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Sustainable Urban Transport Integrated to Energy System for Small and Medium Cities

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Sustainable Urban Transport Integrated to Energy System for Small and Medium Cities

Abstract :
The relationship between sustainability and transportation is intricate and tangle. As the world's population grows up, urban planners confront ever-evolving challenges with regard to issues of sustainability and the health of our natural environment. Cities which implement sustainable policies and climate action plans reduce their vulnerability to energy scarcity and to energy price rises. Also, they have less traffic congestion and lower energy input costs, besides reducing CO2 emissions, all direct related to transport sector. But does implementation for the transportation require which multiple approaches in parallel: infrastructure, technological solutions, policy package? Do the energy system and transport sector have to be integrated? What are the benefits and constraints? This research intent to answer these questions by creating a toolbox of strategies for the stakeholders involved in make their cities more sustainable, in terms of mobility, so as to provide a sustainable cycle of source and consumption. When integrating transportation and energy system, we benefit from mobility, urban, economic and social cohesion. Local governments play a central role in the transport and energy picture of their cities and must implement efforts and initiatives to promote sustainable living and urban development. As well citizens, who should know the best practices to rational use and reduce consumption.

Keywords :
Sustainability, Transport, Mobility, Renewable Energy, Urban Planning

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1. INTRODUCTION

Mobility is a fundamental requirement for the satisfaction of human wishes to become involved socially and economically in the society. There is no doubt all countries need a sustainable transport system and in many cities, the governments are already worried about the sustainability of their systems. Many promising measures have been implemented in an increasing number of cities and countries throughout the world.

The reason is that an efficient transport system addresses other dimensions of sustainable development, in other words is decisive for economic development and asset for local, regional and international accessibility. A stronger sustainable transport argument would require both transport output and energy input to diminish over time, through a combination of measures and technological innovation (Banister et al., 2000). The further steps shall be the adoption more widespread of best practice in the implementation of sustainable transport strategies in small and medium-sized cities.

Small and medium cities are often characterized by low efficiency and lower modal quota in public transports, associated to high energy consumption. Nevertheless, they offer great potential for sustainable changes due to their sizes that permit adoption of more flexible transformations. The main focus of this research is on such cities because, urban centres with less than 100,000 inhabitants represent a third of world's urban population, growing up to 40% by 2050. Considering these realities, the aim of this research is to map out the possible approaches for implementation in the transport and energy transition for small and medium cities by creating a toolbox of measures and local strategies for the stakeholders involved in make their cities more sustainable, in terms of mobility and urban development.

Here, an effort to integrate urban planning and renewable energy to transport planning is addressed. The target of a sustainable public transport strategy is to allow the output from transportation to be maintained (or increased), but at the same time to reduce the energy inputs, particularly in terms of the use of non-renewable resources. Cities that implement sustainable policies and climate action plans reduce their vulnerability to energy scarcity and to energy price rises. Also, they have less traffic congestion and lower energy input costs, besides reducing CO_2 emissions, all direct related to transport sector.

When integrating transportation and energy system, we benefit from mobility, urban, economic and social cohesion. Only logical analyses of the whole urban aspects can display whether the measures to enhance the sustainable public transport are successful and useful for urban planning. The pattern of sustainability needs to be shared by all actors and stakeholders if a gradual change in the issue of sustainable transport outcomes is to be attained.

2. THEORETICAL FRAMEWORK

2.1 Background

At all levels, studies about public transport and sustainability are conducted and proposals are being made. But they are often definitive in an area fraught with uncertainties. Transportation in not a sector of the economy like textile or pharmaceuticals, with a limited number of enterprises competing with each other to produce goods or services. Transportation is indeed a service supplied and demanded on a market, but exhibits very special characteristics (Prud'Homme et al., 1999). Also according to Prud'Homme (1999) Sustainability is a legitimate concern, although not a very clear concept, but applied to transportation system it relates to the possibility of the system to continue to deliver its main outputs at a reasonable cost in terms of inputs.

Rodrigue et al. (2016) have expressed the urbanization as a process of transition from "a rural to a more urban society and since 1950 the world's urban population has more than doubled. This transition is expected to go on well into the second half of the 21st century, a trend reflected in the growing size of cities and in the increasing proportion of the urbanized population. Urban mobility problems have increased proportionally, and in some cases exponentially, with urbanization since mobility demands are concentrated over a specific area".

The process of urbanization is linked to the mobility pattern and vice versa. I would be effective to use urban planning strategies as an instrument for managing mobility. The urbanization has been characterized by the predominance of private cars and this could be observed mostly at the end of the 1990s. The increase in distance between the place of residence and the place of work entailed a substantial increase in the need for motorized travel. The scant level of public transport in some cities meant that this need had to be met by daily commutes made mostly by private car (Mendiola et al., 2014). This movements also tend to involve longer distances (Rodrigue et al., 2016) but evidence suggests that commuting times have remained relatively similar through the last hundred years, approximately 1 to 1,2 hours per day. In the largest cities such as London, road traffic is actually slower than it was 100 years ago. This means that commuting has gradually shifted to faster transport modes and consequently greater distances could be travelled using the same amount of time.

Previous studies have shown that commuting behaviour is influenced by a number of different factors. Concerning land use factors, Cervero and Kockelman (1997) identify the ‘‘three D’s’’ – density, diversity and design – as the characteristics of cities that most influence mobility. Two more factors have recently been added to this list: destination accessibility and distance to transit. With respect to design Rodrigue et al. (2016) distinguish between urban design (characteristics and connectivity of streets, etc.) and urban form (geographical layout of the various land uses and of transport systems).

Rodrigue et al. (2016) also infer that the spatial importance all transport mode varies “according to a number of factors, density being the most important. Further, each transport mode has unique performance and space consumption characteristics. The most relevant example is the automobile. It requires space to move around (roads) but it also spends 98% of its existence stationary in a parking space. Consequently, a significant amount of urban space must be allocated to accommodate the automobile, especially when it does not move and is thus economically and socially useless. At an aggregate level, measures reveal a significant spatial imprint of road transportation among developed countries. In the United States, more land is thus used by the automobile than for housing. In Western Europe, roads account for between 15% and 20% of the urban surface while for developing countries this figure is about 10% (6% on average for Chinese cities but growing fast due to motorization)”.

Over the last half-century, a number of cities, particularly in Sweden, Germany and France, have been at the forefront in developing coordinated transport and land use policy innovations, with a real effort to integrate urban planning and transport infrastructure investment. For example, in its 1952 General Plan, Stockholm, then a relatively small city of about a million people, took a bold and far-sighted decision to grow, through the development of planned satellite city clusters located along a totally new heavy rail metro system, the *Tunnelbana*. Another strategy was provided by the *S-Bahn* networks (*Stadt-Schnellbahn*, City Express Rail) developed around most of Germany’s leading cities. Indeed, in several cities (such as Frankfurt and Hannover) the *U-Bahn* was a converted tram system which, particularly in Frankfurt in the 1920s, had served as the basis for planned satellite developments predating the later Stockholm examples. The unique feature of the *S-Bahn* is that, developed by the German National Railway system (*Deutsche Bahn*), it penetrates far outside the city into open countryside up to 30–40 km distant, serving smaller towns and even villages, and thus bringing them into the city’s extended commuter orbit (Hickman et al., 2013).

Also stated by Hickman et al. (2013), the most recent development is a highly visible feature of many European cities in the 1990s and 2000s: the reappearance of city tram networks after their disappearance in the 1950s and 1960s, especially in France and Germany. In Freiburg, the German city that has come to symbolize best practice in sustainable urbanism in the last decade, tram extensions run right through the central area with links to the new urban extensions of Vauban and Rieselfeld. Major French cities like Lille, Strasbourg, Nantes, Nice and Montpellier now have substantial networks which have been associated with large-scale urban regeneration and new peripheral housing developments. A limitation to these networks is that they are usually restricted to the administrative limits of the city, or at least of the *Communauté Urbain*, a voluntary grouping of the communes around a major city for transport planning and other purposes. They do not, as a rule, extend outside the physical limits of the urban agglomeration.

Linked here are funding mechanisms, and perhaps France also offers a model here. The last 20 years has seen an astonishing level of funding in transport in the French regional cities. This is due to an intentional and radical change in the historically centralized French fiscal system. From 1982 onwards, President François Mitterrand moved generous funding levels to the newly restructured regional councils, to be used for investment in infrastructure as the basis for urban renewal. In addition, a business tax – the *versement* transport – was introduced, first in the Paris region (from 1973) and then extended to provincial urban areas. This allowed capital, and later, revenue (operational) spending. It was used to support a range of new public transport systems and upgraded public realms across all of the major French cities, and increasingly the smaller ones, and supported by an extensive network of inter-urban high speed rail services (Hall, 2013).

Naess et al. (2013) have argued on previous research that planners aiming to reduce car dependency should seek to avoid urban sprawl, increase the proportion of the population living and working in the inner and central areas of the city, and ensure a sufficiently high density in new development areas to facilitate a provision of local service and a good public transport provision.

As stated by Mathiesen and Lund (2007), the global focus on the resource consumptions of transport is increasing over the years due to two main factors. First, when considering renewable energy and CO2 emissions, electricity and heating have traditionally been the only focus. As more and more countries have implemented changes in these sectors, the

focus on transport has been intensified. Secondly, transport gains increasing international attention due to its large oil dependency of approximately 95% globally. In almost all regions worldwide, the oil demand is increasing and the transport sector's share of the total oil demand is increasing even faster, with a share of approximately 50% at the moment (IEA, 2004).

Renewable sources represent an interesting way to reduce the energetic dependence on fossil fuels in the transportation sector. Among the actions that the Kyoto Protocol indicates in order to reduce CO2 emissions, innovative technologies are promoted, in particular based on the exploitation of renewable energy sources (RES) (Franzitta et al., 2017). However, renewable energy sources currently provide about 25% of the energy supply of the energy sector (Sorensen, 2004).

The integration of the transport with the energy system is crucial as is a multifaceted strategy. Short term solutions have to consider the long term goal. it is concluded that it is possible both to reduce CO2 emissions substantially and, at the same time, gain economic benefits. The conversion of the transport sector to 100% renewable energy is possible, but is connecting to an extremely challenging process before reaching such a goal. This includes savings and efficiency improvements, intermittent resources, electric trains and vehicles, hydrogen technologies and etc. It is only possible to propose a coherent sustainable development within transport if transport is analysed in the context of the surrounding energy system and resource potentials. (Mathiesen et al., 2007).

Pojani and Stead (2015) go as far as to state that a focus on smaller and medium-sized cities is "crucial to achieving substantial progress towards more sustainable urban development, not only because they are home to at least a quarter of the world's population but because they also offer great potential for sustainable transformations. In principle, their size allows for flexibility in terms of urban expansion, adoption of "green" travel modes, and environmental protection. At the same time, smaller and medium-sized cities often have fewer resources to implement new transport measures and can be more vulnerable to fluctuations in the world economy".

The construction of sustainable cities has been a huge challenge during the past decades. According to Farías (2012), among the main obstacles, it is the perception that sustainability implies large volumes of public and private investments, due to an additional cost to build cities within this model of development. As a result, it is understood that only

high-income developed countries can opt for the green cities, and this idea delays the advancement of this type of development in low and middle income developing countries. Thus, the inequality gap also widens, especially in the cities of Latin America and The Caribbean. However, a new vision of the so-called "green economy" has emerged, with the aim of provoking a reversal of traditional approaches to sustainable development and, therefore, to cities with these characteristics. It is intended to demonstrate that the premise that sustainability necessarily entails an additional cost has no basis, but on the contrary, developing a green economy, rather than increasing costs, in the long term decreases them. According to this vision, building a city under the precepts of sustainable development and low carbon emissions increases profitability, since with the same cost we can obtain better results. Consequently, a new look of the economy is considered and new tools are delivered that would allow to effectively evaluate sustainable development in order to validate it in economic terms.

Local governments play a central role in the energy picture of their cities and must implement efforts and initiatives to promote sustainable living and development. According to Rodenburg et al. (2002) governments are still forced to intervene in the market to develop a sustainable, well-functioning transport market, since it seems that this will not be realized without intervention. This means that the government has to implement several policies in tandem to archive more sustainable behaviour in the transport sector.

2.2 Concepts & General Descriptions

2.2.1 Sustainability

The concept of sustainability is a relatively new idea, but has many influences in urban planning. It is a way to harmonize the humanity needs, development and prosperity, considering ecological, social and economic dimensions in a way to keep enduring their resources. Applied to the transportation system and urban planning, a sustainable transport involve thee aspects: mobility, environment and economy.

The first aspect, the mobility sustainability is related to the system continue to move around passengers and goods efficiently, meaning in the fastest way through the shortest path. If the transport is able to do that in the present and, most important, in the future, it means the system is sustainable. This question led to the issue of congestions, in

particular, in urban areas and agglomerations. For transport users, congestion becomes a problem when they can no more move around freely and the travel time has a cost bigger than the benefits of travel itself. And that cost compromise the sustainability of the system. The mobility sustainability is also related to urban planning because it enables a larger level of public transport utilization, walking and cycling, and more localized travel patterns.

The second feature of sustainable transport is the environment sustainability; Human activities produce impacts on environment mostly because our transport system has a road-dominance with oil dependent vehicles. There are external costs associated directly to global warming and environmental disturbance, e.g. air, noise and visual pollution, and indirectly costs to public health issues, e.g. accident associated trauma, the effects of air pollutants on respiratory health, increasing levels of stress on driving, and the community costs of noise. In addition, there is a concern about the energy supply exhaustion and the need for renewable resources.

The third point of sustainable transport, the economic sustainability is related to the system keeps intact and activities available to everyone. The transportation system consumes a great amount of public budget, a limited resource managed with restrain. But it also contributes to the budget through taxes and fees. Sustainability in terms of public finance is achieved when revenues from the various transport modes equal or exceed public expenditure for these modes (Prud'Homme et al., 1999). And a reduction of public expenditures is very necessary for the sustainability of the cities welfare.

2.2.2 Renewable Energy

Renewable energy, also known as clean energy, is that type of energy produced using natural resources that are constantly replaced, in a naturally recurring processes and can be used again and again. This does not mean that the energy never runs out, it means that energy is renewed in a human lifetime or in a nation's lifetime, but still in a finite amount of time. All energy resources are finite and they will eventually dwindle, but when they become too expensive or too environmentally damaging to retrieve they become non-renewable. There are many types of renewable energy sources (RES) and the choice of each one depends on the motivation of governments, public entities and private enterprises, that can be financial, driven by regulatory mandates, willing to be ecologically responsible, or all of them.

Annually the earth's surface receives about 885 billion GWh of solar energy. This huge amount of energy is equivalent to 6200 times the primary energy consumed by humankind in 2008 (IEA 2011). The solar energy is one of the most important renewable source, achieved by capturing the sun light directly. There is a variety of technologies used to convert the sun's energy into heat, illumination, hot water, electricity and cooling systems for businesses and industry, and most important, they are already available to general public.

Bioenergy is the type of renewable energy derived from biomass, meaning any organic matter that comes from living plants or animals. It can be used to create heat, electricity, liquid fuels used for transportation, e.g. ethanol and biodiesel. Even though bioenergy generates about the same amount of CO2 as fossil fuels, the replacement plants grown as biomass remove an equal amount of carbon dioxide from the atmosphere, putting the environmental impact relatively in a balance.

Hydrogen is an element that can be converted into energy and it is found in water and organic compound, e.g. hydrocarbons such as natural gas, methanol and propane. Hydrogen fuel cell converts the potential chemical energy of hydrogen into electricity, creating as by-products only water and heat, a little or zero pollution when burned.

Hydroelectric is the kinetic energy of flowing rivers or dams captured and when released, the water flows through turbines to produce electricity. However, the direct use of hydroelectric power depends on geographic location and accessible and available waterway resources. Small and medium cities can make use of the energy of local waterways by building medium-sized hydroelectric power plants, whereas micro-hydroelectric plants can be built to supply electricity to farm operations.

Wind flow, or motion energy, is the one captured by wind turbines and converted into mechanical power or electricity. A wind turbine is just the opposite of a ventilator. While the second uses electricity to make wind, wind turbines use wind to create electricity. On a smaller scale, windmills use the kinetic energy of wind to pump water on farms.

There are others examples of renewable energy less widespread, such as geothermal, wave power or even from household waste. The use of clean energy sources would be an

important way of relying less economically on fossil fuels and nuclear fuels that produce the emissions of greenhouse gases and pollute the environment.

2.2.3 Integration and Transition in Transportation

Urban development takes place conforming to the evolution of urban transportation, notably in terms of their capability and effectiveness. We may consider the function of urban planning in supporting the transition to sustainable mobility when well integrated with transportation planning. According to Rodrigue et al. (2016) the evolution of transportation “has generally led to changes in urban form. The more radical the changes in transport technology have been, the more the alterations on the urban form. Different transport technologies, however, are associated with different travel speeds and capacity. Transport technology thus plays a very important role in defining urban form and the spatial pattern of various activities. Still, the evolution of the urban form is path dependent, implying that the current spatial structure is obviously the outcome of past developments, but that those developments were strongly related to local conditions involving to the setting, physical constraints and investments in infrastructures and modes”.

