 to 2013 (see Figure 102).

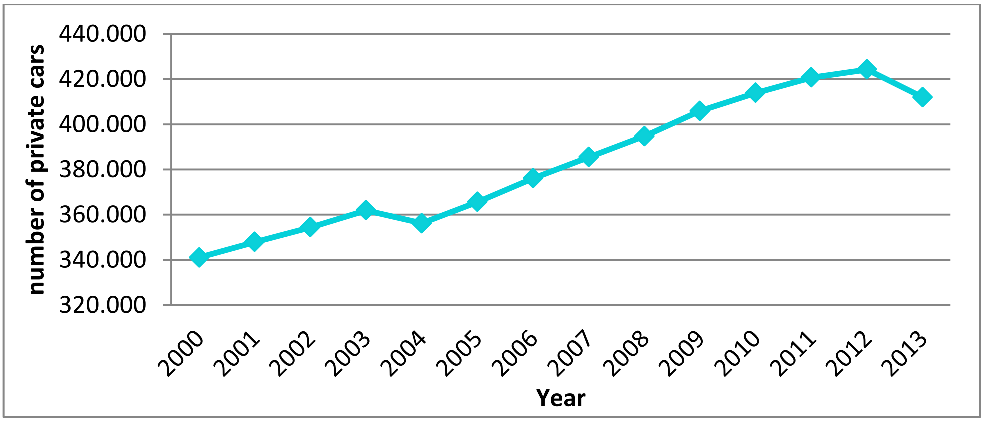


Figure 101: Number of private cars in Genoa.

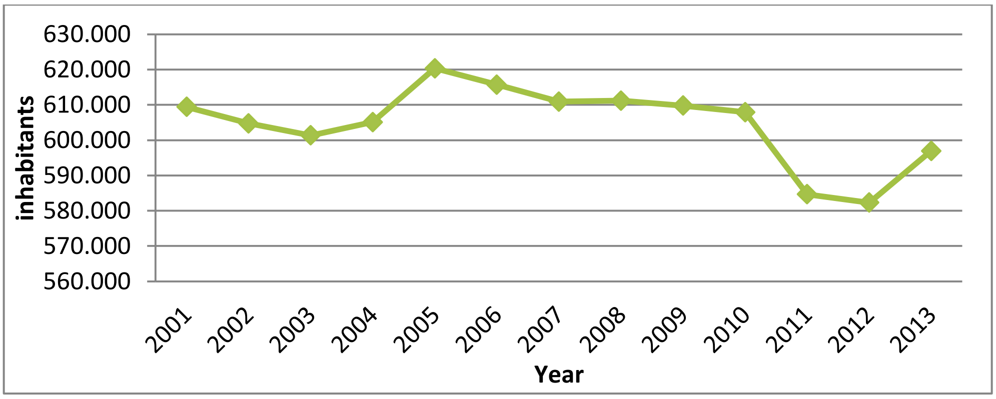


Figure 102: inhabitants in Genoa from 2001 to 2013.

Air pollutant concentration over a specified averaging period, is obtained from Air Quality Sensors (SO2, CO, O3, NO2, C6H6, PM10). Data are acquired every 24 hours. There are a total of 11 sensors in the territory of Genoa (see Figure 103).

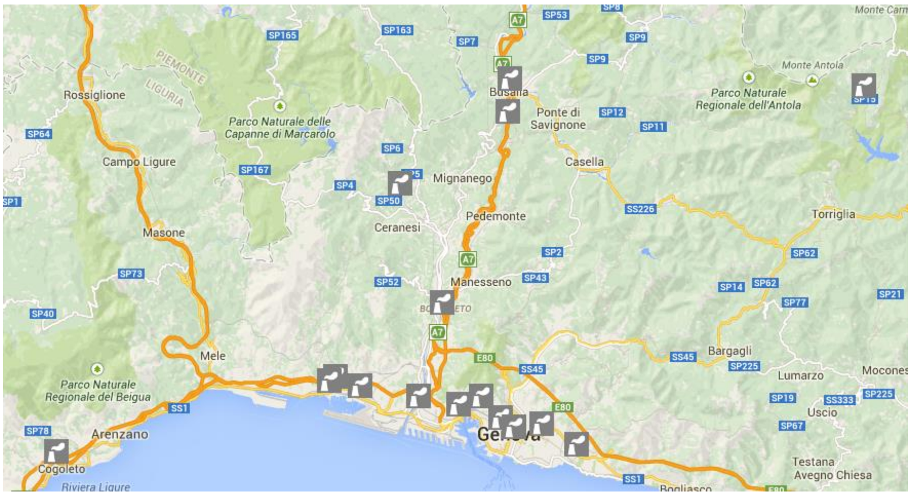


Figure 103: Air Quality Sensors – Localization in Genoa.

Weather sensors network is managed by Local Civil Protection. This network can export a series of detailed information about the temperature, the humidity level, and weather in general, for 26 areas of the Municipality. The network is based on Vantage Pro2 (6152, 6153) hardware. The sensors are composed by two-components: the Integrated Sensor Suite (ISS) which houses and manages the external sensor array, and the console which provides the user interface, data display, and calculations (see Figure 104).

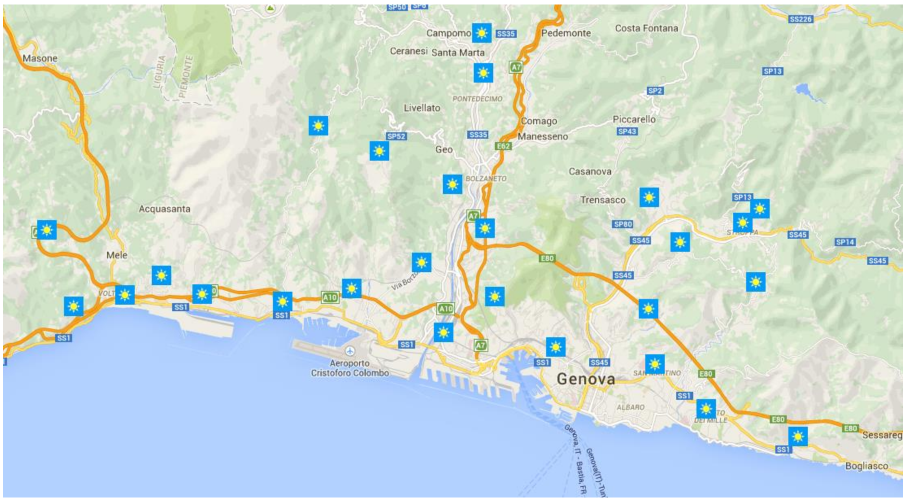


Figure 104: Weather sensors network in Genoa.

These infrastructures can be used as input for Atmospheric dispersion modelling. Genoa's dispersion model is called A.D.M.S.-Urban (Atmospheric Dispersion Modelling System – Urban), and was developed and distributed by Cambridge Environmental Research Consultants. This model estimates the dispersion of emissions in atmosphere from different sources: industrial (points), traffic (lines), thermal systems (areas) with own geometric characteristics rate emissions

The following Figure 105 shows the average concentration of NO2 and PM10 in the city atmosphere from 1998 to 2002. As can be seeing both components had been dropping continuously in 5 years.

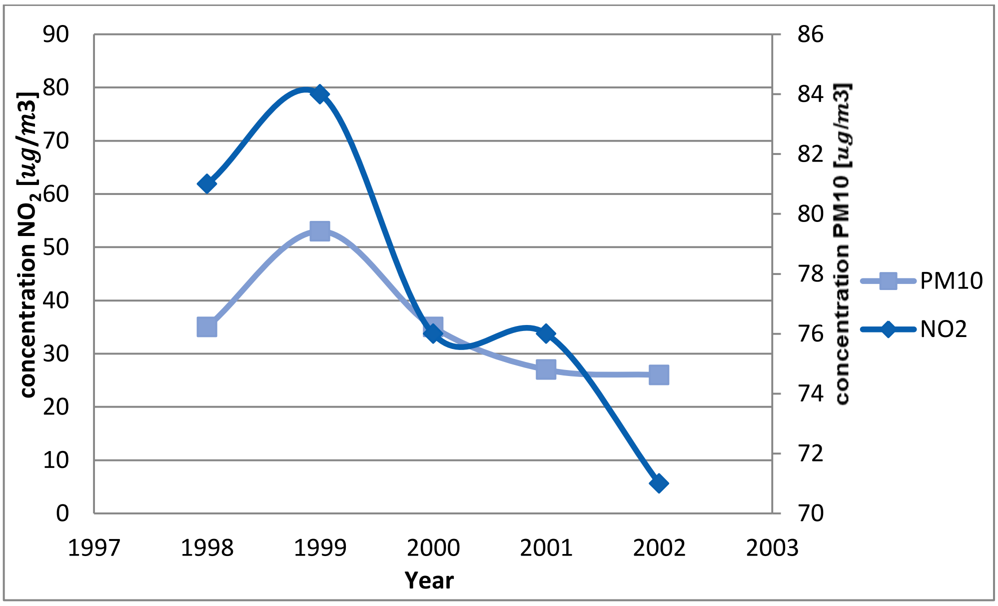


Figure 105: NO2 and PM10 concentrations in Genoa.

Performance Indicators

Based on the previous information and the objectives that Genoa city has defined, a number of KPIs that reflect the performance of the system in terms of energy efficiency/emissions were selected (see Table 11) as well a set of factors that affect in the system (see Table 18).

The following graphs show the behaviour of the KPIs for Genoa City:

KPI4 shows the relation between distance and passengers. This KPI underlines how much efficient the local transport system is. In Genoa AMT S.p.A., the local PT operator, uses buses to carry several passengers on shorter journeys. Buses operate with low/middle capacity and can operate on conventional roads. See the Figure 106 below with the typical bus journey in Genoa.

