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Higher quality public transport services for a sustainable mobility system in the Ecuadorian city of Cuenca towards 2025

Dissertation in Energy Systems and Policy

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ENERGY FOR SUSTAINABILITY • EFS

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Master Dissertation in Energy for Sustainability, developed in the specialization branch of Energy Systems and Policy, presented to the Faculty of Science and Technology of the University of Coimbra, as part of the requirements for the award of the Master Degree.

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ABSTRACT

The evolution of transportation has been a fundamental factor in the quest of economic progress for many countries and has enabled better living conditions for individuals. However, the propensity for using private motorized vehicles over collective and non-motorized modes observed in many societies has brought about multiple economic, social and environmental issues. As cities concentrate much of the demand for transport services, issues derived from increasing car use arise in urban areas in the form of local air pollution, traffic congestion, lost productivity due to time delays, social exclusion, among others. But, the effects of motorized transport transcend the local level and contribute to climate change as well.

Under that context, this master thesis explores the case of the Ecuadorian city of Cuenca. That city is an important center of economic, educational and social activity in the south of Ecuador, and thus experiences phenomena such as urbanization and urban sprawl; giving rise to fast-growing mobility needs. As higher disposable income is available among households, car use has been growing fast at the expense of other modes of urban mobility in Cuenca. Such mobility trends have leaded the transport sector to be largest source of greenhouse gas (GHG) emissions locally. Besides, the provision of good alternatives to private transport is quite poor. All those factors make mobility in Cuenca unsustainable.

To reverse such situation the city aims for reducing car use in 10% by 2025 and is committed to maintain the 2009 levels of GHG emissions by 2030. Given this, the present study proposes a plan for prompting modal shift under the sustainable mobility paradigm and analyzes its potential for reducing GHG in Cuenca. Evidence suggest that improvements in service quality of public transport is the most feasible alternative for increasing public transport ridership; and more particularly, transforming the conventional-bus system into a more attractive option for urban mobility. For that purpose, measures enhancing aspect such as accessibility, comfort, information, customer services, among others are analyzed. And even when the plan proposed in this study has a limited potential for curving both car use and GHG emissions in Cuenca, the introduction of such measures constitute a necessary step in order to reorient travel patterns in Cuenca.

Keywords: modal shift; car use; service quality; sustainable mobility

RESUMO

A evolução dos transportes tem sido um fator fundamental na busca do progresso econômico para muitos países e permitiu melhores condições de vida para os indivíduos. No entanto, a tendência para a utilização de veículos privados motorizados em detrimento de modos coletivos e não motorizados que se observa em muitas sociedades criou um conjunto de problemas económicos, sociais e ambientais. Enquanto as cidades concentram a maior parte da procura de serviços de transporte, questões relativas à crescente utilização do automóvel surgem em áreas urbanas sob a forma de poluição, congestionamento do tráfego, perda de produtividade devido a atrasos de tempo, exclusão social, entre outros. Mas, os efeitos do transporte motorizado transcendem o nível local e contribuem para as alterações climáticas.

Neste contexto, esta tese de mestrado explora o caso da cidade equatoriana de Cuenca. Essa cidade é um importante centro de atividade económica, educacional e social no sul do Equador, e assim experimenta fenômenos como urbanização e expansão urbana; dando origem a crescentes necessidades de mobilidade. Quanto maior a renda disponível nas famílias, maior o uso do automóvel individual motorizado. Tais tendências de mobilidade tornam o sector dos transportes na maior fonte de emissões de gases de efeito estufa (GEE) em termos locais. Além disso, a disponilidade de boas alternativas para o transporte privado é escassa. Todos esses fatores tornam a mobilidade em Cuenca insustentável.

Para reverter tal situação para a cidade dever-se-á apontar para reduzir o uso do carro em 10% até 2025 com o compromisso de manter a níveis de 2009 as emissões de GEE até 2030 de acordo com o plano de mobilidade de Cuenca. Nesse sentido, este estudo propõe um plano para induzir a transferência modal e analisa o seu potencial de redução de GEE em Cuenca sob o paradigma da mobilidade sustentável. Evidências sugerem que melhorias na qualidade do transporte público são a alternativa mais viável para aumentar a utilização dos transportes públicos; mais particularmente, transformando o sistema convencional de autocarros numa opção mais atraente para a mobilidade urbana. Para o efeito, medidas de melhoria tais como a acessibilidade, conforto, informação, serviços ao cliente, entre outros são propostos. Mesmo que o plano proposto tenha um potencial limitado para modificar o uso do carro e as emissões de GEE, a introdução de tais medidas constituem um passo necessário a fim de reorientar os padrões de mobilidade em Cuenca.