As energy prices rise and the effects of global warming get worse, it is crucial that cities start to identify the ways to transition from a fossil fuel to renewable energy sources (RES) more effectively. The tree primary sectors of any national energy system are electricity, heat and transport. Transport earns greater attention due to its large oil dependency, approximately 95% globally (IEA, 2004), and account for a large fraction of energy use, i.e., 25% globally and 30% in EU countries. The stabilization of the transport needs is absolutely essential in a sustainable development.

The integration of transportation with the energy system may give economic benefits of the combined system and diminish oil consumption and CO2 emissions, but these initiatives require long-term planning of the urban development. The benefits of public transport are connected to the fuel savings and the improved mobility in society. This integration also increases the ability of an energy system to balance fluctuating and intermittent resources into the system, especially the electricity supply.

Although within the transport sector this is technically possible, the pathway towards a 100 per cent renewable energy system requires further research because it is connected to an

immensely challenging process before reaching this aim. The total transition to renewable energy requires further analysis of the resource potential and this includes energy savings and efficiency improvements, variety of resources, better technologies and more.

2.3 Purpose of Research

The mobility pattern centred on individual motorized transport is unsustainable, both in terms of environmental protection and meeting the displacement needs that characterize urban life. The traditional response to congestion problems by increasing road capacity stimulates even more car use and generates new congestion, thus fuelling a vicious cycle responsible for the degradation of air quality, global warming and menace of the quality of life in cities (e.g. increase noise levels, loss of time, degradation of public space, stress, among others). So today there is a great need for a profound shift in traditional patterns of mobility from the perspective of fairer and more sustainable cities, and this papers proposes an analysis of the principles, guidelines and instruments for the transition process of transport sector.

This research will take the sustainable context and put forward the argument that, urban planning when well integrated with transport sector is essential because it permits a larger level of public transport utilization, walking and cycling, and more localized travel patterns.

Many researches have demonstrated that the number of vehicles in the world is expected to double in the next 30 years. The cause of this is the growing demand for cars in countries such as Brazil, China, India, South Korea, Mexico, Poland, Russia and Thailand as the people there seek to increase their individual mobility when they become more prosperous (Franzitta et al., 2017). Moreover, the automobile industry has big interests in keep selling vehicles and the civil construction industry has interests in keep building roads, consequently the governments, whilst this two markets yield taxes, income and jobs. The reality is that people will continue to buy cars and the roads will still be constructed - directly linked to urban development - but what may change is the energy (fuel) used to satisfy the growing demand for cars, mainly in developing cities in countries mentioned above. The terminology of developing cities mentioned here relates to towns of all countries included in the World Bank’s 2018 list of developing countries, based on average Gross National Income (GNI) statistics. However, the wealth of different cities within the same country may vary tightly.

Small and medium cities are often characterized by poor efficiency of public transports, lower modal quota of public transport, and higher energy consumption related to transport than other larger cities. Nevertheless, They also offer great potential for sustainable changes due to their sizes that permit adoption of more flexible transformations. The main focus of this research is on small and medium cities which are quite important because, according to the United Nations, half of humanity - 3.5 billion people - live in cities today, and cities with less than 100,000 inhabitants represent a third of world's urban population, growing up to 40% by 2050. Considering these realities, the aim of this paper is to map out the possible approaches for implementation in the transport and energy transition for small and medium cities by creating a toolbox of measures and local strategies for the stakeholders involved in make their cities more sustainable, in terms of mobility and urban development. Here, an effort to integrate urban planning and renewable energy to transport planning is addressed. The target of a sustainable public transport strategy is to allow the output from transportation to be maintained (or increased), but at the same time to reduce the energy inputs, particularly in terms of the use of non-renewable resources.

But having a small or medium size is not the only the decisive factor in transferring examples of transport solutions. Therefore, the search, analysis, and assimilation of urban transport measures, strategies, policies, or instruments from elsewhere are submitted to a set of many influences, such as urban form, density, social and economic aspects, professional skills and political and institutional influences. The aim of this research is to provide other cities with a development tool that they can customize to their specific needs, taking into account their specific constraints, rather than recommend measures whose effectiveness may diverge from place to place. Small and medium cities should consider examples of sustainable transport from both developing and developed countries just because not all innovation moves through north-south pathway. In some cases, the most efficient and cost-effective public transport systems are being developed in Latin America.

3. PROBLEM FORMULATION

Today we can already state the a road-dominated transport system are not sustainable, environmentally and economically speaking. The oil clash and the beginning of the economic crisis in the 1970's, on the one hand, and the increasing of transport related externalities such as congestion, pollution (air, noise, visual), car accidents, health issues, etc., on the other hand, both led to a new political program in some cities concerning public mobility. In the decade of automobile domination, the elements in favour of sustainable urban transport are the continuous worries about dependency on fossil fuel and demands regarding sustainable urban development.

On average, Poumanyvong et al. (2012) suggests that the higher the income per capita of a country, the higher its urbanization level and road transport energy use per capita. However, the average annual growth rate of urbanization and road transport energy use per capita between 1975 and 2005 varied among the low, middle and high income countries. This is illustrated in figure 1. Also, the road transport energy use accounted for a large percentage share of the total transport energy use in all the three income groups compared with the other sub-sectors, as illustrated in figure 2. In the low income countries group, the share of road transport energy use increased significantly in 30 years. Moreover, the total transport and road energy use grew in all the three income groups.

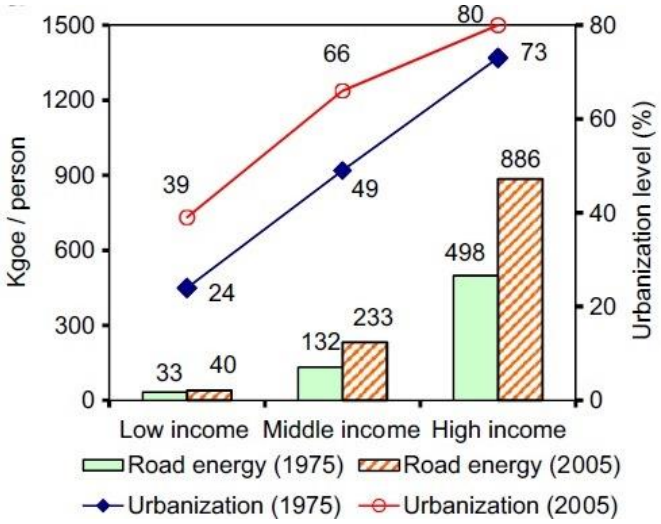


Figure 1 - Urbanization, road transport energy use per capita and urban density by income group kgoe = kilograms of oil (Source Phetkeo Poumanyvong 2012)

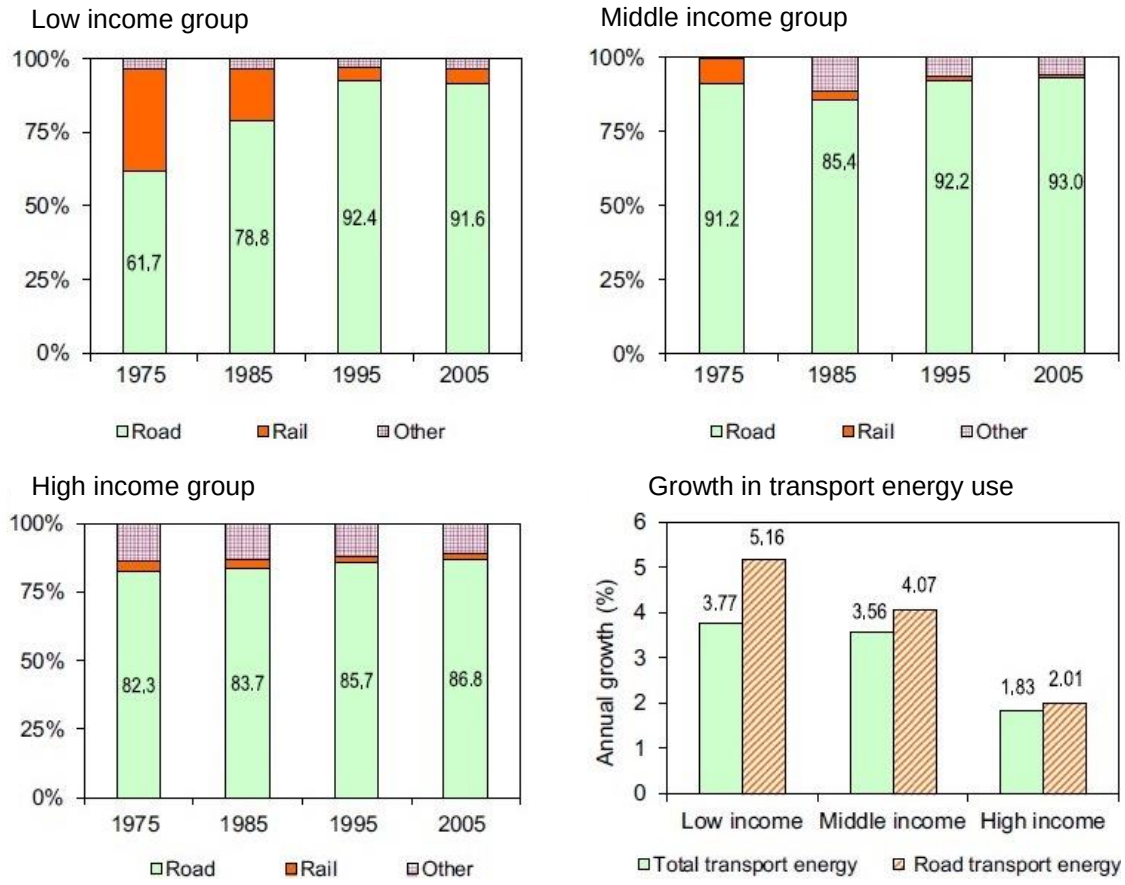


Figure 2 - Composition of transport energy use and its annual change between 1975-2005 (Source Phetkeo Poumanyvong 2012)

One of the transport related externality is congestion. Congestion is a transportation occurrence that most of people has once experienced, when the demand for the use of a infrastructure exceeds its own capacity. In the case of rail transport, it takes the form of delays or of crowding. Congestion has a cost that consists mostly of time wasted (Prud'Homme et al., 1999)

Concerns about reducing CO_2 emissions in the transport system have also been part of a motion for sustainability, with an environmental, economic, social and institutional extensions. In many situations the municipality level can have a much more ambitious target than the national level. This perhaps leads us to question the value of international negotiations, particularly as they are so slow to develop. Certainly it is at the and city levels that more progress is being made and that legally binding targets can be set (Hickman et al., 2013).

A focus on small and medium cities is important in current urban sustainability discourses since close to one half of the world's urban population lives in agglomerations with fewer than half million inhabitants. For this research, the boundaries of the study was established for small and medium cities according the context of developing and developed countries – Population of less than 250,000 inhabitants for developed cities and less than 1 million inhabitants for developing cities. While this proportion of urban population is projected to shrink over time, by 2030 these small cities will still be home place to around 45 per cent of urban dwellers. At the moment, cities with less than 100.000 inhabitants represent a third of world's urban population, a figure which is predicted to grow to 40% in 2050 (UN prospects, 2015). Also according to the United Nations, Latin America is the most urbanized region in the world, characterized by large economic and social inequality, and it is expected that the population of its cities will continue to increase. The urban population in some countries of exceeds 90%, such is Uruguay, Argentina and Venezuela, which have rates above 95%.

Farías (2012) infer that, in general terms, differently to what happens with European cities, Latin American cities develop as monocentric, meaning they depend on an urban centre provided with equipment and services that supply the whole city. Most of the time, these urban centres, over time, tend to move from their place of origin to the area where the high-income sectors are located, and constitute a kind of enlarged downtown figure. Consequently, the majority of the population living in these cities tends to concentrate on the periphery of this consolidated centre. As a result of the type of growth of Latin American cities, we can find a higher energy consumption, a greater generation of CO2 emissions and the consolidation of socio-spatial segregation and poverty.

Small and medium-sized cities are at an intermediate stage of growth, and most of Latin America cities is in a medium stage of development. That can mean they have an opportunity to develop their transport systems toward a more sustainable one, in a way coherent with the proposition of the Avoid-Shift-Improve model. This can be described by Hidalgo and Huizenga (2012) in three types of actions and policies in order to: "avoid long and unnecessary motorized travel, to shift the growth trends of individual motor vehicle travel favouring non-motorized and public transport, and to improve technology and operational management of transport activities".

3.1 Urban Transport Conditions in Latina America

Ongoing economic growths associated to high urbanization rates have input a lot of pressure on the transport infrastructure of Latin American cities. As a result of a larger opulent urban population growth, the urbans centres and agglomerations have not been able to support the increased transport demand, mainly pushed by motorization.

Despite of high urbanization, Latin American cities show a transport modal pattern with great shares of public and non-motorized transport (higher than 65% in most cities). At the same time they face rapid motorization: up to 17% annual growth in the last decade, mainly driven by motorcycles (Hidalgo and Huizenga, 2012). However, motorization levels in South America and México are relatively low in comparison with developed countries, where often more than 600 cars per 1,000 inhabitants can be found (Schipper, Deakin, McAndrews, & Frick, 2010). The intense motorization has direct influence on the rise of externalities, such as traffic accidents, air and noise pollution, and congestion.

Data from the Latin American Urban Transport Observatory (OMU CAF, 2016) indicates that the Latin American cities have relatively sustainable modal shares (figure 3) with the public transport (collective) and walking prevailing over the individual motorized one. Despite this, Latin American cities face strong pressures of urban expansion and motorization. The vehicles available for individual transport are cars, motorcycles and the private taxis. The number of trips in collective transport is made in buses, minibuses, metro and trains. It is very relevant to describe that, public road-based transport is predominantly private, with private fleet of medium size and offered by a large number of private operators that compete for passengers. Although most cities authorize services through public concessions, these concessions do not necessarily come from bidding processes and there is still a large number of cases offered through a simple permit or though informal rules, which is not a stable legal instrument. This frequently causes serious negative externalities, such as accidents, congestion and pollution.

If current rates are kept constant, according to Hidalgo and Huizenga (2012), South America and México are estimated to have on average 77,000 deaths per year from road accidents in 2020, due to the rapid motorization especially pushed by motorcycle use. The estimate will also double greenhouse gas emissions from the transport sector in 2030 despite some improvements in vehicle fuel economy (Hidalgo and Huizenga, 2012).

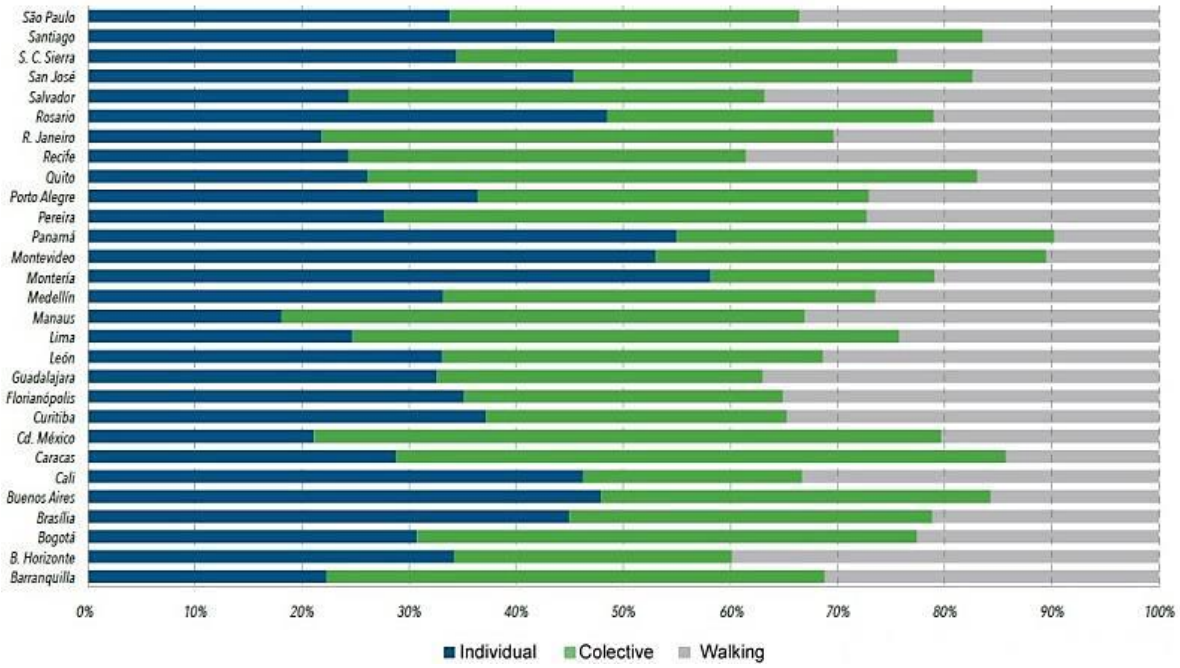


Figure 3 - Modal share for passenger urban mobility in Latin America
(Source: OMU CAF, 2016)

The BRT system with high capacity of passengers and bike lanes have grown explosively in Latin American cities, especially in metropolitan area of large cities, and there are signs indicating that they will keep growing up in the next years. However, the BRT systems has been dealing with problems related to planning, implementation, and operations, mostly as a result of institutional and financial constraints. Also, individual and private companies have the control of the transport service, in many times, without order or institutional surveillance, which leads to several problems and the difficulties. Some of these problems are: lack of security, uncoordinated operation, bad equipment maintenance, high greenhouse gas and conventional pollutants emissions, and the subsequent bad reputation of public transport (Mejía-Dugand et al., 2012).