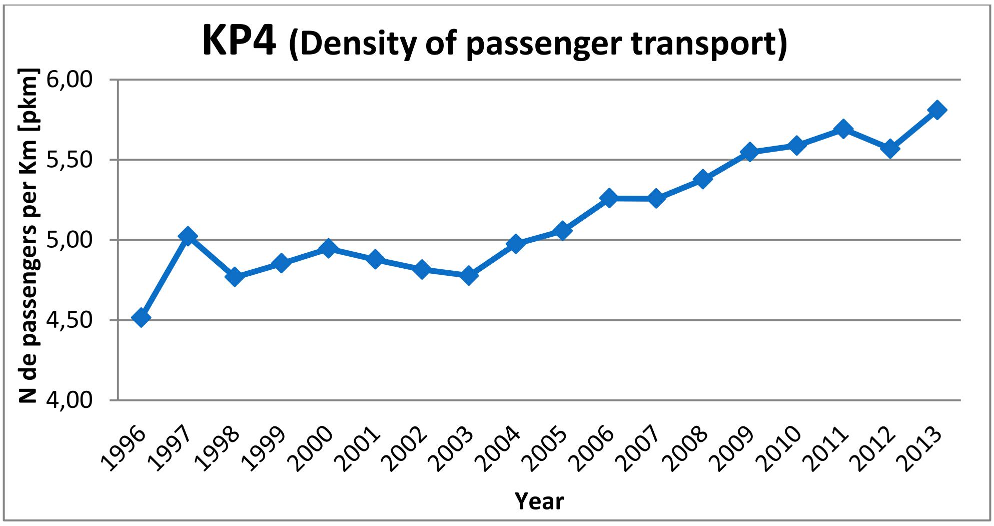


Figure 106: KP4 Density of passenger transport for Genoa city.

The following chart relates the previous KPI4 with the unit of fuel consumed (see Figure 107), showing the number of passengers transported by a unit of fuel (litre). The most passengers per unit of fuel the most efficient transport system is. The average consumption of a bus in Genoa is 2km/litre.

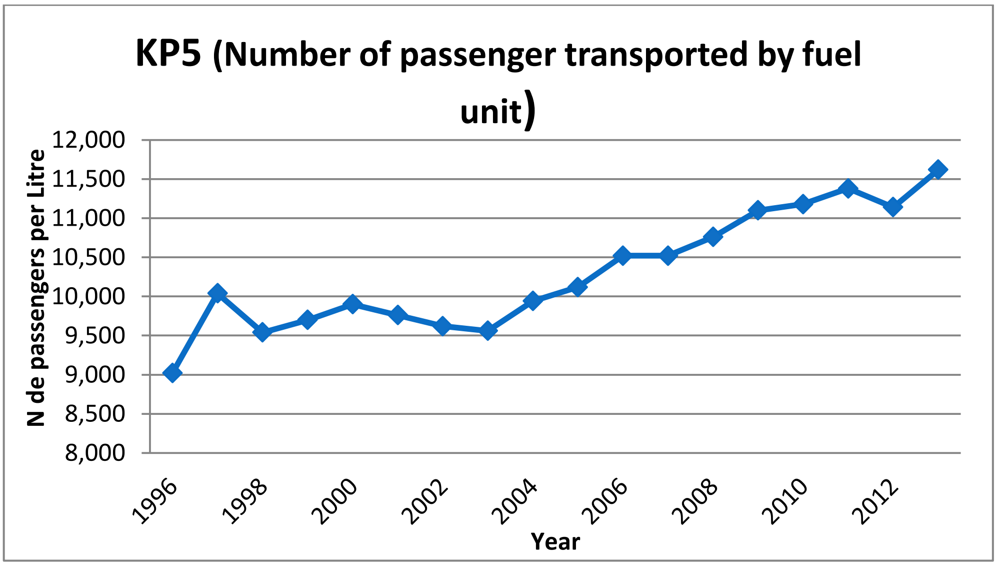


Figure 107: KP5 Number of passenger transported by fuel unit for Genoa City.

The indicator KP6 shows the number of fuel units per passenger. The transport system is more efficient if the quantity of units is low. Considering that all variables are already been calculated in KP5, we can calculate the KP6 trend as follow Figure 108:

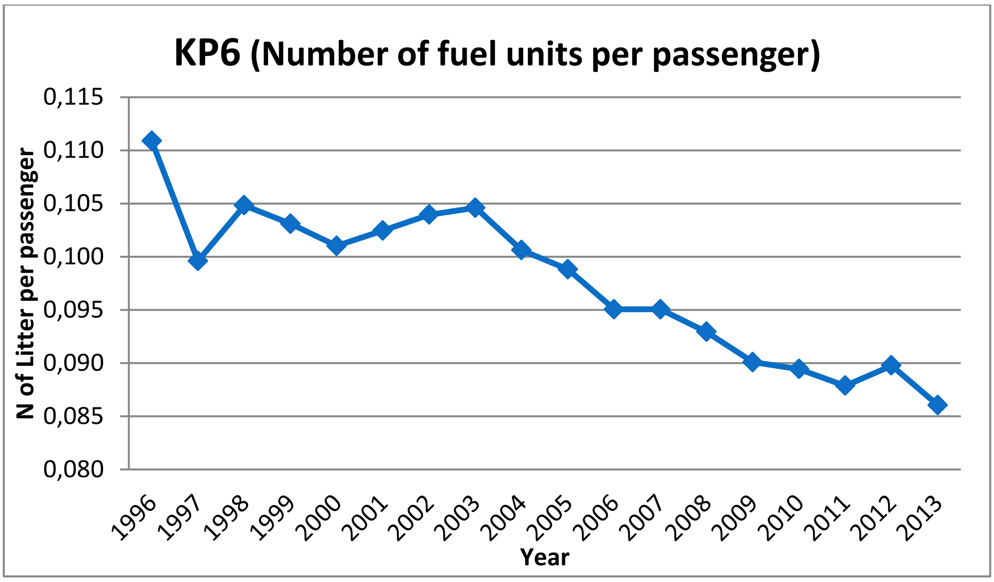


Figure 108: KP6 Number of fuel units per passenger for Genoa City.

The KP10 shows the number of private vehicles per inhabitants: lower number of private vehicles, less emissions. See the trend of KP10 in Figure 109.

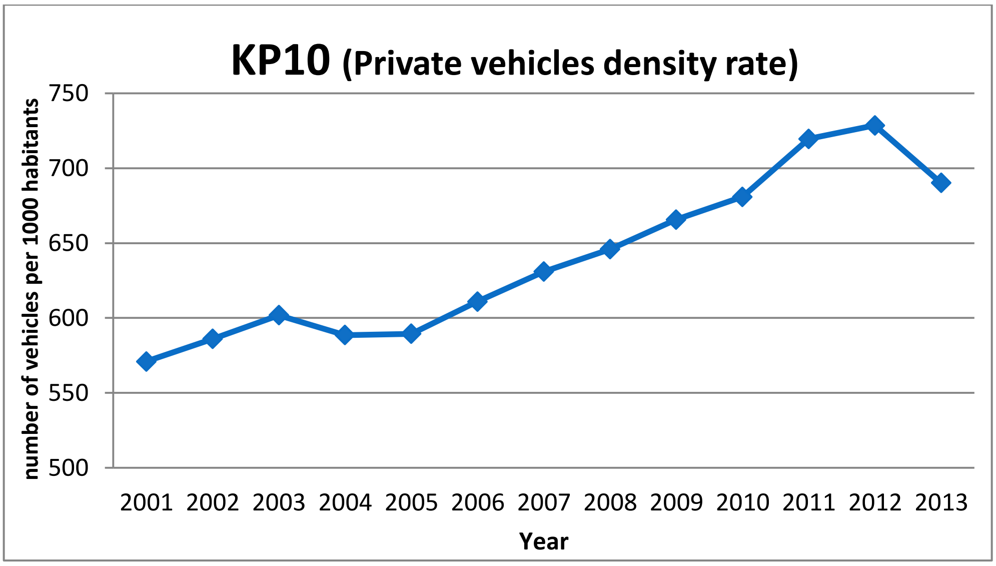


Figure 109: KP10 Private vehicles density rate for Genoa city.

This KP12 shows the percent of vehicles that use diesel engines from total number of unit vehicles. Higher share level (%) means that vehicles fleet is more efficient. See the KPI12 trend in the Figure 110 below.

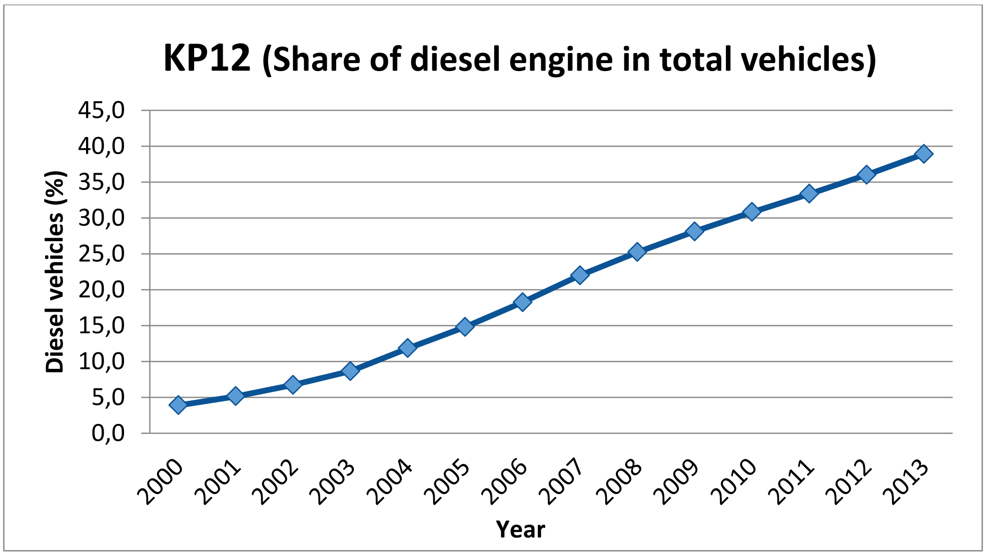


Figure 110: KP12 Share of diesel engine in total private vehicles for Genoa City.

The KP28M aims to follow the evolution of the impact of the mobility system in the local pollution. Computation of this KPI requires an air pollutant concentration over a specified average period, obtained from Air Quality Sensors (SO2, CO, O3, NO2, C6H6, PM10). There are a total of 11 sensors in the territory of Genoa. Data are acquired every 24 hours. The following KPI Figure 111 shows the annual average values from data of Air Quality Sensors of Genoa Territory.