Palavras-chave: transferência modal; uso do carro ; qualidade de serviço; mobilidade sustentável

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ABBREVIATIONS

BAU	Business as usual scenario
BRT	Bus Rapid Transit
CO_2	carbon dioxide
EMOV-EP	Municipal Agency of Mobility of Cuenca (Empresa Pública Municipal de Movilidad Tránsito y Transporte de Cuenca)
EU	European Union
gCO_2eq/km	Grams of carbon dioxide equivalent per kilometer
GDP	Gross domestic product
GEE	Gases de efeito estufa (meaning greenhouse gases in Portuguese)
GHG	Greenhouse gases
$GtCO_2eq$	Gigatons of carbon dioxide equivalent
IADB	Inter-American Development Bank
IEA	International Energy Agency
Km	kilometer
LA	Latin America
LDV	light duty vehicles
mboe/d	Million barrels of oil equivalent per day
$MtCO_2eq$	Megatons of carbon dioxide equivalent
NO_2	Nitrogen dioxide
NOx	Nitrous oxides
OECD	Organization for Economic Cooperation and Development
OICA	International Organization of Motor Vehicle Manufacturers
PMEP	Plan of Mobility and Public Spaces of Cuenca (Plan de Movilidad y Espacios Públicos de Cuenca)
PM	Particular matter
PT	Public Transport
SO_2	Sulfur dioxide
sq. km	square kilometer
tCO_2eq	tons (1000 kilograms) of carbon dioxide equivalent
UNEP	United Nations Environmental Programme
UK	United Kingdom
US	United States
USD	United States Dollar
VAT	Value-added Tax
VKT	Vehicle kilometers traveled
WHO	World Health Organization

1 INTRODUCTION

When disposable incomes grow higher in an economy, private motorized vehicles become more affordable for a larger number of individuals, and thus much of the demand for urban mobility is satisfied through such means, particularly cars, as they offer more autonomy and comfort than collective and non-motorized modes of transport. In many cities, increasing levels of car use have been capable of congesting infrastructures that support urban transport systems, roads in particular, which carries costs in terms of productivity due to time delays. Car use also contributes for accumulation of both pollutants that affect the quality of air locally and greenhouse gases which carry global effects. And when cars rank at the top of the hierarchy of urban mobility options several social issues also come up.

Under that context, the present master thesis seeks to explore the case of the Ecuadorian city of Cuenca since some concerns related with its transport sector have arisen lately. The whole canton Cuenca (city and rural areas) congregates more than 580,000 persons. Urban Cuenca is considered the third most prosperous city in Ecuador. But such characteristic have generated urbanization and rapid urban expansion; leading to high dependency on private cars. In a recent study carried by the Inter-American Development Bank (IADB, 2014) the mobility in Cuenca was labeled as unsustainable mainly due to the high rates of use of private cars that provoke important levels of traffic congestion, especially in the city center, but also, because transportation is the largest source of GHG emissions in the canton, 57% of total local emissions. The car stock in the canton Cuenca, 160,000 vehicles by 2014, increases at least 10% per year (GAD-C, 2015). Such rates of motorization are deemed excessively high for a medium-size city in the Latin American (LA) context.

The Municipality of the canton Cuenca, recognizing that current transportation patterns are deteriorating the quality of life of the citizens, has defined certain objectives in order to reorient the way in which people move inside that city. By defining a plan for mobility and public spaces towards 2025 (GAD-C, 2015), the municipality aims, among other things, to prompt a 10% modal shift from passenger cars to public means of transport. Besides, the canton seeks to maintain the 2009 levels of GHG emissions by 2030, which for the transport sector represents 673,000 tCO_2eq; and avoiding 10 million

tCO_2eq emissions through 2050 by (1) discouraging the use of private cars in favor of sustainable means of transport and (2) reducing mobility needs (IADB, 2014).