Despite the bad prognosis, the International Association of Public Transport (UITP - *Union Internationale des Transports Publics*) states that the pattern of modal share of motorized mode of Latin American cities is in between the most efficient pattern and the European pattern (figure 4). The cities may have the chance of a more equilibrated approach, like the European pattern, instead of opting for a high use of private vehicles pattern, as we can see in the United States or Australia pattern. The most efficient pattern shows the smallest share for private motorized vehicles in answering demand for transportation and the highest role of public transport, biking and walking.

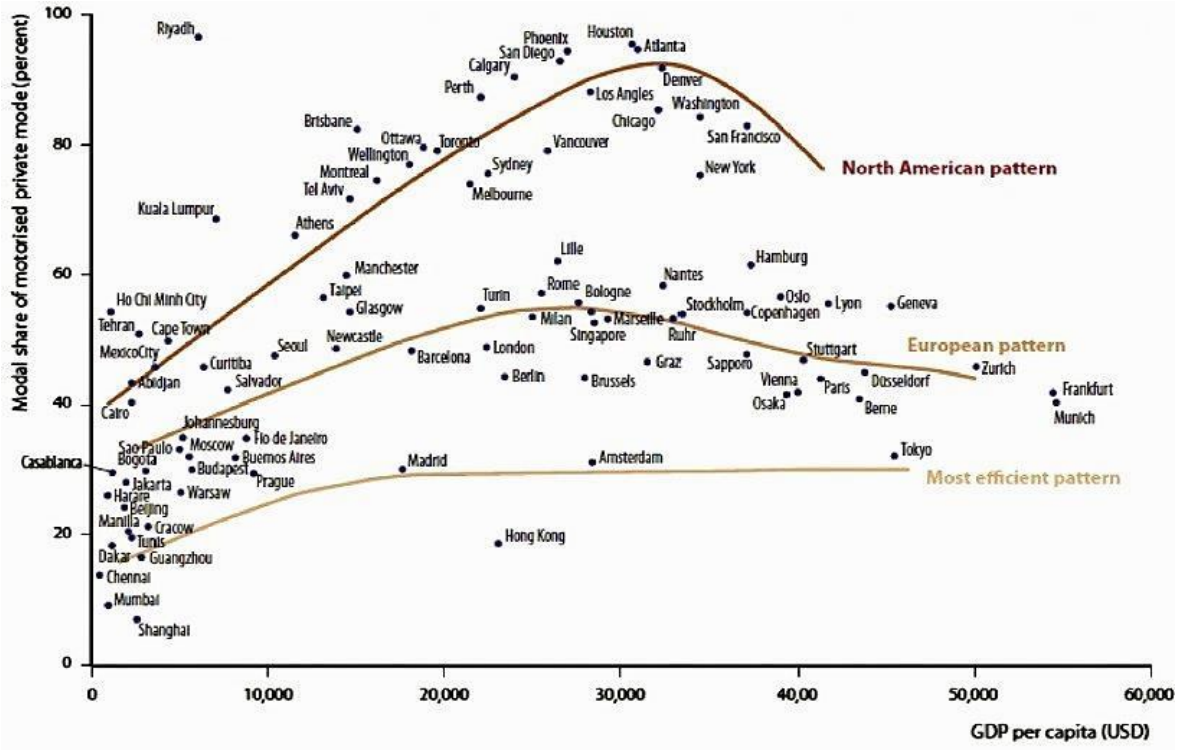


Figure 4 - GDP per capita vs. modal share of motorized private mode
(Source UITP, 2006, Hidalgo and Huizenga, 2012)

A recent regional initiative in Latin America, set up in 2011, quite relevant to sustainable urban transport, was the *Foro de Transporte Sostenible,* (Sustainable Transport Forum), which brought together government representatives of 9 countries in South America and México. The result was presented in the Bogotá Declaration on Sustainable Transport Objectives, that contains 23 goals divided over 4 different strategies: Strategies to Avoid unnecessary motorized travel and reduce travel distances; Strategies to Shift the trend of individual motorization to safer, efficient and environmentally friendly modes; Strategies to Improve technology and management of transport services; and Cross-cutting strategies (Hidalgo and Huizenga, 2012).

3.2 Urban Transport Conditions in Europe

European cities also face problems caused by transport and traffic. A common challenge to most of European cities is to balance sustainable mobility, with reduction on congestion, accidents and pollution. Congestion in the Europe is often located in and around urban centres and costs nearly € 100 billion per year, or 1 % of the EU's GDP (EC,

2011). The success of a variety of policies implemented in Europe in sensitive subjects, e.g. efficiency patterns of transport system, climate change, CO2 emissions, socio-economic objectives, energy dependency, etc., in part depends on plans taken by national governments, but especially by regional and local authorities. Cities themselves are usually in the best position to find the right responses to these challenges, taking their specific circumstances into account.

People search to increase their individual mobility when they become more successful in material terms. There is a correlation between the car ownership and the per capita income, and the most common effect of this correlation is the increasing air pollution and greenhouse gas emissions. Even though transport has evolved to a more energy efficient model, urban transport in Europe is still car dependent and lays on fossil fuel. The modal share of passenger transport is largely dominated by private vehicles, as showed in figure 5. Commercial light vehicles remain as the main source of noise and air pollution.

The European Commission's White Paper (2011) points that transport energy consumption is increasing and around 28% of the CO2 emissions in Europe are related to the transport sector. At the same time, it proposes to dramatically reduce Europe's dependence on imported oil and cut CO2 emissions in transport by 60% by 2050 with respect to 1990. The European Commission has announced in 2013 an ambitious package of measures to ensure the build-up of alternative fuel across Europe with common standards for their design and use. The Clean Power for Transport Package consists of a Communication laying out a comprehensive European alternative fuels strategy, for the long-term substitution of oil as energy source in all modes of transport. The final Directive adopted requires EU Members to develop national policy frameworks for the market development of alternative fuels and their infrastructure, foresees the use of common technical specifications for recharging and refuelling stations, and sets up appropriate consumer information on alternative fuels, including a clear and sound price comparison methodology.

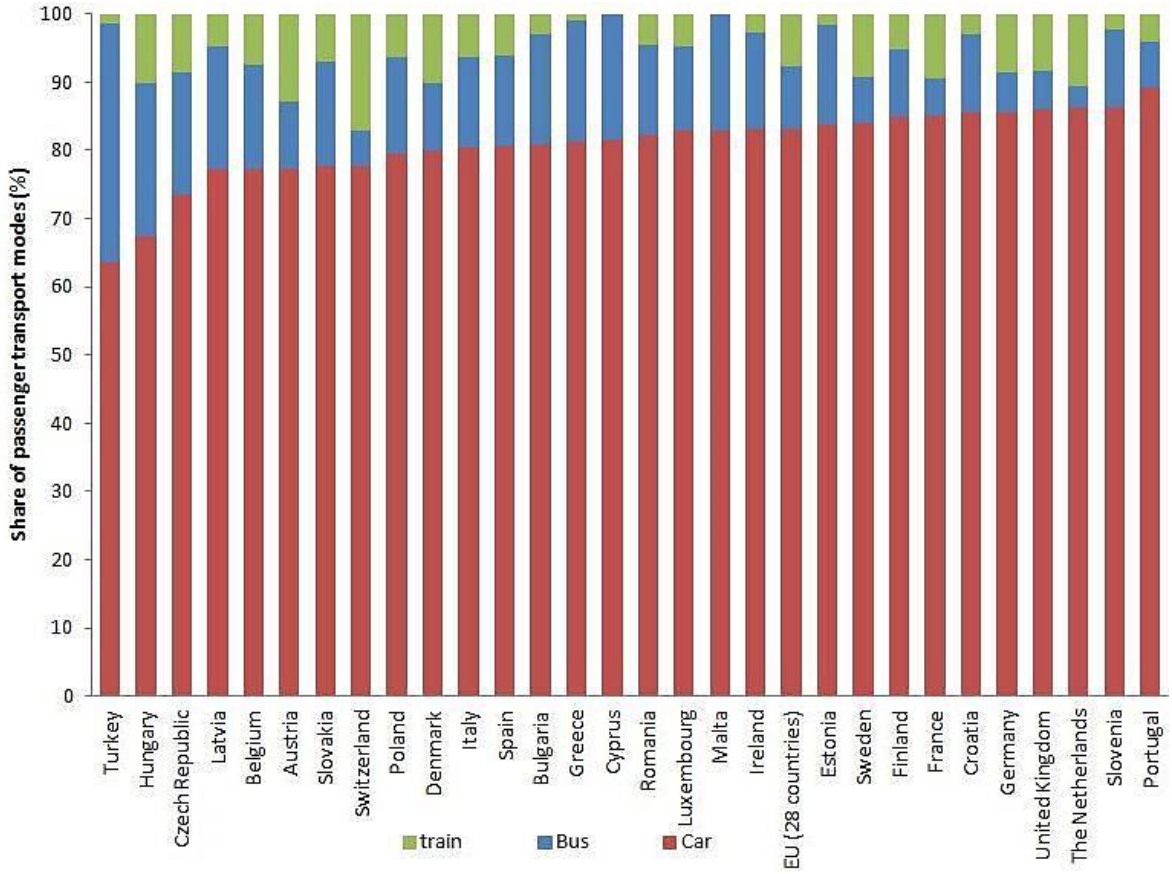


Figure 5 - Passenger transport modal split in Europe
(Source European Environmental Agency, 2016)

The EU addresses urban public transport in several ways, as part of its responsibilities for developing policies and managing funding instruments. For example, It promotes the exchange of best practice in an observatory on urban mobility (Eltis portal), which includes information, knowledge and experiences in the field of sustainable urban mobility, clean and energy-efficient vehicles, collective passenger transport and intermodality from across Europe. Also, it works in related disciplines, including urban and regional development, health, energy and environmental sciences.

The European cities are now looking forward to the development of soft model (walking and cycling) and seeking for a more sustainable city in terms of urban planning, land use and social equity. As a good example, during the last decade, a growing number of cities, particularly in Sweden, France and Germany, have been coordinating transport and urban planning innovative solutions. This includes the promotion of non-motorized modes (biking, walking, etc.), an intense revival of tramways with efforts to set up intermodal

hubs at train stations (specially in France), an increase of cleaner transport usage in order to reduce CO2 emissions.

The reappearance of tramway networks after their disappearance in the decades of 1950 and 1960, especially in France and Germany, now presents substantial networks which have been associated with large-scale urban regeneration and new peripheral housing developments. However, there is one crucial limitation to these networks: they are usually restricted to the administrative limits of the city or a group of the communes around a major city. They do not, as a rule, extend outside the physical limits of the urban agglomeration (Hickman et al., 2013).

3.3 Hypothesis

Here, there are the theoretical statements that are provisionally accepted as a basis for further research in the hope that a tenable theory and empirical evidence will be produced in this research. They are constructed as a statement of expectations, which can be linked to the exploratory research and empirical investigation. It will be used as a conceptual framework for the qualitative (theoretical) and quantitative (empirical) analysis.

Hypothesis 1: Cities which implement sustainable policies and climate action plans reduce their vulnerability to energy scarcity and to energy price rises. Also, they have less traffic congestion and lower energy input costs, besides reducing CO_2 emissions, all direct related to transport sector.

Hypothesis 2: When integrating transportation and energy system, we benefit from mobility, urban, economic and social cohesion.

3.4 Research Questions

This research intent to answer these questions by creating a handbook of strategies for the stakeholders involved in make their cities more sustainable, in terms of mobility, so as to provide a sustainable cycle of source and consumption.

RQ 1: Does implementation for the transportation require which multiple approaches in parallel:

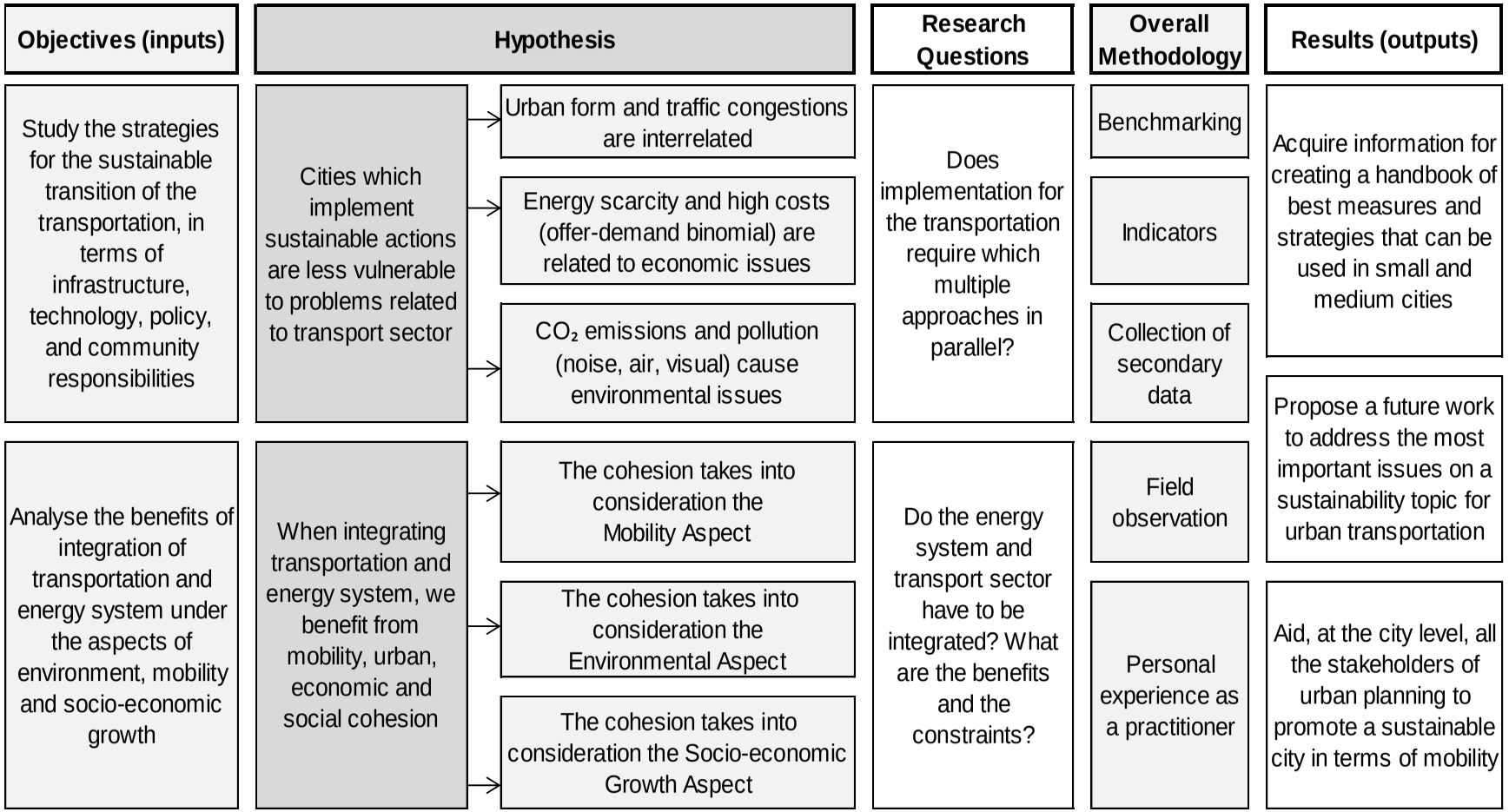
a) Within infrastructure?
b) Within technology?
c) Within policies?
d) Within communities?

RQ 2: Do the energy system and transport sector have to be integrated? What are the benefits and constraints:

a) For environment?
b) For mobility?
c) For socio-economic growth?

3.5 Research Scheme

AIM: Sustainable Urban Transport Integrated to Energy System for Small and Medium Cities



4. METHODOLOGY

The methodology that was applied by the study has been chosen in order to acquire information and deduce conclusions about promoting the public transport more sustainable and how to integrated it to the energy system. The main purposes of this study is to obtain an overview into the current development of transportation system in urban centers so as to propose further recommendations for sustainable transition and integration to the energy system.