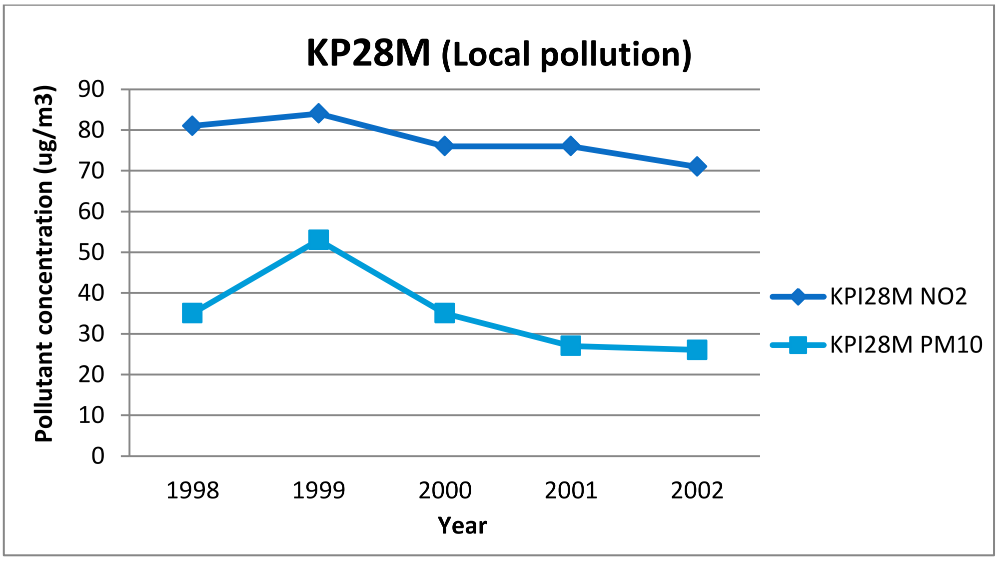


Figure 111: KP28M Local pollution for Genoa City.

Base line and Targets

In order to derive the corresponding overall energy use/CFP, or to be able to perform mathematical operation with KPIs selected, the data should be combining with the conversion factors in the section 3.1.3 (General KPIs conversions). The following information was used for the conversion processes:

- Considering two journeys per day, of less than 20 minutes each, and median speed of 30km/h, the average mileage per person is 4400km per year.

- Average gasoline car Carbon Conversion Factor (CCF) is $220\left[\frac{gCO_2}{km}\right]$
- Average diesel car Carbon Conversion Factor (CCF) is $190\left[\frac{gCO_2}{km}\right]$
- Average Diesel Bus Public transport CCF_{PT} is $237\left[\frac{gCO_2}{pkm}\right]$
- Diesel: $\text{Specific weight } 0.845\frac{kg_{fuel}}{litre}, \text{ Carbon dioxide } 3148\frac{gCO_2}{kg_{fuel}} = 2660\frac{gCO_2}{litre}$

One relevant issue in Genoa city is the low average occupancy level of public transport, which is 5,81 passengers. The Municipality is fully aware of this issue and is focused on adopting various measures to improve from one side the average occupancy and, from the other side, to substitute old vehicles with new ones.

Thus the following Figure 112 and Figure 113 show how the low occupancy affects the overall emissions, especially in the savings. KP4s in Figure 113 reflects how the use of public transport is not efficient, which is not only caused by the low occupancy but also by the relatively old vehicles that are used.

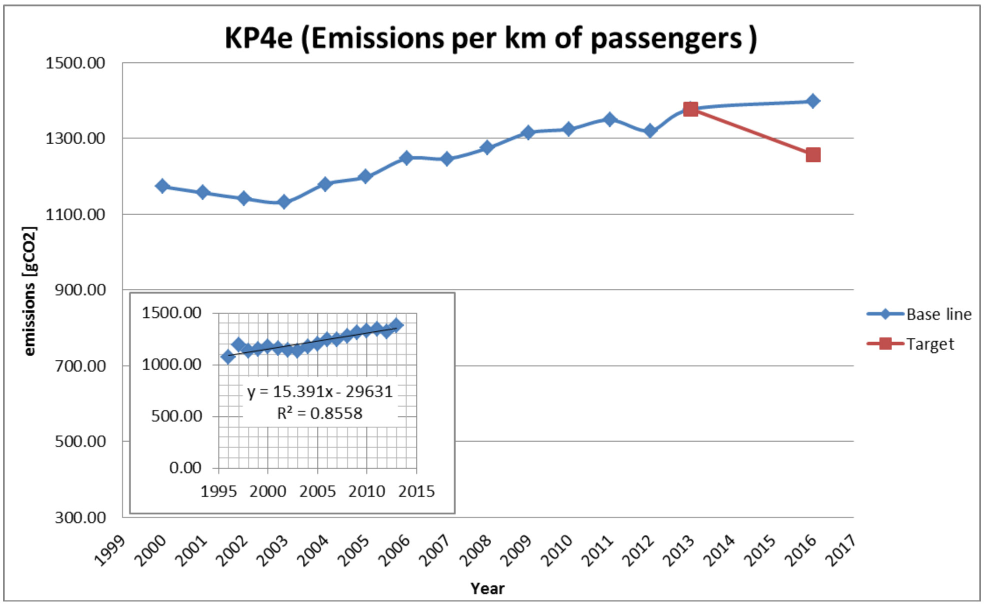


Figure 112: KP4e emissions per km of passengers for Genoa City.

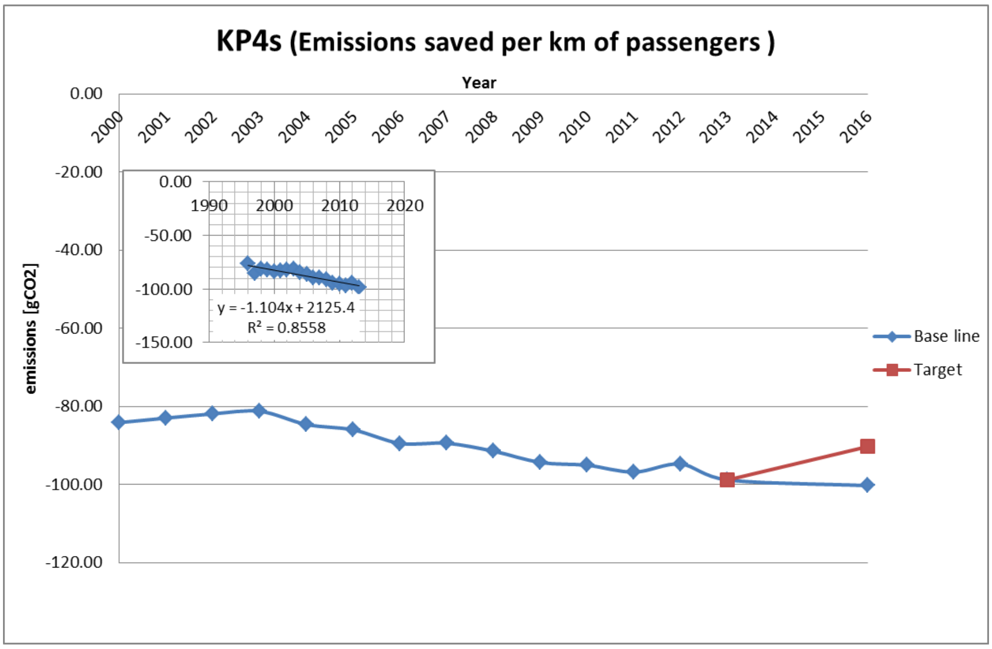


Figure 113: KP4s emissions saved per km of passengers in for Genoa City.

Similar behaviour can be found in KPI5e and KP6e (Figure 114 and Figure 115) where the low occupancy is reflected in the low number of passengers per fuel emission, which reminds low although the number of passengers had been increasing constantly in the last 10 years.

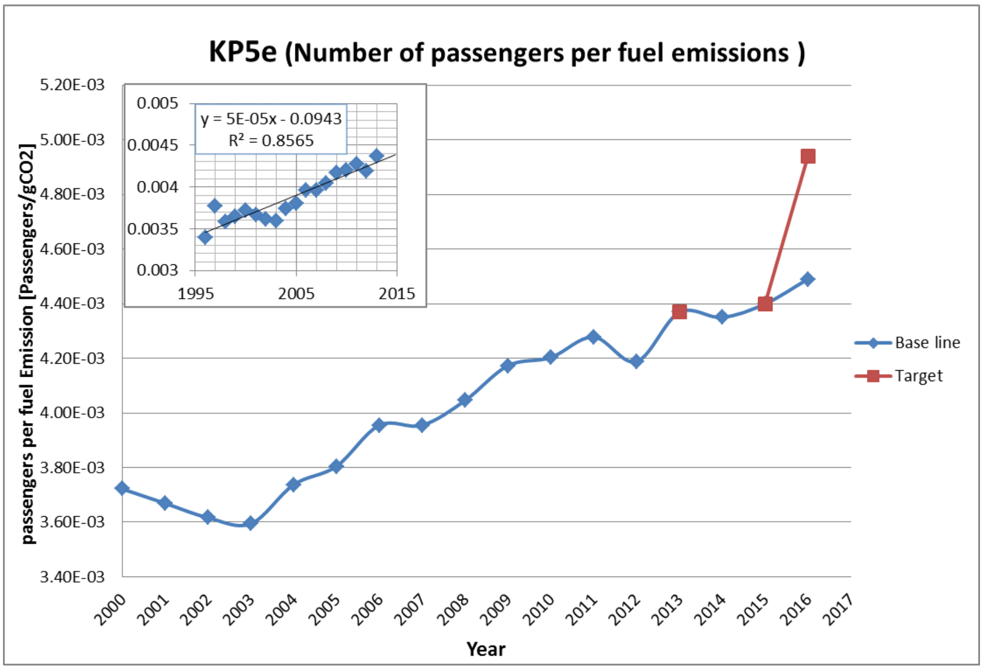


Figure 114: KP5e Passengers per fuel emissions in Genoa City.