This will discuss the multiple aspects of urban transport planning and provide the definition of some concepts related to sustainable development. I will also present the current conditions of the transport system in Latin America and Europe, benchmark examples of best practices, measures and policies in Latin America and Europe, and analyze the results in order to create a handbook of best strategies for sustainable mobility.

The first step in this work was to design the theoretical part to deal with the problematic and the hypotheses. Then, the research defined some concepts used in the study - sustainability, renewable energies and integration and transition in transportation. For this it was done in an extensive literature review of the topics regarding the urban planning, transport sector and the existing energy systems in Europe and Latina America. The preference is for articles from year 2008 to nowadays, a decade, even though there are older references.

Secondly, it was raised a collection of indicators to establish the boundaries of the study for small and medium cities in developing and developed context. That part is divided in two context - the developing cities in Latin American context and the developed cities in Europe context because they considerably differ one from another not only in demographic and dimensions indicators, but also in density, urban form and size, infrastructure, social and cultural behavior, etc. Above all, the two context are defined in relation to the functions the cities perform in the urban network, i.e. the role of the flows of good, information, innovation, administration, etc. It should be pay particular attention to that the wealth of different cities within the same country may vary considerably, since these categories of developed and developing cities are based on average Gross National Income statistics.

For each context was used a different indicator of small and medium-sized city – Population of less than 250,000 inhabitants for developed cities and less than 1 million inhabitants for developing cities. For the developing cities in Latin American context, the concept of small and medium sized cities is defined by CEPAL (Economic Commission for Latin America of the United Nations) as showed on the table below:

Table 1 - Urban Center Sizes in Latin America

City Size	Inhabitants
Small	until 50,000
Medium	between 50,000 and 1,000,000
Large	between 1,000,000 and 4,000,000
Metropolis	between 4,000,000 and 10,000,000
Mega city	of more than 10,000,000

Source: CEPAL (Economic Commission for Latin America)

For the developed cities in Europe context, it was considered the concept of small and medium sized cities of the European Commission, as showed on the table below:

Table 2 - Urban Center Sizes in Europe

City Size	Inhabitants
Small	between 50,000 and 100,000
Medium	between 100,000 and 250,000
Large	between 250,000 and 500,000
X Large	between 500,000 and 1,000,000
XX Large	between 1,000,000 and 5,000,000
Global city	of more than 5,000,000

Source: European Commission -
Cities In Europe, the new OECD-EC definition

After setting up the context, the research focused on a benchmarking of strategies, measures and policies already adopted in other cities in order to promote sustainable transport. This thorough appraisal of samples it was needed to create an understanding of the opportunities and difficulties for transition of transport sector and its and integration to the energy system. To evaluate the measures, a multi criteria analysis was the base for the assessment, meaning, different aspects that were found important and relevant for the urban transport planning vision was used as criteria or assessment categories. Each measure was evaluated based on its results in one or more the six defined criteria (figure 6). To assure that the measures were evaluated from the same context, leading questions were formulated. The categories had objective judgments assured by one or more

indicators, even though there are some categories with subjective judgments related to perception or satisfaction, as quality of life and well-being for example.

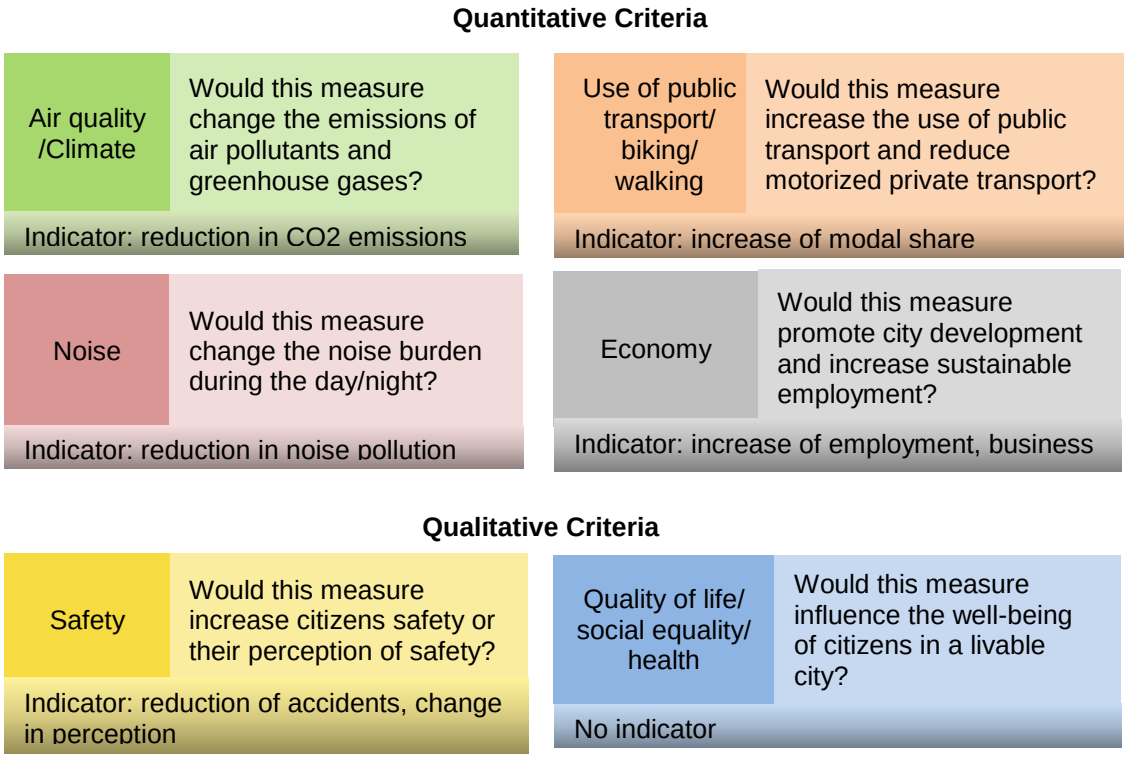


Figure 6 - Multi criteria analysis
Source: The author

Finally, the combination of these methods with personal experience of the author and engagement as a practitioner, added to some field observation had helped to gain some outcomes and reach a conclusion for this research.

4.1 Type of Investigation - Qualitative Research

For the reason stated above, this research will take an explorative approach. According to Sekaran (2002) an exploratory study is undertaken when not much is known about the situation at hand, or when no information is available on how similar problems or research issues have been solved in the past. The aim will be to obtain familiarity with the issues, and to gain a deeper understanding about the topic.

4.2 Data Collection

For the purpose of this research and to achieve its objectives, secondary data was collected (external and desk-based research). This type of data strongly contributed for the formation of theoretical background that is necessary for the researcher, in order to build the research. The data was collected and analyzed from various sources including articles, newspapers, research papers, case study, indicators, websites, etc. Some real cases of existing sustainable transport assessment frameworks were used to illustrate the research analysis. Also, documentation and reference data for multiple transport modes, covering suburban rail, “heavy rail”, “light rail”, bus rapid transit, common bus, and “people mover” were used.

5. ANALYSIS FRAMEWORK

5.1 Implementation for the Transport System Transition

At this chapter, the research will focus on implementation for the transport sector transition towards a sustainable mobility, and other factors that need to be considered. This transition requires multiple approaches combined and implemented in parallel, because those combinations can work jointly, leading to impacts larger than the sum of their individual parts. The key strategies to be considered in this study are based on infrastructure, technology, policies and communities - measures already adopted in other cities, as well the limitations of their application. Drawing on some examples of measures found in small and medium sized cities in Europe and Latin America, this research identified key lessons and multiple approaches, certainly not identical in the north and south globe, that can offer great potential for transition to sustainable transport.

The main characteristics of small and medium sized cities are their small surface area, the human size of relationships and their small investment capacity (Varley et al., 2009). These cities often have a low demographic density, with the population often spread over a large area, most of the times encircled by others small towns, all forming a metropolitan area. This circumstance may signify shorter travel times, freedom to commute or good accessibility, but on the other hand, it may create huge difficulties to organise public transport. In relation to collective transports, buses often provide the larger modal share, being a more affordable and cost-effective mean of transport in small and medium sized cities.

Cities can consider transport solutions from both developed and developing countries but keep in mind that the appropriateness of different forms of transport development is context dependent. Good examples of measures was found in small and medium sized cities in Europe and Latin America, particularly in Nijmegen, Vitoria-Gasteiz, La Rochelle, Pereira, and Mérida. But others larger cities have also showed best strategies that can be applied in small contexts.

The Nijmegen is a medium-sized city in Netherlands with total territory of 5,760 hectares completely urbanized. Currently, the city has 171,000 inhabitants and 70,000 households. Since 2011, the city has a sustainability agenda based on sustainable development, distinguishing five pillars - urban development, mobility, energy, economy and municipal

organization. This sustainable approach applies to economic development (energy and environmental technology), demographic development (binding people to the city, houses for all stages of life) and climate change (adaptation measures). The city was awarded as The European Green Capital of 2018. The implementation programme *Duurzaamheid in Uitvoering 2014-2017* (Nijmegen European Green Capital report, 2017) set priorities in the field of sustainable mobility, such as better public transport and logistics; In the field of energy, such as the energy transition with an ambitious goal to employ only sustainable energy resources for heat and electricity by 2045; And in the field of urban development, such as the bike promoting spatial planning, climate-proof city and an improvement of the quality of the social environment.

Vitoria-Gasteiz is a medium-sized city in Spain with a population of 235,445 inhabitants. As a medium-sized city, for a long time avoided the issues related to urban areas, such as traffic congestion, long travel distances, air and noise pollutions, social inequality, poverty, etc. Vitoria-Gasteiz has a plan to be more accessible for citizens and tourist and that means it is concerned about urban planning that incorporate sustainability as a pillar element favouring public and non-motorized transport. The Sustainable Mobility and Public Space Plan (SM&PSP) seeks to reverse the ascending trend in the use of private cars and to set up a new public space and mobility plan to minimize the dysfunctions caused by the high use of motorized modes, especially the private car, and to improve sustainable mobility modals. For these reasons, in 2012 the city was awarded as The European Green Capital.

La Rochelle, France, and its urban community includes 17 surrounding towns and La Rochelle itself, with a population of 160,000 inhabitants living in an area of 20,650 hectares. The city lies on the Atlantic Coast and the total population may reach 250,000 people in summer. La Rochelle has been involved for several years in improving urban transport and more specifically in introducing clean vehicles, developing new concepts for sharing vehicles, bicycles, in implementing Park and Ride services, among others measures. Regarding sustainable transport and energy policy, the major goal is to show that, with a combination of mobility and traffic management strategies, expressive outcomes can be provided.

Pereira, a medium-sized city in in Colombia with 472,000 inhabitants, and densely urbanized. The city is recognized as having implemented good practices of transport and urban development, and the recent instrumentation of improvements in the systems of

buses (the BRT system). Inspired by projects in the Colombian capital, Bogotá, and in Curitiba, Brazil, two cities that contributed the most to the current maturity of the BRT system, the city of Pereira has remodelled its public infrastructure and revitalized urban areas where the poor conditions of the urban environment have improved enormously along the bus corridors. Pereira e Bogotá contributed incremental improvements to the concept that proved to be adaptive to other Colombian cities sharing similar conditions and acted as contexts for the application of new ideas and the strengthening of the basic ones (Mejía-Dugand et al., 2012).

Mérida, a medium-sized city in Venezuela with 250,000 inhabitants, is located in a long and narrow plateau between two river valleys high in the Andes Mountains. Due to its physical characteristics, the city proved to be a city compatible with the urban planning as well as its budget constraints by developing a mass transport system composed by an aerial cableway down the valleys and the BRT system, with a particular and non-pollutant fleet of articulated trolley buses (buses that run on electricity through an aerial catenary). The BRT started to operate in 2005 and the fleet also have an auxiliary diesel motors to run in case of power shortage.

5.1.1 Infrastructure

Urban infrastructure: the urban infrastructure of a city determine the resource consumption and CO2 emissions of sectors such as transport, energy supply and the built area. Road construction is commonly used to solve congestion problems, but new infrastructure may create new demand for resources and result in even more traffic. Very often, expropriation and demolitions are necessary for create open spaces, a disruptive process for densely built urban areas.

Increased investments in all types of transport is always seen as a promising economic development of a city. In developing cities, the construction of new roads, with enormous public expenditures, is often promoted as a strategy of modernization, sacrificing other public transport investments. Instead of this, the focus should be on the maintenance of existing infrastructure and on the shift to most efficient modes of transport, as the first step towards sustainable development strategy. Also, the focus on the usage of urban planning to support non-motorized based trips. The prospect of induced travel lends credit to a transport policy based on alternative modes, and policy makers in Europe have been

more sensitive this than in Latin America (Banister et al., 2007). Surprisingly, in United States, where the motorization level is the highest, there is a law since 2003 that increases funding for projects of most sustainable modes, walking and cycling, where every new highway project must include provisions to accommodate pedestrians and cyclists. Moreover, the federal law requires that every state department of transport have a special unit that coordinates pedestrian and bicycling programs and policies throughout their state (Clarke, 2003; Banister et al., 2007). However, the car lobby and funding incentives to car ownership in US are still bigger than such sustainable policies and initiatives.

Un example of large scale urban renewal initiative that was implemented following the road corridors construction is showed in downtown area of Pereira, Colombia. The urban renovation of historic districts in Pereira is an ancient project that initiated in the decade of 1990, with pedestrian sidewalk remodelling and recovery of public space around Plaza de Bolívar. The greater achievement was the substitution of the traditional market in very poor urban conditions, so called *La Galería*, by new urban developments, including large scale plazas, malls, cultural centre, housing and new commercial buildings. The renovation project, known as Ciudad Victoria, is directly connected to the BRT corridor, with a station located in front of the Cultural Centre. This implementation, completed in 2006, was the first urban project in Colombia that applied instruments introduced by the Law 388 (*Ley de Ordenamiento Territorial 1997*) to renew degraded urban areas. Other cities of the metropolitan area, Dosquebradas and La Virginia municipalities, along the nodal points of BRT corridor, were also contemplated by new urban facilities, attractive open spaces, and the interchange terminals remodelling.

LRT: Light Rail Transit is a rail-based transport (tramways, trolleys, streetcars) that can circulate on urban streets, alongside the car traffic due to their overhead catenary that feeds them with electricity. They have reappeared and grown quickly, especially the tramways, since the decade of 1990 in developed cities of Europe with low corridor volumes. These vehicles are not very well developed in Latin American cities and there are Tramways only in larger urban centres, such as Buenos Aires (Argentina), Rio de Janeiro and Santos (Brazil).

Tramways are usually seen as symbol of modernity and sustainability by governments and also more appealing to middle class users. In fact, they can be integrated into measures for smart urban planning through the transit-oriented development fundaments,

that use dense urban corridor as the main spine for urban development. In terms of sustainable mobility and social inclusion, investment in this modal is seen as more permanent compromise to public transport, but it implies months of roadworks in city centres, and often a complete reorganization of bus routes. It is estimated that tramways cost two to four times less than metro system per kilometre, which is suitable for urban agglomerations with in average 800,000 people or more. Conversely, tramways cost about three times more than a BRT system with same capacity (Boquet, 2017). Therefore, due their high costs, developing cities usually can only built systems over a few kilometres (in one single corridor), which do not meet the wider transport needs of the population (Pojani and Stead, 2015). The adequate size for tramways appears to be in between 200,000 and 500,000 people range, in a densely populated area, which is the size of many cities in Europe.

In addition to high costs, another obstacle to implement tramway system is the lack of enough energy supply. Power shortages occur very often in many developing cities in Latin America. Therefore, a public transport system that strongly depends on electricity may not be a viable option for developing cities. It is still controversial the increase of LRT systems in medium-sized cities because, nowadays, we can count on new technologies that reduce to a minimum the differences between BRT system and electric trains, in terms CO2 emissions, capacity, and comfort. Consequently, to choose tramways means also to fight against the automobile lobby in the economic and political environments.

The tramway gives an impression of immediate environmental improvement: silent ride, no direct air pollution, tree planting alongside the tramway routes and grassy right-of-way passages, etc. It is the immediate image of a sustainable city (Boquet, 2017). Many cities are taking advantage of tramway works to remodel their downtown areas and historic districts, to restore local urban landscapes before distorted by cars, to reconfigure traffic by removing barriers, to improve soft modes (walking and cycling), and others. One example of reordering of urban space in in the city of Dijon, France (figure 7). The tram is not a simple mean of transport, It made possible to develop new housing areas alongside the tram routes (Junot, Renan) and remodelling older ones turning them into sustainable neighbourhoods (*écoquartiers* Etamat, Petit Creuzot). Also, it was possible to reorganize cities poles, develop new business bunches (the northern end of Line 2, Valmy), and revitalize decaying neighbourhoods (Les Grésilles, Chenôve). The tram links all the major nodes of activity and urban facilities, such as the stadium, The Bocage Central University

Hospital, The Erasmus University Esplanade, and the entertainment and concert venues (Le Zenith).