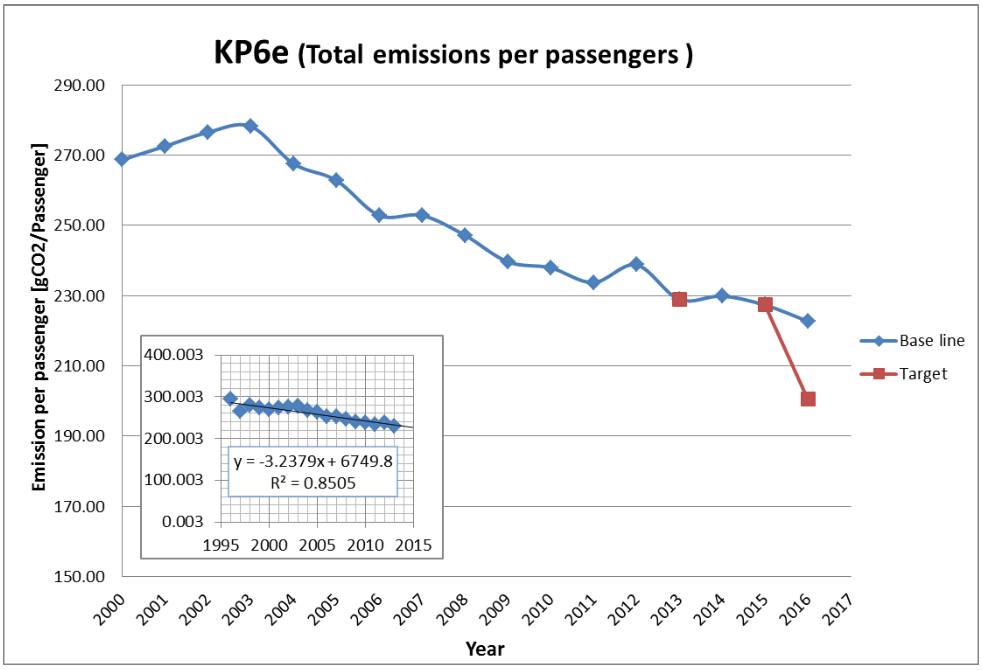


Figure 115: KP6e Total emissions per passengers for Genoa City.

On the other side the number of private vehicles per 1000 inhabitants has been fluctuating constantly in 12 years (from 2001 to 2013) in where the lowest point was in 2001 with 570.9 vehicles and the highest in 2012 with 728.5 vehicles. Despite this behaviour, the last years the city has experienced a decrease in the number of private vehicles, which is supported by policies is expected to be maintained.

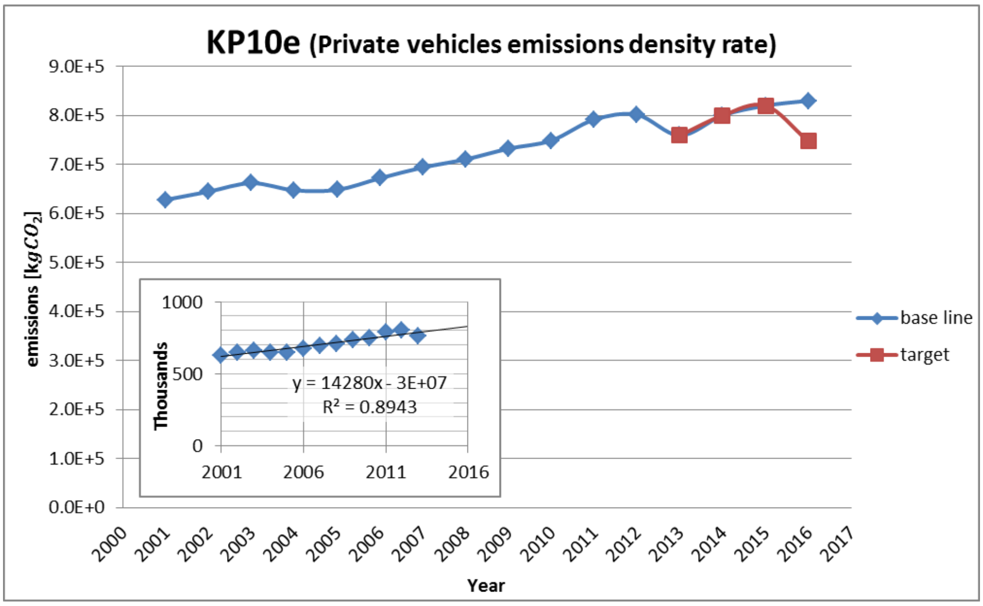


Figure 116: KP10e Private vehicles emissions density rate for Genoa City.

Finally KP12s shows a stable growing which is expected to be maintained. As can be seen in the Figure 117 bringing new technologies like diesel engines can represent considerable savings in CO_2 emissions.

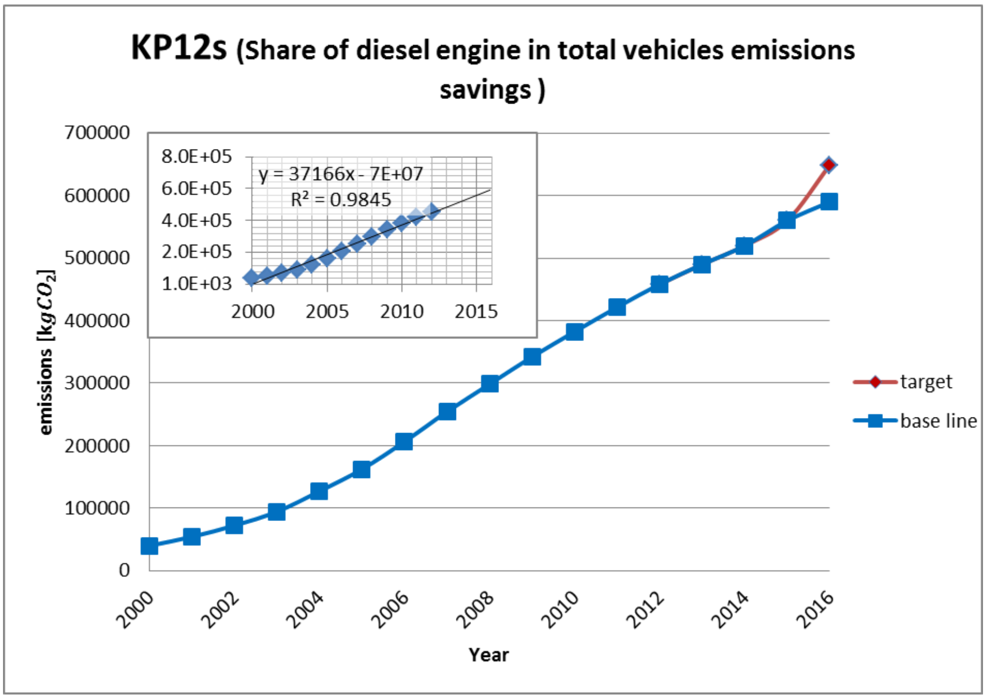


Figure 117: KP12s Share of diesel engine in total private vehicles emissions in Genoa City.

The KPIs described above are characteristics for the Genoa territory and the value targets are linked to the mobility policy that the Public Administration intends to conduct.

According to the fact that the Genoa pilot will experiment the MoveUs services by a mobile APP and that citizens data (ex. total distance travelled and modal share) could be collected using the MoveUS mobile APP, it could be interesting to calculate KPIs considering the travels of the MoveUS app users (in total 100 users: 60 citizens, 20 tourists, 5 transport operators, 5 cities authorities and 10 local businesses) with the aim to understand the CO_2 saving at micro scale.

The forward table resumes the KPIs' Base line and Target values for Genoa pilot in MoveUs project.

ID	Name	Base line value	Target value
KP4e	Emissions per km of passengers	1397.26 gCO_2	1257.53 gCO_2
KP4s	Emissions saved per km of passengers	-100.23 gCO_2	-90.20 gCO_2
KP5e	Number of passengers per fuel emissions	0.00449p/gCO_2	0.00494 p/gCO_2
KP6e	Emissions per passenger	222.72 gCO_2/p	200.45 gCO_2/p
KP10e	Private vehicles emissions density rate	8.30E+05 $kgCO_2$	7.47E+05 $kgCO_2$
KPI12s	Share of diesel engine in total vehicles	590000$kgCO_2$	649000$kgCO_2$

KP28M	C_P= Pollutant concentration	PM10 = 27,89 $\frac{ug}{m3}$ NO2 = 32,8 $\frac{ug}{m3}$	PM10 = 25,1 $\frac{ug}{m3}$ NO2 = 29,5 $\frac{ug}{m3}$

Table 33: List of KPIs' Base line and Target values for Genoa City.

6 Recommendations for the incentive-based model

A list of recommendations/suggestions to be taken into consideration when building the incentives based model of Task 6.2 Incentives-based model are defined after the extensive research on projects, methodologies of applications that have as target the EE of cities. Recommendations include, e.g., parameters of interest for dedicated target user profiles, such driving suggestions for drivers, in order to decrease their energy use, identified in D2.1 intended to raise energy efficiency awareness.

6.1 State of art in energy applications

There are several journey planners, however just very few of them focus on the energy point of view. Energy saving applications are limited and most of them are focused on house EC, however this review will show some applications that motivate energy saving habits, use of alternative transport modes or carbon foot print mitigations.

One of the principal limitations for travel behaviour change is that the private car owners perceive the car characteristics better than in reality. In consequence they judge PT and other modes (cycling and walking) worse than how they are in reality. This happens because the real value of the car ride is rarely estimated, unless the fuel prices get too high. This part is a review of the different strategies that various entities use to persuade consumer to reduce its car drive or use a more efficient car. The first one in the list is the ***Fuel economy label*** from EPA. This application allow the user to get a vehicle label where the user can see the different aspects of the car and some calculations, but what is remarkable is the number 5 in the Figure 118 calculation that shows where the car is positioned in the scale of consume, higher position means less efficient is the vehicle [80].

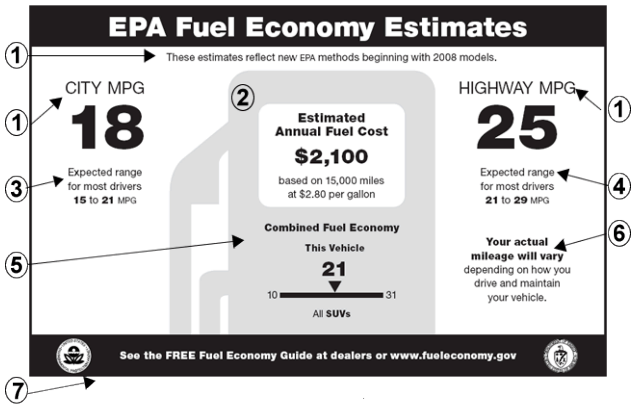


Figure 118: Fuel economy label by EPA [80].

FuelGood is an application that tracks user fuel efficiency and the potential savings by suggesting fuel-efficient driving tips, which can be seen in Figure 119. This application allows the user to specify the type of vehicle they own, and each trip is tracker by a GPS that calculates and estimates savings and CO_2 emissions compared with average values for the same vehicle. Additionally the journey list section of the app compares savings over similar distances and progressing as well as the equivalence of the savings in money [81].

Figure 119: FuelGood app, main sections by Energy saving trust, UK [81].

GreenMeter is another application for energy saving for driving a car. Additionally to showing fuel consumption and savings, it has a simulator where a user can see the effects of acceleration, aerodynamic drag, and rolling resistance across the speed range. Finally *GreenMeter app* provide eco-driving efficiency leaves, where consumer can see by leaves' colour as can be seen in the Figure 120 (from red to green) if his/her driving is efficient or not [82].

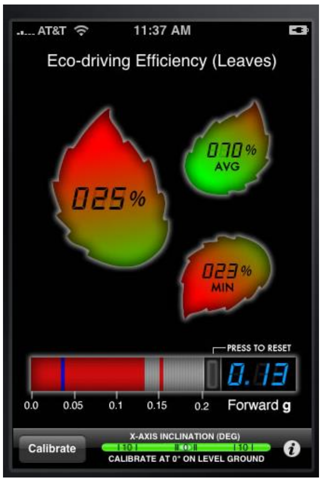
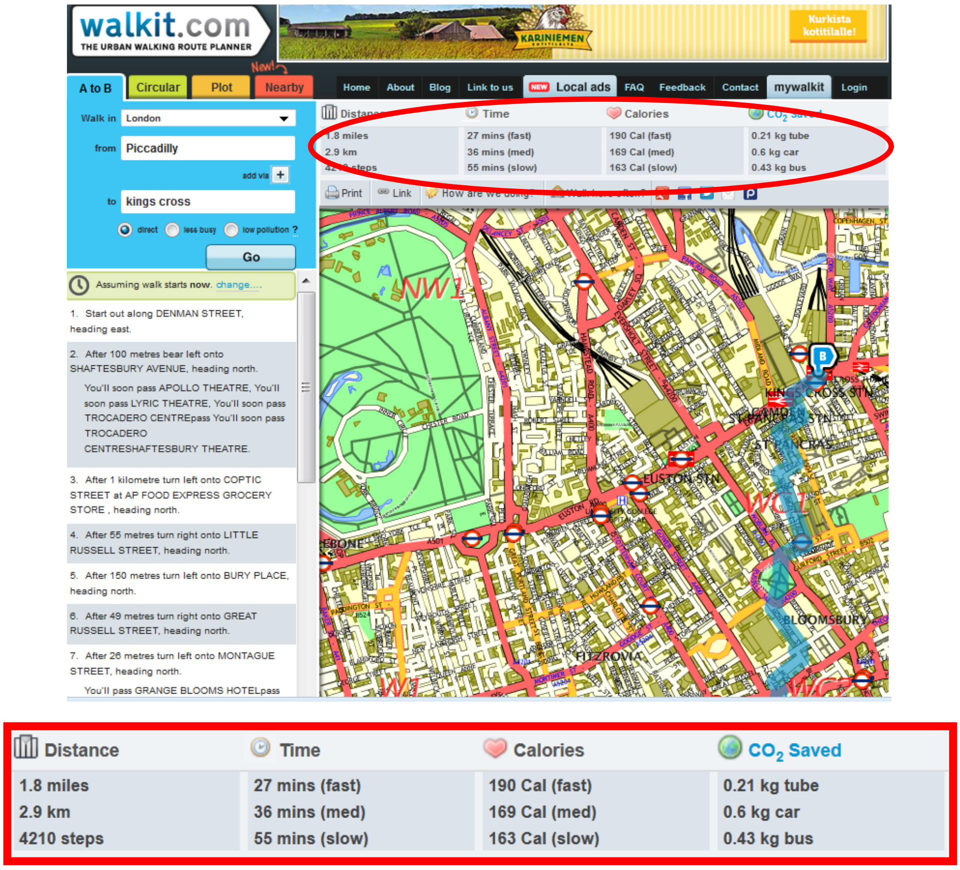


Figure 120: GreenMeter by Hunter Research & Technology [82].

Also from energy saving trust, they offer a web site (see Figure 121) in where information from walking, cycling, and PT is available for users depending on the area inside UK. Some other applications are attached to this service like ***walkit.com***, where urban walking routes can be calculated and at the same time it estimates the walking time, a calories burn and a carbon emission savings [83].



Distance	Time	Calories	CO_2 Saved
1.8 miles	27 mins (fast)	190 Cal (fast)	0.21 kg tube
2.9 km	36 mins (med)	169 Cal (med)	0.6 kg car
4210 steps	55 mins (slow)	163 Cal (slow)	0.43 kg bus

Figure 121: Urban walking planner by Walking.com [83].

Another service is the website ***Sustrans***, that contains information about walking and cycling links. Figure 122 shows the UK national cycling network that users can consult in this website. Additionally it is a platform where different population groups can share their experiences using ALM (car-sharing clubs are also included) as well as encourage others to do the same [84].

Next is ***cyclesheme.co.uk*** which is a web site that focus on cycling to work by enabling employees to get a tax-free bike and save half of the cost. Additionally it has services like saving calculator, that shows annual money saving by using a bicycle, the burn calories and CO_2 savings, see Figure 123 [85].

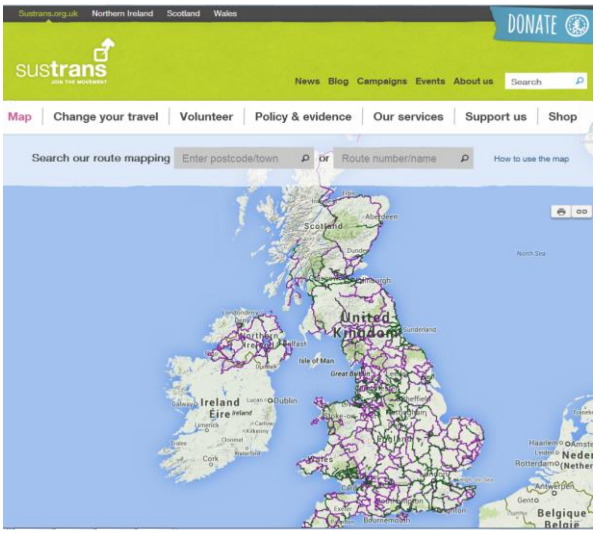


Figure 122: Sustrans journey planner by sustrans UK charity[84].

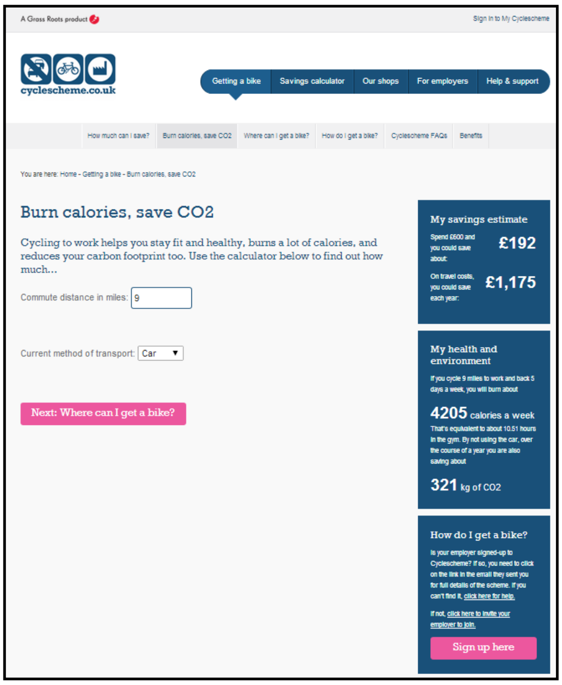


Figure 123: Money savings and calories calculator by Cyclescheme [90].

In Helsinki city, Finland, the regional transport agency offers the ***journey planner***. Additionally to offering an efficient route in terms of fastest, least transfers and least walking as well as different modes of transport. The *journey planner* shows the CO_2 emissions of the route and the basic presentation only shows the most inefficient mode vs the user's choices, see Figure 124. The larger version shows the energy and emission in each of the route suggestions and travel modes [86]. Another application on the *journey planner* is the section dedicated only for cycling and walking and it shows the users EC, weather and characteristics of the route.