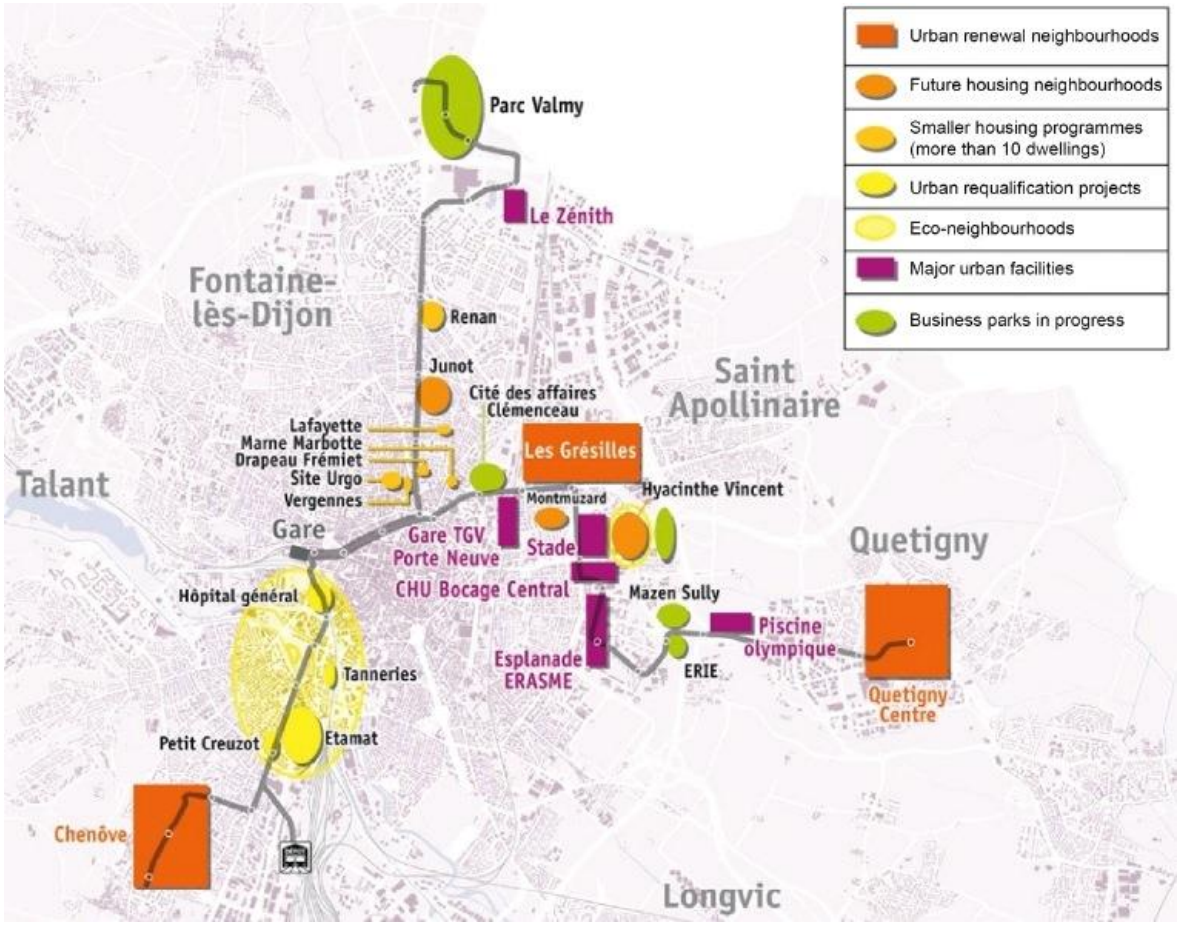


Figure 7 - Tramway Oriented Development in Dijon, France
(Source: Boquet, 2017)

However, these evident benefits can be seen only in the very long term. Obviously, they represent good tools for reordering of urban space, but they are not the only one, and mainly of their efficiency as transport instruments can be overcome. Buses can be more flexible than tramways in terms of use the space, since buses can go in and out of the BRT corridors for example, which is impossible for trams, restricted by their rails. In case of accidents, malfunction or power shortage, the whole tramway line activity can be suspended whilst buses can deviate.

Bus Rapid Transit (BRT): BRT system is understood as the systematic combination of infrastructure (i.e., busways, stations, terminals) with organized operations and intelligent technologies, geared toward providing a higher quality experience with traditional bus

operation (Hidalgo and Graftieaux, 2008). BRT has grown substantially in the past decade, with high levels of public acceptance and political commitment, especially in Latin America, due to a relatively low investment in comparison with others mass transports, and few or almost any operational subsidy. While heavy rail (metro and suburban trains) had not grown substantially in Latin America, BRT has expanded vary fast and trends indicate that it will continue to grow in the next decade. The city of Curitiba (Brazil) and Bogotá (Colombia), are accredited as being the two cities that most contributed to the current maturity of the concept, adjusting urban planning and budget constraints. BRT is also known in Europe as BHLS (Buses with High Level of Service) and it was implemented in many cities of Netherlands, France, Sweden, Spain and United Kingdom.

Depending on the characteristics of the city where BRT is implemented, the system may vary in some aspects. Nonetheless, two basic features include a separated bus ways over the most part of the system corridor and high performance, carrying up to 30,000 passengers per hour per direction, on average. Moreover, pre-boarding collection that permits fast boarding of passengers as in the metro system, level access between the platforms and the buses, and integrated network are other important features of BRTs. These features make BRTs more suitable for medium-sized cities in support of quality public transport. Besides, BRT seems quite attractive because it can be implemented in a short term, varying in between one and five years, and it provides flexible adaptation to narrow streets, especially in historical districts and downtown areas. A particular attention needs to be given to the entirely transformation of the dispersed and informal public transport services into regular and integrated system that can be seen in many cities of Latin America. It is expected though, that the focus now will be the integration with the rest of public transport and the expansion of existing ones, instead of constructing new systems.

In many developing cities, BRTs went through a series of difficulties during implementation and operation, issues related to financial restrictions and institutional constraints. Investments from USD 1.4 million per km to USD 8.2 million per km, depending on the size and complexity of the project, force cities to rely on budget allocations from the national governments or international loans. Valuable time is necessary in process of applying for required approvals and funds by sponsoring institutions, decreasing the time window for project accomplishment. Hence, most of the BRT systems had rushed kick-start, without all the elements operating, such as incomplete stations and terminal (León, Mexico), incomplete corridors (Pereira, Colombia)

or insufficient fleet for initial demand (Quito and Guayaquil, Ecuador). Scare or non-existent public information and education also caused initial confusion, fare evasion and performance below expectations of the system

It is important to mention the example of the BRT system in Mérida, a medium-sized city in Venezuela. The transport system is composed by articulated trolley buses, fed by electricity via aerial catenary, and giving a particular and non-pollutant characteristic to the fleet (figures 8 and 9). The BRT started to operate in 2005 and the fleet also have an auxiliary diesel motors to run in case of power shortage. Unfortunately, among all its currents problems, Venezuela now suffer from power shortage daily and the BRT of Mérida began to use their auxiliary motors on the route. In June 2016 the municipality reported that no longer any trolley buses run on the BRT corridors at all. The electric power had been turned off, then the entire fleet runs exclusively on diesel fuel, after 10 years of electric operation (Morrison, 2016).

Figure 8 - Trolleybus at Alto Chama station, Mérida
(Source: Geraldo Sánchez, 2009)

Figure 9 - Interior of Alto Chama station, Mérida
(Source: Jorge Paparoni, 2009)

Park and Ride system: It is a multimodal site that promotes alternatives to car usage, mainly in downtown areas. The most important features of Park and Ride (P&R) system is a parking lot close to the main road axis, public transports (bus lines or tramway) located very close and ensuring a good frequency to the city centre (the set-up of dedicated bus lanes that connect the city centre and the P&R site is preferable), and in many times with an option of a bike sharing station or a bike park. Also, the system should be combined with other measures, such as high restrictions of parking in the city centre, so that users would be compelled to use the P&R system.

To illustrate the system, in 2002 the municipality of La Rochelle, France, built its first P&R facility in the south-east area. Two years after, it was introduced a dedicated electric shuttle bus service connecting the city centre and the P&R, each 10 minutes. After the success of the first P&R system, the municipality decided to build P&R in another areas, with the objective of targeting strategic traffic hotspots, notably commercial areas and highly used zones (figure 10). In addition to the new dedicated bus lane, three other main measures were put on practice to ensure that P&R is the best alternative, more attractive and more efficient, for car travellers: Firstly, the reorganization of the bus network; Secondly, the abolition of free parking close to the city centre; Third, the extension of the Bike-Bus Scheme.

Figure 10 - Park and Ride scheme of La Rochelle
(Source: yelo.agglo-larochelle.fr, 2018)

The main difficulty in this implementation process was to establish an agreement between the various stakeholders, e.g. bus operators, local decision makers, users, and to coordinate parallel aspects, such as availability of large areas to build the P&R, land expropriation, technical feasibility, users' behaviour, delegated management procedure and common image. A considerable time was necessary to overpass all barriers and to concur on such long term decisions.

5.1.2 Technology

New technologies may help to tackle certain transport-related problems, such as air and noise pollution, oil dependency, traffic congestion, and accidents. However, many new technologies are out of hand, in the financial aspect, of most individual residents of developing cities and even in developed cities. But some transport alternatives more feasible could be implemented through technological measures without have an effect on the travel behaviour or lifestyle.

Alternative fuels: A wide range of public and collective vehicles (heavy-duty trucks, garbage trucks, three-wheelers, and buses) can run on alternative fuels including natural gas, electricity, and biofuels. While biodiesel can be used in any diesel engine without modification, other fuels as ethanol, gas, hydrogen, and electricity can be used only in specially-produced or modified cars (Offer et al., 2010).

In comparison to the cost of an internal combustion engine (ICE) vehicle that uses fossil fuel, the economic investment costs of hybrid vehicles are approximately 20% higher and for battery electric vehicles (BEV) is 80% higher. Conversely, energy efficiency of a combustion engine vehicle is about 17km/L petrol, while the corresponding energy efficiency of a BEV is 80km/L (Mathiesen et al., 2007). The governments could start by increasing the use of alternative fuel vehicles in its own fleet (including gradual full conversion to hydrogen fuel, production, storage, refuelling and maintenance facilities) because they have more investment power than an individual user.

The city of Nijmegen and the metropolitan region has one of the greenest public transport concessions of Netherlands, the entire fleet of municipality vehicles already runs on electricity or biogas (regionally produced), resulting in cleaner public transport vehicles in the city and surrounds. Transport correspond to 20% total of energy use in Nijmegen. Today 7% of energy use of city is generated locally and sustainably. In 2020 they intent to increase to 15%, through the construction of a wind park and later a solar park (in 2018). The GDF Suez Company closed its coal-fired power plant at the end of 2015 and will build a solar park, windmills and biomass plants (Green Delta 2015-2020 program).

Electric vehicles (EV): In comparison to ICE vehicles, electric vehicles (fuel-cell, battery, or plug-in) have a low autonomy (about 160 km when 100% charged or 100 km in city traffic conditions). That restricts its usage and becomes more attractive for use in small and medium-sized urban areas. However, while some estimates indicate that in few decades the capital costs will decrease substantially, ICE vehicles still remain cheaper than EV. For that reason, the market penetration of electric vehicles in developing cities is not much propitious in the short-run. The capital costs of electric vehicles are significantly higher than the costs of ICE vehicles, and they have to be used to cross significant distances, typically more than 20,000 km per year, in order to amortize the acquisition costs through energy savings (Pojani and Stead, 2015). In the European context, the purchase of electric vehicles became more significant due to large government incentives.

Currently, Europe is the second largest EV market in the world, just behind China (figure 11).

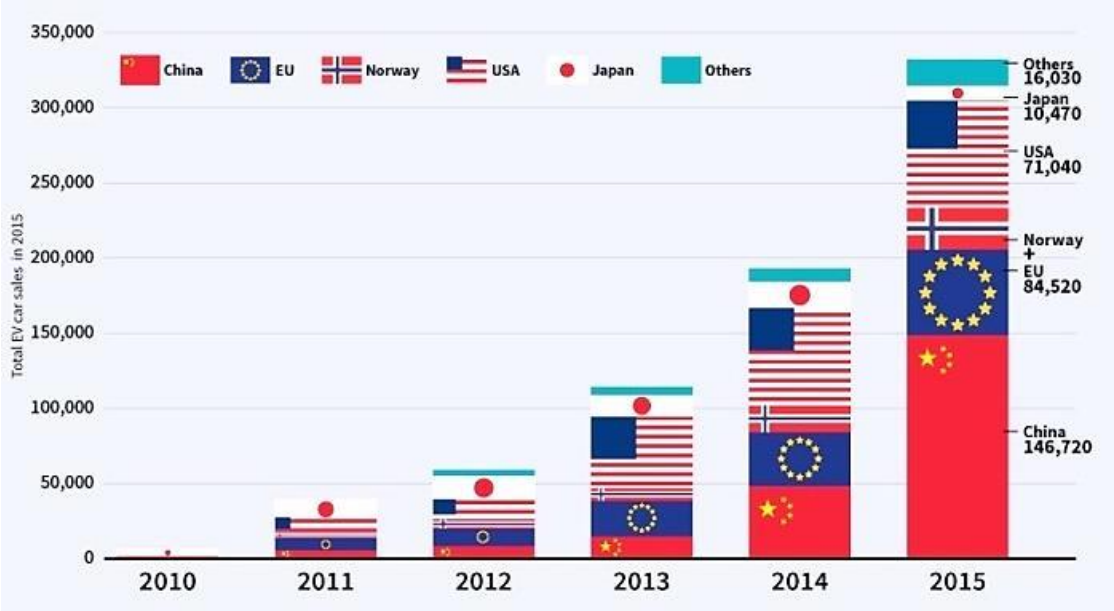


Figure 11 - Global EV sales in 2015
(Source: www.edie.net, 2016)

Intelligent Transportation Systems (ITS): It consists on advanced management systems that foresee traffic congestion and provide instructions of alternative routes in real time, in order to improve the efficiency of the road network and maintain priorities for high-occupancy vehicles. Also, ITS may give to users information about incidents on route, weather issue warnings, traffic conditions and parking availability. In Europe and Latin America, the most common forms of ITS that have been introduced to date include traffic signal systems, traffic surveillance systems using CCTV, commercial vehicle (e.g., taxi) tracking systems using GPS, electronic ticketing services, electronic toll collection and fare payment systems, bus management systems, and traveller information systems (Pojani and Stead, 2015).

The use of ITS in developing cities is moderate to low if compared to developed ones. Although the low spread, small and medium-sized cities can take advantage of ITS applications that had already been tested and established in larger cities because they are fully developed and stable. It is possible for developing urban centres to implement ITS infrastructure at the same time new roads are constructed, which is far cheaper than adding new components to the existing physical infrastructure. However, there are some

disadvantage in applying ITS in developing cities, mainly due to economic reasons. Besides low financial resources, we see many other issues that diminish ITS implementation, such as lack of basic infrastructure, institutional and political will, reluctant user acceptance, high dependency of imported technology, etc. Another worry is the replacement of jobs by adopting high technology, especially the low-skilled jobs in developing cities, where unemployment levels are often high.

The city of Nijmegen, Netherlands, has developed a good example of ITS, which the focus is on the optimal use of the available traffic infrastructure via dynamic traffic control. It is led by fulltime manned traffic control centre, which works with cameras and give the priority to public transport and bicycles within the city ring road. Traffic lights are adjusted to measure traffic over the ring road and to not let traffic stop flowing. Whenever the traffic from the city route does not flow properly, the influx of new traffic is limited and the outflow of traffic is increased by a “green wave”. The traffic lights are adapted to the current situation of the streets and the users are informed via dynamic information signs. This can also diminishes noise burden, since cars do not need to slow down and after accelerate. In and around the city centre there is a parking referral system to prevent driving around unnecessarily, by providing high-grade driving advice in real-time.

5.1.3 Policies

Local governments may influence the accomplishment of greater sustainability in the transport sector by means of laws and regulations, imposing taxes on most polluting vehicles, providing subsidies of cleaner modes, etc. This is a top-down approach on implementing sustainable transport and the type and intensity of the policies may differ according to the level of governance. A combination of measures that reinforce each other is necessary to avoid ineffectiveness, and for this reason, the design of policies depends on feasibility and acceptability. Charge mechanisms are the major bases of policy strategy in most of cities. That means the external cost of transports (e.g. environmental impacts, accidents, etc.) may be traded off against economic gains, with aim at a most favourable social conditions. Conversely, other transport policies are considered as painless and aim to influence in a non-financial way, with higher levels of public acceptance, especially when the individual benefits are emphasised.