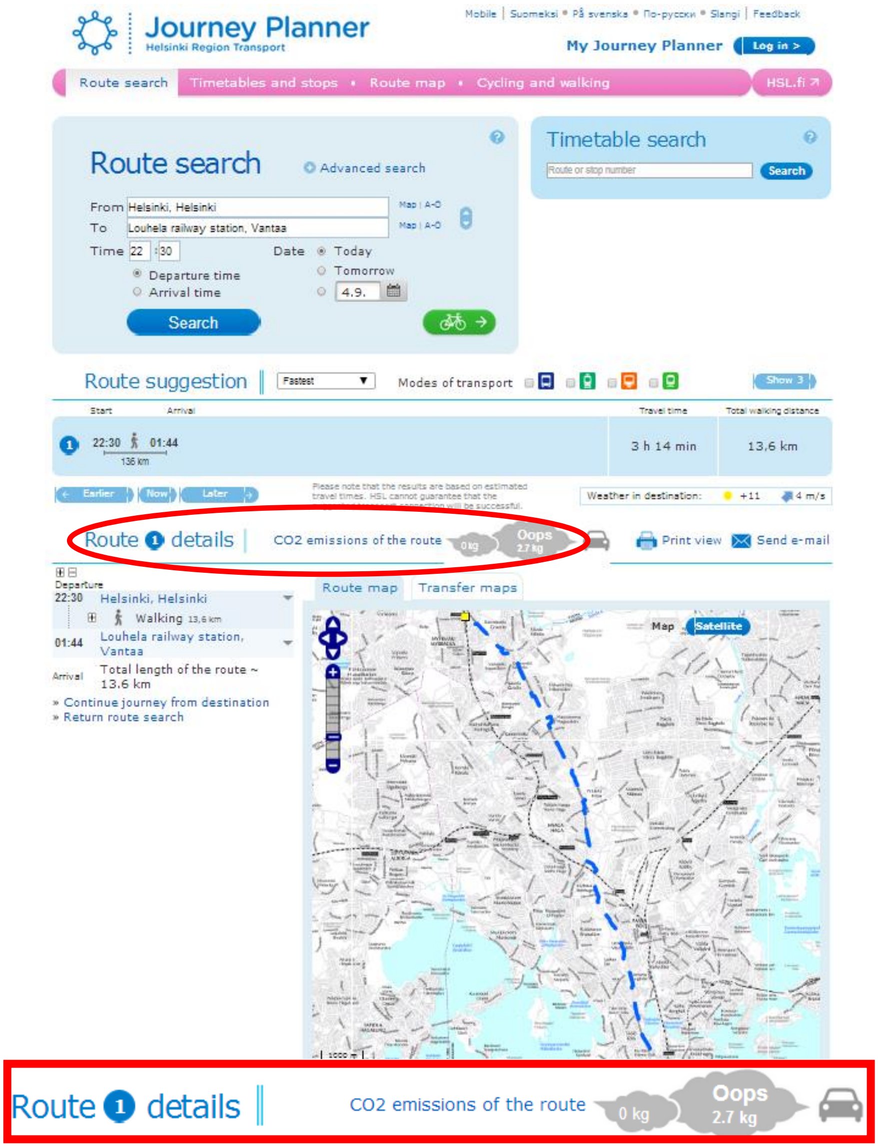


Figure 124: Journey planner by Helsinki Region Transport.

Carpooling applications and web services are several, the most recognized ones are ***carpooling.com*** mostly used in Europe and ***carpoolingnetwork.com*** used in U.S.A. *Carpooling.com* offers a multiplatform system, where the user make their profile and choose who they want to ride with, how much space and comfort they need, where they want to meet and what they are willing to pay. Additionally, the web site often updates the carbon emissions savings as well as other interesting facts for users as can be seen in the Figure 125 [87]. *carpoolingnetwork.com* has less functionalities and is not available as an app, however for the driver the web site offers a cost sharing calculator (see Figure 126), that helps the driver to calculate its fuel consumption and keeps the user consume level [88].

Figure 125: Carpooling app by carpooling.com GmbH [87].

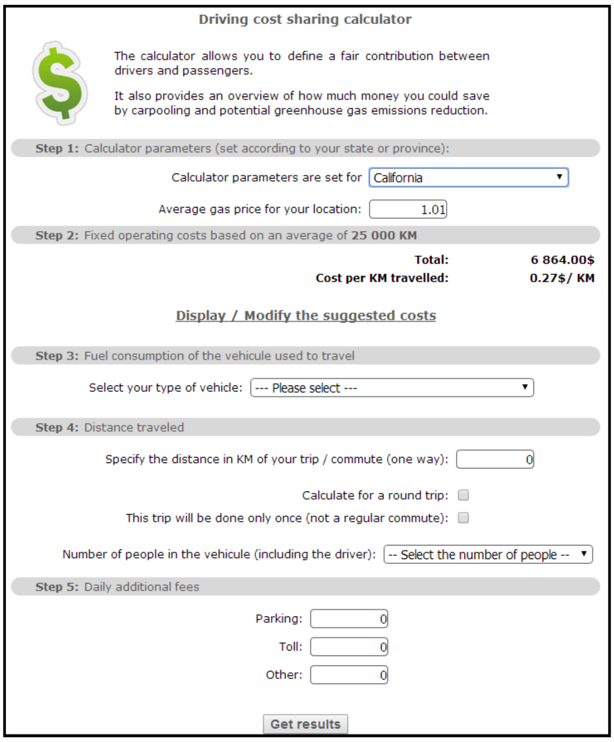


Figure 126: Driving cost sharing calculator by Carpooling network [88].

On the side of alternative fuels, the US energy department they have a web site called ***alternative fuel data centre***. In there, users can find locations closer for alternative fuelling stations; as well as, allows the user to plan a route that includes those stations, see Figure 127. Other part of the web site provides information for electrical car owners about where to charge their cars, and also the infrastructure available for them. Additional information about tax credits and incentives is also available [25].

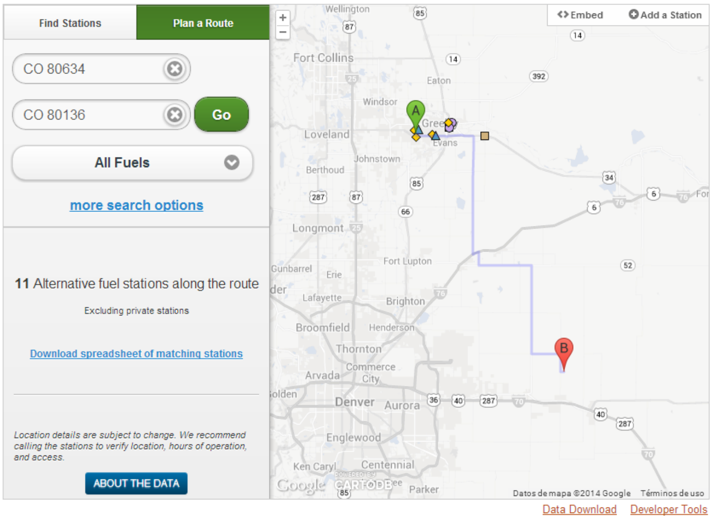


Figure 127: Alternative Fueling Station Locator by U.S. Department of Energy [25].

Other apps related with sustainable consumption are: ***Joulebug*** or ***my CO_2 Carbon Calculator***. Figure 128 illustrate *Joulebug app* that through small games changes the users' daily habits to more sustainable ones. This games allow to share the information with friends and in that way the savings are not only in terms of money saving but also in a healthy competition for gaining points [89].

Figure 128: Joulebug app [89].

My CO_2 Carbon Calculator App allows quantifying the effect of the users on the environment at work, home and travelling. It is a way of tracking the footprint over long periods of time. From here users can total their emissions and actively set targets month by month to reduce their environmental effect as individuals or as company (it is possible to create groups, e.g. family). At the same time the app provides hints and tips that can be used to reduce the CO_2 emissions. Goals and emissions levels can also be shared via Social Networking sites like Facebook or Twitter to show others the users' green credentials, that he/she/their gain when achieving targets, see Figure 129 [90].

Figure 129: My CO_2 Carbon Calculator App by Zero Above Ltd [90].

Web sites calculators like ***Carbon Footprint Calculator*** from carbon footprint illustrate the impact on the environment from users' day-to-day activities. In this website, the register is optional, but users have to register in order to save their data so they can revisit and update their calculation, (Figure 130**)**. Additionally it is possible to simulate and compare multiple sets of results, allowing users to track their progress from one year to the next and also to get the best ways to reduce their emissions [91].

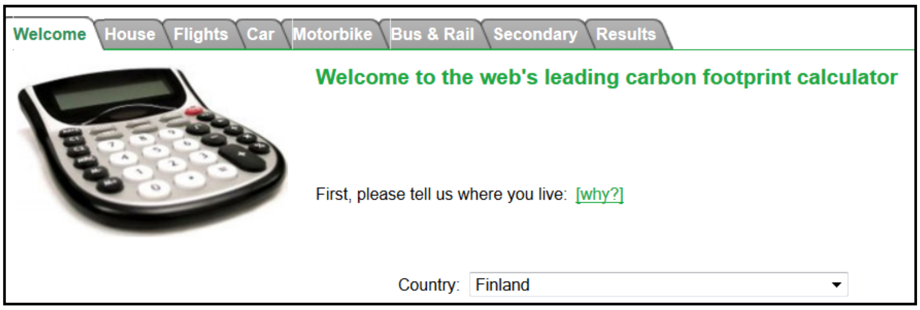


Figure 130: Carbon Footprint Calculator by carbon footprint Ltd [91].

Figure 131 illustrate ***WWF footprint calculator***, through small questions, also calculates the users' footprint; not only in terms of CO_2, but by showing how many planets are required is everybody lived user's lifestyle. Additionally offers a way to share user achievements through social medias like Facebook, and allows the users to challenge friends [92].

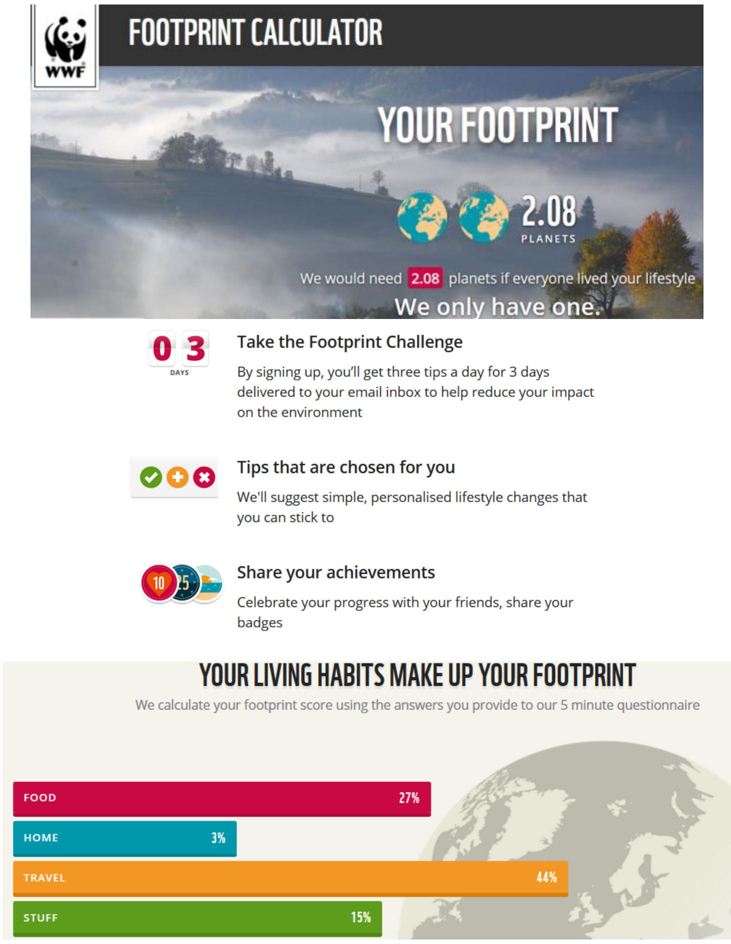


Figure 131: Footprint calculator by WWF [92].