Support for Non-Motorized Modes: The promotion of soft modes of travel, such as walking and cycling, and their related infrastructure offer improvements in health (individually and collectively) as well as a cleaner environment. Walking and cycling are all more healthy than using a motorized mode of transport, and there are evidence that links transport emissions and declining health, above all the strong relation between lack of exercises and obesity. Best examples of promoting the use walking and cycling as alternatives to the car can be seen in many European cities with positive results, e.g. reductions in car use of around 10% (Banister et al., 2007) and enduring travel behaviour changes.

Despite some political disregard and omission, walking and cycling have a higher modal share in Latin American cities. The preference is directly related to difficulties in afford individual motorized transport, and for many individuals it is preferable spend more time than more money to travel. However, soft modes face demotivation when its infrastructure is scarce, when climate conditions are not favourable (hot weather and heavy rains), and when the coexistence between car, vendors and even animal traction vehicles are conflicting.

Becoming a cycling city does not happen in a short term, even in industrialized cities with budgetary conditions. Rather than this, it took decades of planning, implementation of bicycle infrastructure, construction of parking facilities, integration with other modal systems, combined with promotion and public acceptance.

Vitoria-Gasteiz created the Bicycle Master Plan that included measures to promote less environmentally damaging modes of transport, such as, creation about 46km of cycle paths, increase of bicycle parks by 142 for 8,588 bicycles (the total offer reached a figure of 13,565 places) (figure 12), investments about 900,000€ in bike promotion, development of a fully integrated system with the public transport network, and increase the number of lending points to a total of 35, placing these at no more than 5 minutes walking from anywhere in the city.

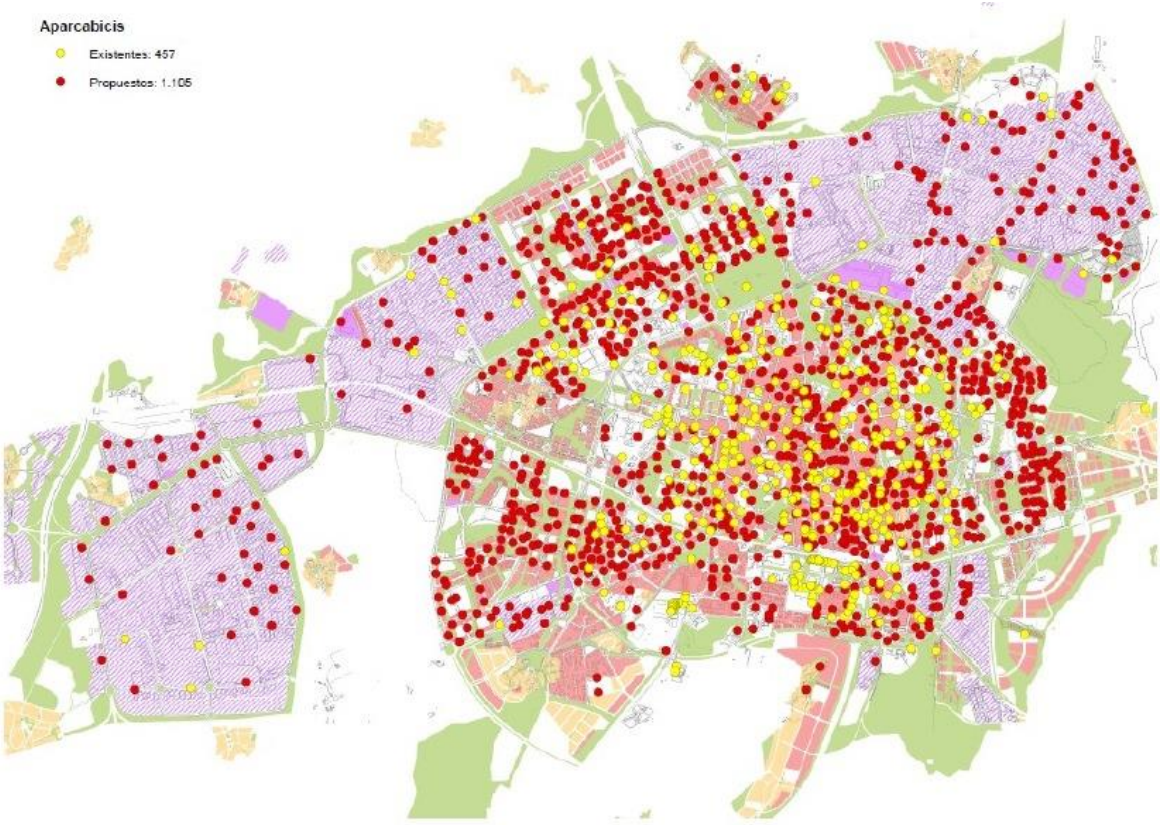


Figure 12 - Bicycle parks (Yellow dots: existing, Red dots: proposed)
(Source: *Ayuntamento de Vitoria-Gasteizko Udala*, 2012)

Land-use Controls: The urban transport system, understood as a system of linkage, is strictly related to the location of the elements to which it links. Therefore, transportation and land use are directly related and have important implications and complexities for travel behaviour, increasing or reducing transport intensity. Decisions made on where to build new houses, hospitals, schools, shops, etc., will considerably influence future travel standards. Many of the problems created for the transport system do not come from the transport sector, but from other sectors. In this sense, those places that have better accessibility are generally the most demanded places and acquire a greater value. In those places will be located those activities of greater profitability and whose managers are willing to pay more for the land of better location (figure 13). Greater accessibility implies a lower transportation cost.

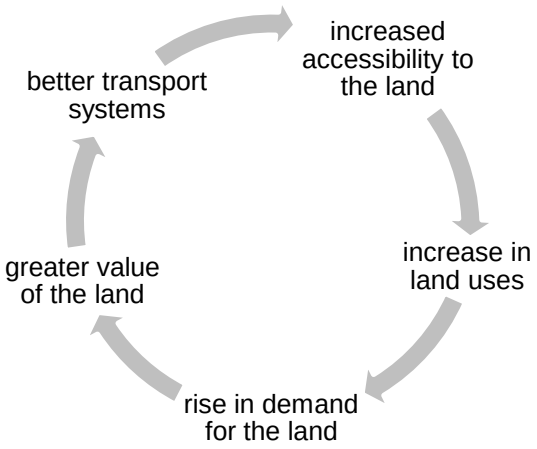


Figure 13 - The relationship between the urban transport system and the value of land (Source: Lorena Farías 2012)

Establish land use policies that restrain low-density sprawl, preserve of open space and ecologically sensitive areas, favour mixed uses, concentrate new development in existing urbanized areas are measures often considered within sustainable development or smart growth. Because of that, they may have an impact in the human living space and consequently in the travel demand. Land use and development factors have an important role in reducing transport intensity (Rodemburg et al., 2002).

Sustainability choice of traveling depends on local features, such as climate variations, cultural factors, levels of consumption, etc. In terms of functional mix, developing cities are generally characterized by high levels of mixed use, mainly due to higher urbanization rates. However, in most developing cities, land use intensification often takes place in the lack of government control or even in total absence of land use policies. In addition, some cities of Latin America are located in naturally hazard areas, e.g. floodplains, seismically active zones, foot of volcanoes, etc., and densification has directly implications for disaster mitigation and management (Pojani and Stead, 2015).

Some European developed cities have strong economies which enable transport investments and land use control, with greater potential for conversion of abandoned and ramshackle urban lots, as brownfield sites, former industrial buildings, etc. The renovation and restoration of decadent sites is also important to increase the quality of live and the liveability of the space.

If it is not possible to accomplish a dense and compact development or if densification shall be avoided (hazard areas, hyper-dense centres), land uses can be implemented by

means of transit-oriented development (TOD), i.e. urban development along transport path or around transport nodes at a regional scale. Many settings of TOD have been implemented in Europe and Latin America, in successful ways. The development of new settlements rather than remodelling existing ones is perhaps preferable, in order to increase access to high concentration of the population. Land use policies can indicate the areas where activities will be abandoned and where they may be promoted.

City of Nijmegen, Netherlands, has various restructuration projects in the city centre, residential areas and industrial estates, in order to promote urban development and sustainable mobility. The renovation of urban space is associated to transform residential buildings in more energy efficient ones and improving the structure of public transport and bicycle traffic. The relocation of industrial properties has provided new space for housing, and the renovation of the university campus (Radboud University, HAN University of Applied Sciences and Hospital) was a project with huge investments in public transport, biking and green living and working environment.

Pricing Mechanisms: The method of applying financial taxes by using coercive pricing mechanisms is a common strategy used by governments as an effective administrative instrument to reduce car use in urban areas, manly in historic districts and downtown areas where space is scarce. The most used mechanisms are: to impose charges to access or circulate by car within a limited zone, occasionally with some degree of time distinction (congestion charges); To apply higher taxes on fossil fuels (gasoline, diesel) to encourage the use of public transport or switch to less pollutant fuel; To relate registration taxes and the vehicle annual tax to their level of CO emissions; Parking fee based on distance to city centre, the closer is the parking, the more expensive is the fee.

These instruments may discourage the car use in the short term, but also they may change travel behaviour in the long term, if alternative options are available and attractive. That means efficient and integrated public transport, and vast and secure routes for walking and bicycling. Once the users experience the benefits, the barriers to pricing mechanisms may diminish (public and political oppositions). Controversial policies such as pricing mechanisms shall be gradually implemented, in order to gather public acceptability, meanwhile other choices would be provided by means of high quality public transport and soft modes.

Small and medium-sized cities with low administrative capacities may prefer mechanisms that demand few control management or small monitoring costs, for example taxes on fossil fuels, the vehicle annual taxation, parking fees. Congestion charges are essentially necessary in larger cities that suffer from intense congestion problems. Probably the best example is the experience from congestion charges in London, UK. In the first two years of implementation (2003 to 2005), the mechanism had worked well and gained public acceptance, with measurable reductions in both traffic levels by 15-20% and congestion over 20% in Central London and around the congestion charging area, and most travellers switched to bus services (Livingstone, 2004). In this case, both the social norms and perceptions of its effectiveness were sufficiently high for implementation, and the outcome has exceeded expectations. The potential effects of the congestion charging scheme are substantial, as many other cities may learn from London and introduce their own schemes (Banister et al., 2007).

Vehicle Access Restrictions: It is a command-and-control based instrument to reduce vehicle usage in urban areas, through laws and regulations related to a variety of criteria, such as limited urban area, vehicle weight, license plate number, parking restrictions, single occupancy, days of the week, time of the day, speed limits, among others. Some of these measures may have sub-measures specific to some streets or areas within the city.

This instrument is referred as politically easier to introduce than pricing mechanisms because it is seen as equally fair for all parts of the society. To be successful, these types of command-and-control measures must be reinforced by other complementary transport policies and promotional measures, as law enforcement and large administrative monitoring (Mahendra, 2008). Vehicle access restriction policies should be escorted by well publicized programs to promote the attractiveness of alternatives to car usage (public transport, soft modes). These parallel programs can be financed by dedicated incomes from pricing mechanisms .

Reorganized mobility networks from a new urban cell (superblock) is a key element of vehicle access restriction in the Mobility Plan of Vitoria-Gasteiz, Spain. This strategy classifies the roads in a core network for road traffic (perimeter of the superblock) and pedestrian-priority streets (inside the superblock). This scheme dissuades private car traffic by limiting access and on-street parking inside the specified home-zones. This improved the public transport share and promotes short distance modes such as cycling or walking through a safe and functional approach. The internal streets became

preferential for pedestrians, cyclists and service, emergency and residents' vehicles, being transformed into sections with roadways and sidewalks at the same level and set out as low-speed zones (figure 14). Each of the 68 proposed superblocks Interior streets cuts off to through-traffic and has a speed limit of 10km per hour. On-street parking was gradually reduced and freight distribution was subjected to a new form of management. This scheme started with the city centre and the medieval district, and the it was applied to the whole city, as well in each urban district going through redevelopment.

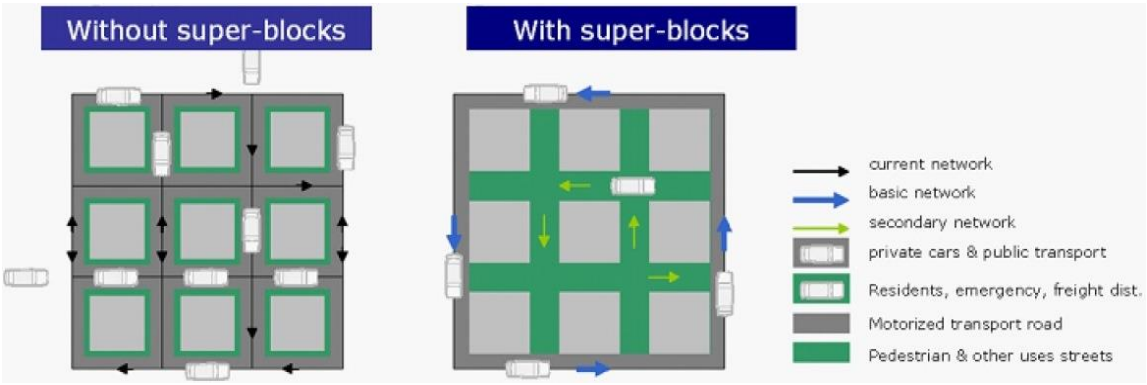


Figure 14 - New urban cell of Vitoria-Gasteiz
(Source: *Ayuntamento de Vitoria-Gasteizko Udala*, 2012)

Use of Information: The objective is to explain the necessity of transport policies, using information in favour of sustainable mobility, through emphasis on the positive aspects and the benefits to the individual in the short-term and to collective in the long-term. Policies acceptability is crucial and it is not possible to apply coercing policies without public understanding by means of education, persuasion, awareness campaigns, media and social pressure, among other strategies.

The publicity created by the car industry is quite effective in promoting private motorized vehicles. Owning a car is sold by industry as profiting pleasure, comfort, freedom, power, social status, convenience and protection (Diekstra and Kroon, 1997), and all of these qualities are psychological barriers for shifting to a more sustainable transport. So, information should introduce, in the best possible way, all the urgent urban transport problems and the real necessity of the solutions implemented. Public activities should stimulate paradigm shift: Public transport as comfortable and smart; Bicycle should be promoted as healthy, modern and practical; sidewalks and pedestrian path provide an aesthetic pleasure and is a democratic place; And finally, cars should be shown as

expensive, pollutant and an obstacle free mobility. Also, several strategies to raise awareness on sustainable transport policy should be applied to make people to think about the consequences of their choices of using a motorized vehicle, as air and noise pollution, congestion, accidents, impaired health, etc.

For over a decade, the city council of Vitoria-Gasteiz, Spain, has been accomplishing an annual programme of education and awareness-raising campaigns for sustainable development. The entire population, not only children, are now reached by this program, with a focus on public action and on preparing citizens to shift their travel behaviour. This program was launched in 1995 but since 1998 it has been associated to the Local Agenda 21 process. The program scope includes awareness-raising campaigns, training activities and public information centres, and education in schools as well. Currently, there are around 100 initiatives happening per year and the results show improvement in several areas that require cooperation of people, e.g. travel behaviour, waste sorting and recycling, reducing water consumption, among others.

5.1.4 Community Responsibilities

The intervention of the society plays a very important role in the transport demand and the general public acceptance and support are quite necessary to build a successful sustainable mobility. The communities have responsibilities over the modal share once they can increase or decrease the demand for public transport through their choices of means of displacements. Governments and technology cannot provide the answer to sustainability alone, even though in some societies this is a belief, especially in Latin American cities, where communities are more passive and take few action by themselves. So, a bottom-up approach is needed in addiction to measures and policies, in order to achieve a desirable change. Sufficient public support and action may positively influence political thinking.

Sustainable transport initiatives: Responsibility for implementing sustainable transport solution should be placed not only on the hands of local authorities but also on the hands of private actors, companies, firms, businesses, etc. They can create travel plans for their employers and offer incentives to increase soft modes (walking, and cycling), public transport, carpooling between employers, as alternatives to solo vehicle use commuting to

work. Jobs, businesses and schools are major generator of traffic and voluntary initiatives coming from these groups may lead to new attitudes to the car.

For example, every school in the UK has its own School Travel Plan since 2010 that provides alternatives to the car use. Even in the USA, where there is a strong culture of individualism, there are 146 voluntary transport associations (funded by groups of private companies) that coordinate public transport, car-sharing and other alternatives for the work travel. Other initiative is the Safe Routes to School Programs (SR2S), implemented in many states of USA. The focus is to stimulates the students to go walking to school instead of going by car with their parents. Nonetheless, all these programs are totally voluntary for participation, there are no laws to oblige them to do it and they can count on very few funding resources, provided by some non-profit organizations (Banister et al., 2007).

Partnerships: Knowledge and expertise in sustainability can be shared between people through partnerships. Institutes, universities, enterprises, industry, car manufacturers, energy suppliers and citizens can work together on projects and strategies that promote sustainable transport. The goal is exchange information and experience in this field and also influence users and consumers through active involvement in participatory and inclusive processes.

The car industry, transport suppliers and research institutions can work on development of new vehicles, more efficient and cleaner, by means of environmentally friendly technologies; The press, social media network and universities can invest in education and information, including persuasion, demonstration, social pressure, individual marketing and awareness raising for the best travel behaviour through soft modes.
The city of Nijmegen, Netherlands, has formed partnerships, including the Nijmegen Energy Covenant (NEC) and the Power2Nijmegen network. NEC is a network of 16 of Nijmegen's largest companies and Power2Nijmegen is a network formed in 2012 in which companies, education and research institutes and citizens come together to work on ideas and projects that contribute towards the goal of making the city more energy neutral. The companies involved in the NEC initiative share the focus on making major reduction in CO2 emissions (a 36% reduction has already been seen from year 2008 to 2014). Over 250 organizations are involved resulting in collaboration between 400 individuals all making great efforts to achieve the sustainable mobility end zero emission.

Voluntary Agreements: Governments, car industry, manufacturers and other transport suppliers can sign voluntary agreements in order to improve sustainable transport by setting directions on priorities, including vehicle technology, alternative fuel efficiency, etc. These initiatives show high commitment although they are very difficult to achieve. In many developing countries that aspire industrial growth, the importance of environmental issues are relative and weak. In addition, in Europe, where the voluntary agreement was already established, the results of CO emission reduction were under expectations.

In 1998, European Commission and car manufacturers signed a voluntary self-commitment, where they agreed to reduce the CO2 emissions of their new cars from 186g/km to a level of 140 g/km by 2008. That means a reduction rate of 2.1% a year, based on 1995 numbers. However, the results of 2007 showed that CO2 emissions had decreased more slowly than expected, which made the European Commission to substitute the voluntary agreement by a mandatory regulation. So, in 2009, the EU's first CO2 regulation for light commercial vehicles was adopted, setting a mandatory average target of 130g/km by 2015. Again, the annual CO2 reduction rate was very low, even under the previous voluntary agreement, 1.7% a year, based on the original 1995 numbers. As a result, in 2013, EU policy makers added a second regulation, with new CO2 target defined as 95g/km by 2020, with a phase-in until 2021. After that, the annual CO2 reduction rate over 2015-2021 reached 5.1% (Mock, 2017).

5.2 Integration of Transportation and Renewable Energy System

There is a long debate regarding the transport sector, the urban form of the city and the use of energy. However, there is growing evidence that a compact urban form with greater density and diversity of uses, together with a good public transport system, reduce energy consumption (Kenworthy, 2006; Farías, 2012). Effective planning and adequate urban governance, which tend towards densification, would produce a greater urban mass and, consequently, a reduction in consumption patterns. The target of a sustainable public transport strategy is to allow the output from transportation to be maintained (or increased), but at the same time to reduce the energy inputs, particularly in terms of the use of non-renewable resources.

Globally, there is an increasing concern about the resource consumptions of transport over the past years due to two main factors. Firstly, transport sector is largely dependent

of oil, approximately 95% over the world (Mathiesen et al., 2007), which obtains international attention. The second factor is that the more changes in others sector (electricity and heating) countries implement, the more the focus on transport sector can be boosted, when they consider renewable energy versus GHG emissions.

The goal is to increase the share of renewable energy sources (RES) in the transport sector, in combination with other flexible technologies and solutions which are technically innovative, energy-efficient in terms of supply and economically feasible. These challenges can be achieve by matching planning for long term objectives, in the shorter term measures. This paper intent to show not only the benefits of transportation and renewable energy system integration, but also the constraints, both in terms of environment, mobility and socio-economic growth.

5.2.1 Environment

The transport sector is a large contributor to negative impacts on the environment. Problems that are often mentioned include energy consumption, pollution (air, water, noise, etc.), CO2 emissions. Internal combustion engine (ICE) vehicles are responsible for approximately 30% of the total energy consumption and 27% of CO2 emissions in Europe (EEA Report 2014) and they are a major source of air pollutants, such as NOx, particulate matters (fine solid or liquid particles) and other volatile organic chemicals. The situation is not far from different in Latin America since the motorization level is increasing quickly, under the pressures arising from rapid economic growth.

Green Vehicles: Vehicles that run on alternative fuels, so called clean or green vehicles, constitute a cleaner option to diesel and gasoline. However, the conversion of oil products within urban transport into electricity, hydrogen and biofuels requires different solutions. Also, these fuels can only be considered sustainable if they are produced from renewable sources such as biomass, wind, wave, solar energy, or other decarbonized fossil source. These vehicles can produce zero CO2 emissions and are a promising way to reduce air pollution, if they are combined with renewable energy sources. According to a recent study a 10% penetration of electric vehicles leads to 11% reduction in direct particulate matters (PM) emissions, but it leads to 5-8% increase in indirect emission due to higher electricity use (Baumann et al., 2012; Dedinec et al., 2016). The rise in indirect emissions is caused by the coal powered plants that supply the energy matrix, and that is why coal

power plants need to be replaced by renewable energy sources, so as to reduce indirect emissions. The environmental aspect would be balanced if technological improvement reaches not only the final user but also the energy matrix.

Biofuels: Globally, the focal point on biofuels (ethanol, biodiesel, other blends) has been rising over the years, as they may offer significant reduction in greenhouse gas emissions. However, depending on the type of feedstock, biofuels are documented by increasing food prices over the world. Even in Latin America, where there are surplus land compared to Europe, biofuels still compete with food supply through land use and are frequently restricted by technical and economic barriers. Moreover, in countries where the Amazon Forest is located (Brazil, Venezuela, Colombia, Peru, Bolivia and Ecuador) other impacts, such as the burning of cleared vegetation for biofuel production, the release of carbon stored in the forest during land conversion to crop production, and the fugitive emission of methane from palm oil production, have emphasized the low contribution of biofuels to GHG expected reduction.

Without affecting the production of food, biofuels can be other option to reduce negative impacts on the environment, if they are combined with other technologies (savings and efficiency improvements, intermittent resources, hydrogen technologies and more). Biodiesel can be used in any diesel engine without modification while ethanol, gas, hydrogen, and electricity can be used only in specially-produced or modified cars. In some countries, especially in South America, the availability of natural gas resources and existing pipeline and delivery infrastructure are incentives to encourage natural gas use for transport (compressed natural gas and liquefied petroleum gas). Brazil and Argentina combined have more than half of the world's total natural gas vehicles (Pojani and Stead, 2015).

Hydrogen: Hydrogen is an energy carrier with large capability for clean and efficient power in transport sector applications, besides allowing a vast diversification of energy sources. In combination with fuel cells, it can deeply mitigate climate change, mainly when produced by renewable energy sources. Hydrogen can be produced from ethanol and biomass through many thermochemical processes. Notwithstanding, more than 95% of hydrogen produced today comes from fossil fuel technologies, e.g. steam reforming, partial oxidation, gasification (Franzitta et al., 2017). So this does not represent a solution to the problem of CO2 emissions, only a low reduction. Few years ago, the European Parliament passed a law on hydrogen vehicles' homologation, in an effort to protect the

environment in urban centres. The law applies not only to the development of fuel cell vehicles but also to the development of hydrogen filling stations and the necessity of producing hydrogen in sustainable ways (Franzitta et al., 2017).

Energy from waste: Residual biomass resources can be transformed in energy and supply the transport sector and the electricity demand. These resources include biogas, organic waste, straw (which is not needed for animal purposes) and waste from wood industry, among others. After a separately collection and fermentation in a yeasting installation, the organic waste can be transformed into compost for biogas and other green fuels, and also for agriculture and horticulture.

Resources that can generate biogas are varied, such as landfill sites, wastewater treatment plants, anaerobic digesters, etc. Biogas typically comprises of 50-75% methane and CO2 along with other minor gases. It is the methane that is used for the generation of electricity or use as a fuel for transportation. Biogas is produced by anaerobic digestion where complex carbon molecules in organic material are broken down into simpler structures including CH4 and CO2. Biogas can be produced from a variety of biodegradable waste feedstocks including sewage sludge, biodegradable waste and mixed municipal waste or as a natural process of decomposition in landfills (Omer, 2007).

Woody biomass is usually converted into power through combustion or gasification. It can be specially grown in the case of energy crops. Wood waste makes up a significant proportion of municipal, commercial and industrial waste streams (Omer, 2007). The practice of dispose the waste in landfill where it slowly degraded and takes up valuable empty land is very usual, especially in Latin American cities. So, wood waste can be a good source of energy and an alternative to energy crops.

There are some factors that should be taken into consideration about waste management. Firstly, the environmental issues, e.g. forest conservation or environment pollution represent a large constrain to cities to implement energy from waste solutions. Second, the economic issues, such as current/future cost of construction, maintenance and repairs of plants, availability of materials and land required, also may create barriers to cities to implement these solutions.

The employment of waste as a resource is well exemplified in Nijmegen, Netherland. The city has a program focused on capturing energy from waste and putting it to reuse,

demonstrated on recycling rates, currently 67% of total waste and with a goal of 75% by 2020. Apart from asbestos, no more domestic waste stream has been dumped since the decade of 1990. The domestic waste is treated since 2013 in a fermentation plant that provides electricity and district heating to Nijmegen's residents and the surrounding regional communities (around 4,500 households). The fermentation plant produces composts and extracts green gas by using a biogas digester. This in turn is used to fuel the green bus fleet in Nijmegen. Pure CO2 is also produced for use in horticulture, and residual waste is incinerated with energy recuperation.

Policy Aspect: Some countries in the Europe connect the annual taxation for vehicles to their pollution performance. For example, Germany has set up different classes of vehicles for annual taxes imposed on cars owners. In the United Kingdom, the annual vehicle taxation is related to the CO2 emissions numbers, with six bands from better to worse (table 3). The least pollutant vehicles and the more energy-efficient ones benefit from considerable reduced tax fees, while large vehicles that are energy inefficient and more polluting have higher taxes, according to the Euro IV standards (Banister et al., 2007). Conversely, environmental sustainable measures in transport requires a radical change in people's life, making them reluctant to alter their behaviours, and this may represent a huge difficulty for the success of environment policies. For that reason, it is recommended to implement controversial policies in stages so that public acceptability can be build up in terms of positive results.

Table 3 - Annual Charges for Vehicle Taxation in London (£)

Band	CO_2 Emissions (g/km)	Diesel Car	Petrol Car	Alternative Fuel Car
AAA	Under 100	75	65	55
AA	101 –120	85	75	65
A	121-150	115	105	95
B	151-165	135	125	115
C	166-185	155	145	135
D	Over 185	165	160	155

Source: Banister et al. (2007)

5.2.2 Mobility

Dwelling standards are becoming more intricate and sub-urbanization is a continuous processes that represents one of the main aspects of medium-sized cities. Urban travel

length, both by private vehicles and by public transport, have been expanded as jobs and activities have become more spread. Associated to this, the large increase of car ownership in almost all countries provide people more freedom to travel everywhere.

Feasible Mobility: When we talk about green vehicles we refer not only to the car itself but the infrastructure that can maintain the green vehicles feasible for sustainable mobility. Requirements for production, storage, refuelling and maintenance facilities are necessary conditions for implement the mobility in cleaner modes. Since the autonomy of electric vehicles is still restricted - about 160 km when 100% charged or 100 km in city traffic conditions) - in comparison to internal combustion vehicles, it is necessary to create a larger electric supply network or battery swap for the user to be stimulated to opt for the electric vehicles. They are attractive for use in small to medium sized urban centres but not for traveling between cities. If the displacements continue to be limited to few kilometres, the user will keep preferring the internal combustion engine vehicle that have already a greater supply network. The recharging/ swapping stations can be, in general: at home, at work, on public roads, in long-time parking places, such as supermarkets and shopping malls, and in a battery swap station (a similar concept to gas station, where the batteries can be swapped in 2-3 minutes).

One of constrains to enlarge the electric supply network for green vehicles is that power shortages occur very often in many developing countries. Therefore, a public transport sector that depends entirely on electricity may not be a viable option for these cities. It is still controversial the increase of rail-based public transport (light rail transit - LRT) in medium-sized developing cities because, nowadays, we can count on new technologies that reduce to a minimum the differences between bus rapid system and electric trains, in terms CO2 emissions, capacity, and comfort. Also, LRTs may not be so environmentally-friendly as they seem especially if theirs energy source comes from a nuclear power plant, which is not a renewable source of energy at al. Buses that run on biofuel are already present in many cities over the world, and associated to BRT system, they have been a frequent low-cost strategy for sustainable transport in developing cities of Latin America.

In particular for small-sized cities, LRT needs strong and crucial advantages over bus systems to legitimate its implementation, since LRT construction and operation are very expensive. In Latin America context, LRTs exist only in larger cities such as, Buenos Aires, Rio de Janeiro and Santos. BRT system that operates with clean vehicles has been largely implemented in medium-sized cities in Latin America, both the full BRT version

(figure 15) and the simple BRT version (BRT-Lite), which includes unsegregated bus lane (painting in a different colour of a lane from the rest of the asphalt). The simple version is a low-cost solution for cities with lack of resources but it shows poor effectiveness of public transport in some situations, when there are limitations in narrow street, low level of respect for traffic rules, conflicts with other turning vehicles, among others.

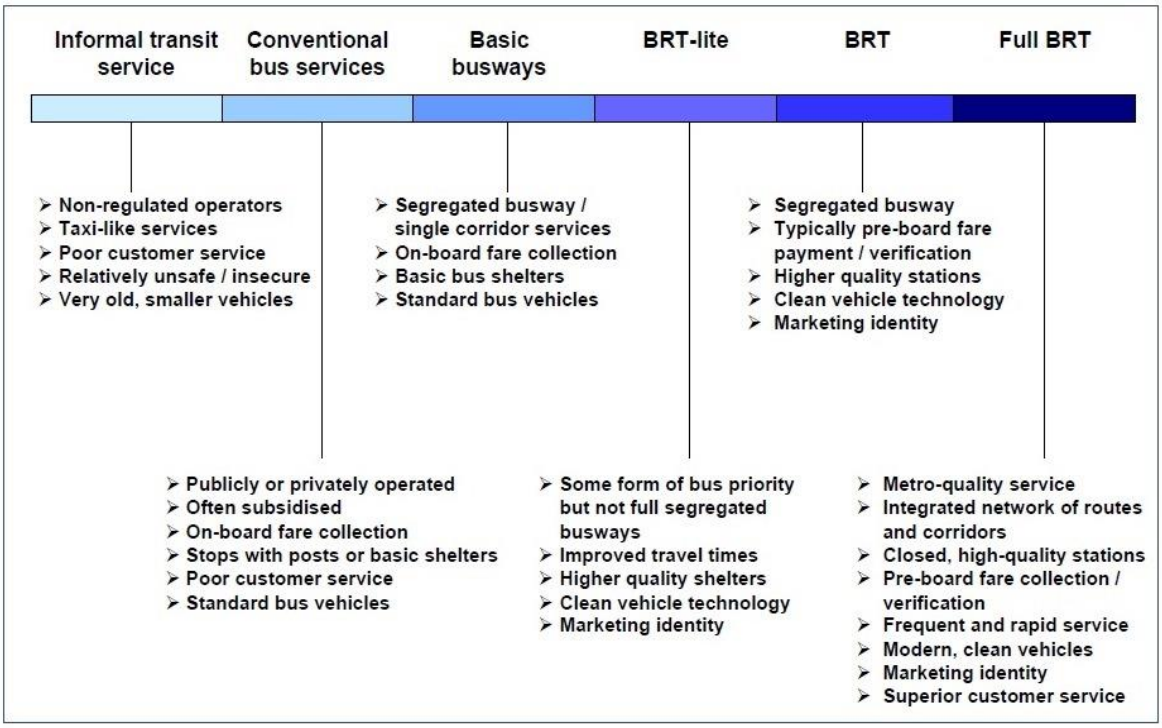


Figure 15 - Characteristics of bus services
(Source: Institute for Transportation and Development Policy, 2007)

Incentives and subsidy: Despite some difficulties of achievement, investments in clean vehicles is more feasible to implement for municipalities, as in a BRT fleet, than for private car owner, since the initial cost of clean vehicles is still higher than ICE vehicles and an individual user may not have economic power to acquire them. In order to increase the share of clean motorized transport, some governments offer to consumers financial incentives and grants to purchase clean vehicles and equipment suppliers, and also to natural gas fuels or others alternative fuels. The final user price, assigned to government incentives, around 40% to 60% below the gasoline price is usual in some countries which have showed successful implementation of natural gas vehicles. Examples in Argentina, Brazil (discount over the annual vehicle taxation) and Europe (Norway, UK, France, Germany, Netherlands, & Belgium), figure 16, demonstrate that subsidy programs and good advertisement shall be maintained for long time before propagation hits the point at

which those implementations become more significant, enough to cause a larger change of behavior. Long term programs are owing to the long life of a vehicle fleet and social and economic barriers as well.