A combination between a journey and footprint calculator apps is ***CarbonDiem***. This application automatically detects the user's transport mode by GPS technology, calculates the distance and gives in real time the CFP for that journey. One outstanding feature is that does not require a constant input from the user, however initially requires a personalized process. As same as other applications, this allows users to create reports and compare their results with other users (see Figure 132)[93].

Figure 132: CarbonDiem from Carbon Hero Ltd. [93]

On the side of tracking directly the energy use, applications like ***Opower*** and ***nest*** offer platforms where users can see in their EC, see Figure 133. *Opower* allows users to challenge friends simply by signing in via Facebook and inviting them to get involved. Users can follow energy-saving challenges month by month, so at the end of each month the best of all, publish their results in its Newsfeed, so the whole world can appreciate his/her/their eco-efforts [94].

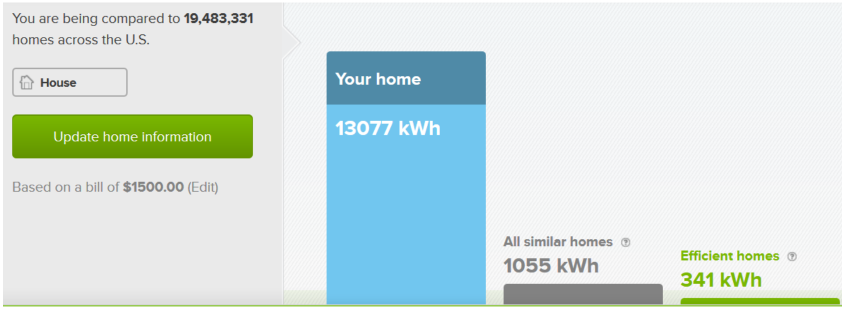


Figure 133: Opower in partnership with Facebook [94].

Nest mobile is an application that allows the user to track his/her EC in house heating system and additionally control the nest thermostat from anywhere. It also shows users a Nest Leaf if he/she is saving energy. The Leaf is not related to overall energy use—it appears based on user's interactions with the Nest thermostat, including on the Web and Mobile apps. The Leaf is designed to guide users to bigger savings (see Figure 134) [95].

Figure 134: Nest mobile app and nest leaf by Nest [95].

The following Table 34 resumes the applications and briefly describe their services and target groups.

Application	Location	Information	Target
Fuel Economy label Website	US	Fuel efficiency for each vehicle's environmental impact	Car owners
FuelGood App	UK	Fuel efficiency in real time and driving tips (eco-driving)	Car owners
GreenMeter App	US	Fuel efficiency, allow	Car owners

		simulations in acceleration	
Walkit.com Website	UK	Journey planner for walking. Shows the calories and CO_2 saved.	People in general
Sustrans Website	UK	Journey planner for alternative modes, as well as share platform for users.	People in general
cyclesheme.co.uk Website	UK	Calories and save CO_2 calculator. Also estimate the money saving by using bicycle	Commuters
Journey Planner HRT Website	Finland	Journey planner for conventional (car and PT) and alternative modes (bicycle and walking). CO_2 and calories calculators.	People in general
Carpooling.com App and Website	EU more 40 countries	Carpooling platform. Also calculates the CO_2 emissions saved by users.	Car owners and car users
carpoolingnetwork.com Website	US and Canada	Carpooling platform. Includes a driving calculator as well as CO_2 emissions calculator	Car owners and car users
Alternative fuel data centre Website	US	Journey planner that includes the location of alternative fuel stations.	Car owners
Joulebug App	US	Shows the more sustainable habits though several games, as well as gives points for changes.	People in general
my CO_2 Carbon Calculator App	UK	CO_2 calculator for several daily activities includes travelling.	People in general
Carbon Footprint Calculator Website	All world	Calculates the users' carbon footprint from different activities, also allows simulations.	People in general
Footprint calculator Website	UK	Footprint calculator, tips based on the answers in the test, and possibility to share the results	People in general
CarbonDiem App	UK	Calculates the CO_2 for different modes in real time.	People in general
Opower Website	US	Energy consumption calculator for homes, also simulator	People which energy provider is connected with Opower

Nest App and Website	US and EU	Thermostats' energy consumption calculator and monitoring system for homes.	People how has Nest products

Table 34: Applications and websites for EC/EE/CFP.

6.2 Recommendations

By doing this review, it was found that even though all the applications aim to improve the energy consumption or to reduce carbon emissions; most of them translate that amount to some other value, such as money, calories or points. This action is referred as soft measure, which pretends encouraging voluntary changes like reductions in car use or rises of use of alternative modes. In order to address changes in the inhabitants' behaviour on transport choices, multiple lessons should be considered. A project from social science disciplines brought a better understanding of how to achieve a change by OEDC [96]. The lessons learned are:

- To guaranty the effectiveness of the message, it is needed at the same time, to **provide the opportunity for change**.
- Individuals that had **habits of travel** by certain way **for long time** are less open to change.
- **Not all kilometres travelled are equal**, just as there are no standard individuals, not all kilometres travelled are valued equally by individualism (e.g. people may value certain trips over others and be less willing to change these).
- The **message** should be **relevant for the audience**, the research pointed out that for some people it is easy to see the value on quality of life over CO_2 indicators.
- The **message** also should be **delivered at moments when there are higher opportunities for behavior** change. Those moments are clear and well-defined as moments of rupture, such entering to adolescence, collage or retirement.
- **Guaranty different scenarios** where children and young adults can develop cognitive maps on their communities by using multiple transport modes.

In conclusions in order to change inhabitants' travel behaviour the message should be delivered in an **early stage** and **should be focused** on the practical and positive alternatives on mobility modes to current patterns travel choices.

Additionally, when a message is delivered through technologies like smart phones, a report from UKs sustainable development commission, found six potential points where those ICT[45] applications can be used to reduce energy consumption in transport sector. Those points were also found in the review of the applications: reducing travel needs, influencing travel choices, changing driver behaviour,

[45] ICT=Information Communications Technology

changing vehicle behaviour, increasing vehicle load factor, and increasing network efficiency [97].

Further reference is made in the chapter 4 where the factors that affect the transport mode choice are listed on the Table 14. By following the previous lessons and combining the information in this chapter, incentives can be focused on giving incentives in situations where identified factors are present, especially for promoting the use of ALM and PT. Some recommendations are listed forward:

- Increase incentives in the case where ALM/PT is affected negatively by the factors, before users make choices.
- Increase incentives to reinforce ALM/PT when the user is going for that alternative and the factors are affecting negatively.
- Penalize users when using private modes, such as car and motorbike in situations where the factors are affecting negatively so the opportunity of change is reinforced. Those incentives can be found in deliverable 2.2 section 2.3 (Rules for reducing driving).
- Penalize users who use private modes, such as car and motorbike in situations where the factors are affecting positively so the opportunity for change can be stablished. Deliverable 2.2 section 2.3 (Rules for reducing driving).

Increasing incentives in the case where ALM/PT is affected negatively by the factors, before users choose. Those incentives are describe on deliverable D2.2 section 2.4 (Rules for using alternative modes). Those incentives can be also used to reinforce ALM/PT when the user is going for that alternative and the factors are affecting negatively. However for reinforcing the choice, it is necessary to create additional incentives like financial incentives for shifting transport mode, or cultural interventions such as supporting cultures, like the bicycle buddies or BUGs (Bicycle User Groups) in England.

Transport Mode	Effect of the parameter	Increase Incentives	Penalize
ALM/PT	Positively	• Share facilities • Ticket PT (Price reduction) • Specific facilities • Bicycles/ Buses(Amount available) • Travel distance (for PT) • Travel time (for ALM) • Temperature (summer) • Precipitation (Rain for PT) • Precipitation (snow for PT) • Fog (for PT) • Support during winter (cleaning) • Bike parking	
	Negatively	• Station/Stops distance • Car/ Motorbike (Amount	

		available) • Travel distance (for ALM) • Travel time (PT) • Temperature (winter) • Precipitation (Rain for ALM) • Precipitation (snow for ALM) • Fog (for ALM)	
PV	Positively		• Car/ Motorbike (Amount available) • Travel distance • Travel time • Temperature (winter) • Temperature (summer) • Precipitation (Rain) • Precipitation (snow) • Fog
	Negatively		• Fuel (increment price) • Ticket PT (Price reduction) • Support during winter (cleaning) • Car parking (cost-based)

Table 35: Recommendations for incentives module.

7 Conclusions

The MoveUs methodology for energy assessment allows doing comparisons on energy performance from different City transport projects. The set of steps that conform the methodology offer an opportunity for cities to compare their result with different targets, different city projects, and other cities' performance, and also learn from the result and collect data for future research and analysis on how the system (transport sector) behaves in terms of energy. Additionally, the methodology is based on a basic planning process (step 1 to 3), which gives cities a clear definition of what is expected from the projects and how they are going to contribute to the cities' main goal.

Therefore, cities should plan their actions based on the performance that they want to achieve, which are reflected on the cities' main goal and objectives. In consequence, performance measurements should be objectively related with those objectives and also be a tool for monitoring the state of the system and for analyzing further results. Step 4 (energy evaluation) provides the opportunity to have a perspective on how is the current energy state of cities' transport system and shows how the cities can use those performance measurements for the next steps of the methodology.

This deliverable presents performance measurements that are used in step 4 of the methodology, they are composed by a list of Key Performance Indicators (KPIs), conversions and affecting parameters. These lists can be found in the documents as well as a more detailed explanation of its origins, and besides, the KPIs, conversions, affecting parameters definitions along with explanations as to their application. Those performance measures intend to show an overview of all the aspects in cities transport energy, and also to follow if the system energy behavior changes by external or internal factors (affecting parameters). After European cities had followed the first 4 steps of the methodology they can stablish their target values and proceed with implementation, monitoring and final analysis of the project results.