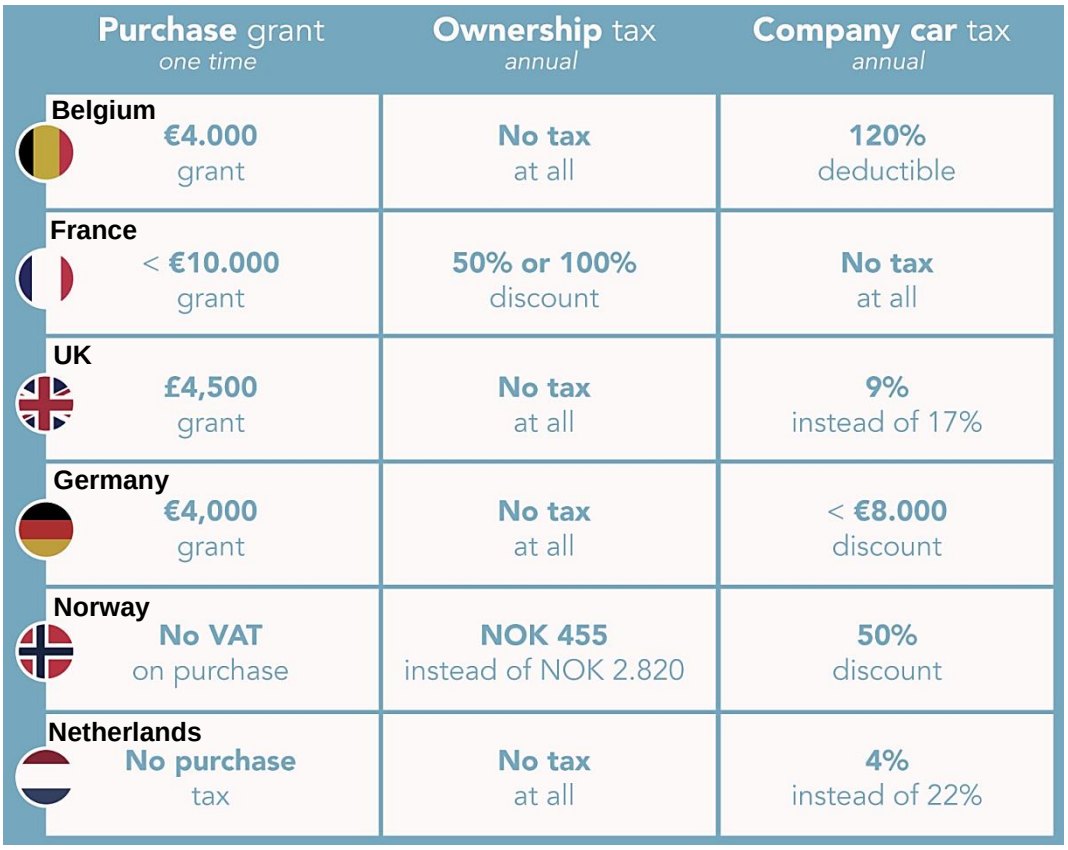


Figure 16 - Electric cars incentives in Western Europe.
NOK 455 is the annual road tax for clean or hybrids vehicles, as opposed to NOK 2.820 for petrol and NOK 3.290 for diesel cars.
(Source: https://blog.evbox.com/electric-car-incentives, 2017)

5.2.3 Socio-economic Growth

An efficient transport system is an asset for local, regional and international accessibility and, consequently, creates conditions for economic development. It is important to know that mobility of passengers is considered a crucial attribute of a modern society because the quality of life may declines without physical access to jobs, health, education and other amenities; economic growth may stagnate and poverty reduction may not be supported without physical access to resources and markets. For those reasons, the transport sector became a major economic sector characterized by both qualitative and quantitative growth.

New Demand: New opportunities and new markets for sustainable products and processes have been opened as cleaner transport has been developed. The possibilities are varied - a huge boost for eco-innovation and networks in the bio-economy and sustainable mobility - and more and more a new demand is created based on environmental measures and policies. Public transport, such as the bus concession and car sharing, can create new demands for biogas, equipment, spare parts, etc. the same way that companies can start new business in fields of car technology, bioenergy and bio-refinery.

Job Market: The same way, substantial employment opportunities may arise from sustainable transport. Also, the environmental education and the recycling culture and behaviour can be a breeding ground for green jobs, either linked to technology and innovation, or through programmes to improve the natural environment and reduce energy consumption. Recycling actions play an important role in the circular economy, managing waste, removing from environment recyclable garbage, by putting transformed and recycled goods back into the hands of customers.

Two examples of job market improvement are showed: First in Victoria-Gasteiz, Spain, where an environmental studies centre was set up at the end of the decade 1980. The centre's aim is to promote environmental education, training and research whilst, at the same time, providing practical and theoretical knowledge for future green jobs. The initial task was provide training for 'environmental technicians' in areas such as geography, environmental services to companies, and assessment of environmental impact. As it has developed, the centre has formed close relationships with universities and research organisations and has started designing courses for people with lower-level qualifications, and refresher courses for the municipality administration and private firms. These institutions perform a social role in aiding people who have had difficulty entering the job market gain employment and building their skills.

Second example is in Nijmegen, Netherland , where the cycling policy aims to improve the share of bicycle trips by 20% between 2017 and 2027. This policy has not only stimulated an active bicycle commuter population but it has also created sustainable employment in the sector. Recently, a research of the Radboud University concluded that many business have been created from repair shops to consultancies and have brought together more

than 20 businesses which operate in different markets within the cycling economy, from mobility consultants to infrastructure innovators, among others.

RES + Green Vehicle Scenario: From the economic point of view the introduction of RES will increase the cost of the system of 2% in 2050, and with penetration of electric vehicles the cost will be increased by additional 7% compared to the current scenario without any measures (Dedinec et al., 2016). However, the increase in costs can be amortized by reduction of production from coal and gas thermal power plants and the possibility of new created jobs associated with the higher penetration of RES, although a specific study is necessary to monetize this positive impact to the economy.

While some estimates indicate that in a few decades the capital costs of electric vehicles may decrease considerably, the ICE vehicles will remain cheaper. The availability of components of batteries (lithium) and fuel cells (platinum) constitute barriers to a higher penetration of electric vehicles. In the short term, the market penetration of electric vehicles in developing cities is not favourable. Another point of concern is the environmental impact of electric vehicles, which is linked to the way in that electricity is generated, stored, and distributed and the problems associated with the expired batteries and properly recycling issue. However, one point that needs attention is that fact that electric cars are still more expensive at the moment of purchase, but they have lower maintenance costs over their useful life, e.g. they do not require lubricants for the engine, less moving parts, etc. Also, they have lower costs per km if compared to internal combustion vehicles. In order to amortize the cost of acquisition through energy savings, an electric vehicle has to be used for significant long distances, more than 20,000 km per year (Pojani and Stead, 2015).

Various studies of green vehicles (electrical, battery, biomass and fuel cell technologies) has showed that the integration of transport sector into the energy system can give economic benefits and decrease CO2 emissions and fuel consumption (Mathiesen et al. 2007). But one of the constraints to reach this goal is the impossibility of construction of new biofuel power plants due to lack of investors and/or resistance of local community and non-governmental organizations. For that reason, the future plants should likely not produce more biofuel, instead they would be more effective by consuming less electricity and heat, thus demanding less investment costs to produce the same outcomes.

Circular Economy: The circular economy is one which makes use and reuse of all material in the production chain. One can consider something as waste but it can be a useful raw material for another. A true re-utilization of resources and primary example of this is the processing of organic waste into energy, as cited before.

In many cities, the collection and reuse of industrial waste is not a statutory task, so voluntary agreements with commercial companies and industry is necessary to improve recycling culture, reduce energy consumption and save resources. The use of general and specific awareness campaigns regarding behavioral change associated to cooperation with strategic partners (manufactures, supermarkets, schools and retail trade) is a good strategy oriented towards a circular economy, by processing each waste stream as sustainably as possible. Collection streams such as glass, drink cans and paper cardboard can be immediately reused as raw material by industry. The goal is to reach a realization that waste doesn't exist, but that it results in valuable raw materials. In many cities, residents pay taxes for their residual waste and the individual benefits of collection and processing waste streams can be emphasised as a convincing way to save money.

6. RESULTS AND DISCUSSION

The dynamics of the transport sector, the transition toward a more sustainable mobility and its integration to urban planning and energy system discussed in the analysis part are under new challenges. Small and medium sized cities deal with the “metropolisation” issues, i.e. urban development, economic growth and social equity needs. It must be pointed out that this transition requires multiple approaches combined and implemented in parallel, mainly based on infrastructure, technology, policies and also on community responsibilities. With respect to integration, the dense urban form allied to diversity of uses and a good public transport system, reduces the energy consumption, which is a global concern nowadays, particularly in terms of non-renewable resources.

In terms of infrastructure, the main accomplishments of sustainable transport in Latin American cities were shown in travel time reductions and amplified reliance on BRT systems. As the transport increased its efficiency, the system experienced reducing in energy consumption and CO2 emissions. The implemented systems proved the adequacy of BRT for variety of applications, from small to high demand, that are often associated with LRT. It is important to mention that most of the cities in Latin America have higher densities than European cities and much less car ownership (Hidalgo and Graftieaux, 2008). Moreover, after to BRT system implementation, large scale urban renewal and improvements in quality are evident in former degraded urban areas. A particular attention needs to be given to the entirely transformation of the dispersed and informal public transport services into regular and integrated system, very often seen in Latin America.

In the European context, the reappearance of tramways represents the main sustainable approach of developed cities. They have been largely integrated into measures for smart urban planning through the transit-oriented development fundaments, that use dense urban corridor as the main spine for urban development. Many cities are taking advantage of tramway works and TOD concepts as an opportunity to restructure the urban fabric, e.g. remodelling their downtown areas and historic districts, restoring local urban landscapes before distorted by cars, reconfiguring traffic by removing barriers, improving soft modes (walking and cycling), and so on. For this reason, investment in this modal must to be very high and implies dozens of months of roadworks in city centres, which are the major constrains for the tramway spread.

In terms of policies, the top-down approach on implementing sustainable transport depends on the level of governance. A combination of measures are needed to avoid ineffectiveness, and for this reason, the design of policies depends on feasibility and acceptability. Policy transferability is possible - from north to south, from larger cities to small ones and in the contrary way - but many variables must be analysed, e.g. city size, density, population growth, commuting characteristics, cultural preference and transport demand and supply. At the political level, there is the issue of implementing the sustainable policies within the political term of the elected policy makers (of four or five years). In many developing cities the transport sector does not figure on the political agenda as a urgent matter. Hence, immediate action in this subject is translated into poor planning and rushed commissioning. Given the vast diversity of policy solutions and constrains, it is very hard to define recommendations that can be suitable to all small and medium sized cities. However some degree of success may be accomplished if a pragmatic approach is used, rather than idealistic one.

Regarding community responsibilities, it is important public action and support to build successful sustainable mobility. Governments and technology cannot provide the answer to sustainability alone, so, a bottom-up approach is needed in addiction to measures and policies, especially in Latin American cities, where communities are more passive and take few action by themselves. In order to achieve a desirable change, sufficient public support and action may positively influence political thinking. Initiatives from citizens, partnerships between transport actors, and also voluntary agreement can contribute towards the goal of sustainable mobility.

Of course small and medium cities in both context faced some difficulties during the implementation and operation process of their transport transition, mainly in the financial matter. Actually, the difficulties starts in the planning process, for example when the new ideas for sustainable transport face public and political opposition to behaviour change. As a result, we can learn from cases studied and consider some general points:

- In the planning process: we can use experience from other cities as a guidance, but characteristics and local conditions shall be taken into account and adaptations in the system are required; Technical and engineering aspects of planning are important but shall be associated to financial, institutional and environmental aspects.

- In the decision procedure: new regulatory framework is necessary to implement new strategies of sustainable transport. Government plays a central role in the plan and also in the control of new mechanisms.
- In the implementation matter: do it gradually, in phases, because once the users experience the benefits, the barriers may diminish. Adaptation may be need after the initial phase of implementation; Education programs must receive proper attention and funds; Other urban development concepts need to be combined to transport strategies in order intensify the positive results. This can favour new projects of sustainability and expand existing ones.

This research also presented many benefits and constrains of transport and urban planning integration with the energy system, especially the renewable sources. The integration pass through aspects of environment, mobility and socio-economic growth, since the transport sector is one of major contributor to negative impacts. Having this in mind, the challenge of integration can be achieve by matching planning for long term objectives, in shorter term measures and solutions, including promoting green travel modes, shifting from fossil fuel to biofuels, electricity or hydrogen, and finding new eco-sources of energy. However, the feasibility of sustainable mobility is not easy to achieve, due to high cost and long term implementation. Two major constrains is to balance available land for both food production and biofuel crops, and to provide electric supply network for green vehicles. In both cases, private interests and government strategies are in opposite sides. Strong lobbies and social and economic barriers are common problems faced by municipalities.

It is important to know that mobility of passengers is considered a crucial attribute of a modern society because the quality of life may declines without physical access to jobs, health, education and other amenities; economic growth may stagnate and poverty reduction may not be supported without physical access to resources and markets. For that reason, the integration between transport and urban planning and the energy system should be seen as an opportunity to create new markets, to rise employment, and favour a circular economy where the production chain has no end by means of reutilisation of materials. An recycling culture can reduce energy consumption, save scarce resources and reduce prices. Saving money is a convincing way to emphasised the individual benefits of recycle culture and, consequently, the sustainable transport.

7. CONCLUSIONS

Under new urban challenges, transportation has gained considerable attention because of its role in the urban development. Mobility is a fundamental requirement for the satisfaction of human wishes to become involved socially and economically in the society. The underlying idea is that urban transport planning should preview and follow the continuous expansion process of cities, adapting to changes over time. Considering these issues, this research mapped out the measures and strategies for implementing sustainable public transport integrated to urban planning and energy system, in the scale of small and medium-sized cities. Two context were taken into account, Latin America and Europe. Their cities considerably differ one from another not only in demographic and dimensions indicators, but also in density, urban form and size, infrastructure, social and cultural behavior, etc. Still, there are many lessons that can be seized for urban transport planning, for instance, where urban planning has been used to improve the use of public transport, walking and cycling.

The transition toward sustainable public transport requires multiple approaches combined and implemented in parallel, because those combinations can work jointly, leading to impacts larger than the sum of their individual parts. Drawing on some examples of measures found in small and medium sized cities in Europe and Latin America, this research identified key lessons and multiple approaches, not identical in the north and south globe, that can offer great potential for transition to sustainable transport.

The effectiveness of the transport sector is essential for growth, employment and social development. It will not suffice to design and implement transport strategies independently, without others considerations of urban development, such as housing, health, education, leisure, etc. A combination of measures that strengthen each other and steer clear of unfavourable side-effects is needed. Cities should include in their participatory process all the key stakeholders, with broad coalitions including specialists, policy makers, researchers, academics, practitioners, and activists in the related areas of public transport, land use, environment, public health, urban affairs, engineering, green modes, etc.

Cities can consider transport solutions from both developed and developing countries but keep in mind that the appropriateness of different forms of transport development is context dependent. Good examples of measures was found in small and medium sized

cities in Europe and Latin America, particularly in Nijmegen, Vitoria-Gasteiz, La Rochelle, Pereira, and Mérida. But others larger cities have also showed best strategies that can be applied in small contexts.

In many occasions, governments had to adopt controversial policies, in order to reorganise and improve their transport sector. We can conclude that implementation in gradual phases, with possible adaptation after first results, is a good option to gather public support and acceptability. The public acceptability was a sensitive point to reach out because it requires the involvement of many stakeholders, including citizens, businesses, industry, etc. and both top-down and bottom-up initiatives are indicated. It is only with the support of a considerable majority of actors and political leadership that effective action will occur.

The impacts of the transport solutions are difficult to predict and cannot be standardized. So, they should be supported by analysis and monitoring of the effectiveness after implementation. In this research, we could find examples of good strategies that did not work as expected, so the behaviour of individuals and groups shall be assessed. Each situation requires separate analysis, including possibility to change or reverse the measures, if the results do not correspond to the goals of environmentally sustainable transport.

Communication and active involvement of different transport actors in the process is also crucial, “selling” the idea of sustainable transport to all stakeholders, and demonstrating the real need for shifting their travel behaviour and convincing them of the importance of their commitment. There are a wide range of positive results that can be emphasized and promoted, such as better health conditions, reduction of pollution and global warming, money savings, less car accidents, among others.

The research has shown that reductions of CO2 emissions and non-reliance on fossil fuels in the transport scenario are reachable, but very dependent on successful development strategies, funding resources and political willing. In addition, great aspirations of the transport integration mean a long term commitment. This can be further possible with intensification on investments in public transport and soft modals (and without use of the private car), enhancing the quality of life and social equity. Concerning the energy sources, within the transport sector, the design of a fully renewable energy

system is theoretically viable, but it should be analyzed in the context of each city, region and country potential, and requires deeper research as well.

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