The next work (T4.2) from this study includes a definition of how to show the energy consumption to transport users and an implementation of energy calculator through journey planner in some European cities, Tampere, Genoa and Madrid.

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Appendix A

Table of equation

Name	Equation	Units
Key Performance Indicators KPIs		
KP1 (Performance of freight transport)	$\frac{\sum W_i}{ADT}$	$\frac{kg}{km}$
KP2 (Fuel consume by freight transport)	$\frac{\sum W_i}{ADT} * C_i$	$\frac{kg}{km} * \frac{\text{km}}{\text{litter}}$
KP3 (Unitary gross annual energy savings)	$(En_{inef\ fveh} - En_{ef\ fveh}) * ADT$	$gCO_2 * km$
KP4 (Density of passenger transport)	$\frac{\sum P_i}{ADT}$	$\frac{number\ of\ passengers}{km}$
KP5 (Number of passenger transported by fuel unit)	$\frac{\sum P_i}{ADT * C_i}$	$\frac{number\ of\ passengers}{km} * \frac{\text{km}}{\text{litter}}$
KP6 (Number of fuel units per passenger)	$\frac{ADT * C_i}{\sum P_i}$	$\frac{km}{number\ of\ passengers} * \frac{\text{litter}}{km}$
KP7 (Offer volume in public transport)	$\frac{ADT}{A}$	$\frac{km}{km^2}$
KP8 (Total CO_2 emissions for travel (multiple modes) passengers)	$\frac{\sum P_i}{ADT} * S * ADT * En_*$	$\frac{number\ of\ passengers}{km} * \% * Km * gCO2$
KP9 (Total CO_2 emissions for travel (multiple modes) freight)	$\frac{\sum W_i}{ADT} * S * ADT * En_*$	$\frac{kg}{km} * \% * Km * gCO2$
KP10 (Private vehicles density rate)	$\frac{V_{pi}}{H} * 1000$	$\frac{number\ of\ vehicles}{total\ population} * 1000$
KP11 (Average vehicle power)	$\frac{\sum V_{hpi}}{N_i}$	$\frac{hp\ (horse\ power)}{number\ of\ vehicles}$
KP12 (Share of diesel engine in total vehicles)	$\frac{N_{Di}}{N_i} * 100\%$	$\frac{vehicles\ with\ diesel}{total\ number\ vehicles} * 100$
KP13 (Share of public transport in total passenger traffic)	$\frac{P_{pi}}{P_i} * 100\%$	$\frac{public\ transport\ passengers}{total\ passengers} * 100$
KP14 (Share of heavy trucks in total freight traffic)	$\frac{V_{ht}}{V_{ft}} * 100\%$	$\frac{heavy\ trucks}{vehicles\ use\ in\ freight} * 100$
KP15 (Share of new units in vehicles fleet)	$\frac{V_{yi}}{V_i} * 100\%$	$\frac{vehicles\ with\ new\ technology}{total\ vehicles} * 100$
KP16 (Presence of alternative fuels vehicles)	$\frac{V_{Ai}}{V_i} * 100\%$	$\frac{vehicles\ with\ alternative\ fuel}{total\ vehicles} * 100$

KP17 (Presence of alternative fuels vehicles offering)	$\frac{V_{Aoi}}{V_{oi}} * 100\%$	$\frac{vehicles\ with\ alternative\ fuel\ offer}{total\ vehicles\ offer} * 100$
KP18 (Traffic-free (TF) and on-road (OR) routes)	$\sum A_r$	km
KP19 (Annual usage estimation in alternative modes)	$\sum A_u$	$number\ of\ users$
KP20 (Facilities density in alternative modes)	$\frac{\sum A_f}{\sum A_r}$	$\frac{ALM\ facilities}{km}$
KP21 (Density of links in multimodal)	$\frac{\sum L_{im} P_S}{A}$	$\frac{Link * \%}{km^2}$
KP22 (Link's Length in multimodal)	$\frac{1}{n} \sum L_{ilm} P_S$	$\frac{1}{number\ of\ links} * km * \%$
KP23 (KPI's change per time unit)	$KPI_i - KPI_{i-1}$	$KPI's\ unit$
KP24 (KPI's percentage of change)	$\frac{KPI_i - KPI_{i-1}}{KPI_{i-1}} * 100\%$	$KPI's\ unit * 100$
KP25M (User spending in transport)	$\sum S_{UT\,i}$	[€]
KP26M (Public transport reliability)	$\frac{T_{IT}}{T_T} * 100\%$	$\frac{In\ time\ trips}{total\ trips} * 100$
KP27M (Cycling intensity)	$\frac{B_i}{Ti} * 100\%$	$\frac{bicycle\ trips}{total\ trips} * 100$
KP28M (Local pollution)	C_P	$\frac{ug}{m3}$
KP29M (Private vehicle cubic capacity average)	CC	$cm3$
KP30M (CNG vehicles in public fleet)	$\frac{N_{NCGi}}{N_i} * 100\%$	$\frac{Number\ of\ vehicles}{Number\ of\ vehicles} * 100$
General KPIs conversions		
$KP2_e$ (Emissions produce by freight transport)	$\mathrm{KP4} * conv$	$\left[\frac{\mathrm{km}}{\mathrm{litter}}\right] * \left[\frac{\mathrm{litter}}{\mathrm{gCO_2}}\right]$
$KP4_e$ (Emissions per km of passengers)	$\mathrm{KP4} * \mathrm{CCF}_{PT}$	$[\mathrm{pkm}] * \left[\frac{\mathrm{gCO_2}}{\mathrm{pkm}}\right]$
$KP4_s$ (Emission saved by passengers in public transport)	$\mathrm{KP4} * \mathrm{CCF}_{car} - KP4e$	$[\mathrm{pkm}] * \left[\frac{\mathrm{gCO_2}}{\mathrm{km}}\right] - [\mathrm{pkm}] * \left[\frac{\mathrm{gCO_2}}{\mathrm{pkm}}\right]$
$KP5_e$ (Number of passengers per fuel emissions)	$\frac{\mathrm{KP5}}{emission\ \ fuel}$	$\frac{\left[\frac{\mathrm{p}}{\mathrm{fuel\ kg}}\right]}{\left[\frac{\mathrm{gCO_2}}{\mathrm{kg\ fuel}}\right]}$
$KP6_e$ (Total emissions per passenger)	$\mathrm{KP6} * emission\ \ fuel$	$\left[\frac{\mathrm{fuel\ kg}}{p}\right] * \left[\frac{\mathrm{gCO_2}}{\mathrm{kg\ fuel}}\right]$
$KP7_e$ (Emission volume in PT)	$\mathrm{KP7} * \mathrm{CCF}_{PT}$	$\left[\frac{\mathrm{km}}{km^2}\right] * \left[\frac{\mathrm{gCO_2}}{\mathrm{pkm}}\right]$
$KP7_s$ (Emission volume saved by PT)	$\mathrm{KP7} * \mathrm{CCF}_{car} - KP7e$	$\left[\frac{\mathrm{km}}{km^2}\right] * \left[\frac{\mathrm{gCO_2}}{\mathrm{km}}\right] - \left[\frac{\mathrm{km}}{km^2}\right] * \left[\frac{\mathrm{gCO_2}}{\mathrm{pkm}}\right]$

KP10$_e$ (Private vehicle emissions density rate)	$KP10 * CCF_{car} * ADT$	$[Vpl^{46}] * \left[\frac{gCO_2}{km}\right] * [km]$
KP11$_e$ (Average emission equivalent from average vehicle power)	$\frac{KP11}{1,34} * crten$	$\frac{[hp]}{1,34\left[\frac{hp}{kWh}\right]} * \left[\frac{gCO_2}{kWh}\right]$
KP12$_s$ (Share of diesel engine in total vehicles emissions savings)	$(CCF_{car} - CCF_{carDiesel}) * N_i * KP12 * ADT$	$\left[\frac{gCO_2}{km}\right] * \frac{vehicles\ with\ diesel}{total\ number\ vehicles} * [km]$
KP13$_s$ (Share of PT in total passengers traffic emissions savings)	$(CCF_{car} - CCF_{PT}) * P_i * KP13 * ADT$	$\left[\frac{gCO_2}{km}\right] * \frac{public\ transport\ passengers}{total\ passengers} * [km]$
KP14$_s$ (Share of heavy trucks in total freight traffic emissions savings)	$(CCF_{fta} - CCF_{fth}) * V_{ft} * KP14 * ADT$	$\left[\frac{gO_2}{km}\right] * \frac{heavy\ trucks}{vehicles\ use\ in\ freight} * [km]$
KP15$_s$ (Share of new units in total vehicles emissions savings)	$(CCF_{car} - CCF_{carN}) * V_i * KP15$	$\left[\frac{gCO_2}{km}\right] * \frac{vehicles\ with\ new\ technology}{total\ vehicles} * 100$
KP16$_s$ (Presence of alternative fuels vehicles emissions savings)	$CCF_{car} * V_i * KP16 * ADT$	$\left[\frac{gCO_2}{km}\right] * \frac{vehicles\ with\ alternative\ fuel}{total\ vehicles} * 100 * [km]$
KP18$_s$ (emission saved in TF and OR routes)	$KP18 * CCF_{car}$	$[km] * \left[\frac{gCO_2}{km}\right]$
KP19$_s$ (Savings from TF and OR usability)	$KP19 * CCF_{car} * KP18$	$[users] * \left[\frac{gCO_2}{km}\right] * [km]$
KP27$_s$M (Cycling intensity savings)	$KP28M * T_i * CCF_{car} * ADT$	$[\%] * \left[\frac{gCO_2}{km}\right] * [km]$
KP29$_e$M (Average emission equivalent from average vehicle cubic capacity)	$\frac{KP29M}{1000} * convfuel$	$\frac{cc}{\left[\frac{cc}{fuellitre}\right]} * \left[\frac{gCO_2}{fuel\ litre}\right]$
KP30$_s$M (Share of CNG in total vehicles emissions savings)	$(CCF_{car} - CCF_{NCG}) * N_i * KP31M * ADT$	$\left[\frac{gCO_2}{km}\right] * number\ of\ vehicles * km$

[46] VpI is vehicles per 1000 inhabitants