By analyzing the factors that lead car use to be a problem for that city, the specific objective of this master thesis is to propose a plan to support the 10% modal shift target that Municipality of Cuenca aims towards 2025. For that purpose, the present study explains specific policies and strategies able to prompt changes in the way people travel in Cuenca under the sustainable mobility paradigm; which systematically address economic, social and environmental aspects of urban mobility.

Different types of strategies can be used in order to prompt modal shift depending the context; some of them point to discourage car use by increasing the cost of driving; and some others seek to persuade people about using more sustainable modes of mobility instead of cars. For the case of Cuenca, evidence suggest that improvements in the service quality of public transport (PT) is at this moment the most feasible alternative for curving car use; particularly, transforming the conventional-bus system into a more attractive option for urban mobility. Based on the perceptions of the citizens of Cuenca about several attributes of PT services – accessibility, information, comfort, cleanliness, customer service, etc. – this study proposes a plan which contemplates specific actions able to lead to PT ridership uplifts. Finally, some projections done by the end of this study suggest that the gains in PT ridership coming from the execution of that plan would contribute modestly to the 10% modal shift goal towards 2025; however, gains in terms of social sustainability would be significant for Cuenca.

Coming next, a literature review on the evolution of mobility, its implications and the sustainable mobility paradigm is provided. Following, the methodology applied for the analysis of the case of Cuenca is outlined. Then, the present study exposes general elements that configure mobility patterns in Cuenca. After that, a plan for prompting modal shift in urban Cuenca is proposed. Finally, some conclusions are drawn.

2 LITERATURE REVIEW

2.1 The evolution of mobility and its implications

Technological innovations have improved mobility of people, goods and information offering multiple travel options which have spurred economic development and better living conditions for many societies. However, in the presence of increasing mobility demands, our travel decisions, particularly in terms of personal mobility, carry negative consequences of different type that need to be fully understood in order to make tradeoffs between those mobility needs and the unwanted consequences of transportation.

2.1.1 Background

Transportation has notoriously evolved in the last two centuries, particularly due to the industrial evolutions and the use of fossil fuels to power vehicles. The modernity of the transportation started with the invention of steam powered technologies that spurred the railway industry after the first industrial revolution; later, it continued with the emergence of industries dedicated to serial manufacturing of automobiles in the second industrial revolution; and more recently, we have witnessed the use of ITC meant to facilitate mobility in the so-called digital era (Van Audenhove et al., 2014). And innovations in the transport sector will continue to come up; especially seeking to reduce the energy intensity and switching energy carriers used for motorized vehicles.

Factors such as the increasing income levels and economic growth observed during the last century in many countries, as a result of the industrialization, but also, the constant quest for higher levels of comfort of individuals have boosted ownership of motorized vehicles and kilometers traveled at expense of both usage of massive means of transport and non-motorized mobility. The autonomy that cars brought to individuals has spurred personal mobility for many years, but at the same time, has make of the transport sector another factor for unsustainable development (Davison & Knowles, 2006). Besides, in modern societies owning and using a car is regarded as a proof of success and also as an essential element of modern lifestyles (Hickman & Banister, 2014). Around ten billion trips are made every day in urban areas across the world mostly by means of high carbon and energy intensive private motorized vehicles (Rode et al., 2014).

Urban transportation, in particular, represents more than 60% of total kilometers travelled worldwide (van Audenhove et al., 2014); therefore many of the unwanted consequences derived from current mobility trends arise in cities. And if such trends are not reversed it is projected that the global car stock is going to sum up between 2 and 3 billion cars by 2050 (IEA, 2009), scenario that will further aggravate all those negative impacts transport sector generates nowadays. Some of those effects are discussed next.

2.1.2 Local air pollution

The combustion of fossil fuels in vehicle engines, as well as brake and tire wear, generates substances that pollute air and in high concentrations are harmful for living organisms. Such substances - carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and particular matter (PM) - have mainly local or regional effects. According to a report of the OECD (2014) air pollution is the major environmental cause of premature deaths in the world and causes more deaths than traffic accidents in most OECD countries. Globally, air pollution is attributed 3.4 million deaths per year. And since car ownership and usage keep growing frenetically in many parts of the world, air pollution in urbanized areas will continue to be a major issue in terms of public health.

In the case of CO, it is a colorless and odorless gas generated by combustion processes of motor vehicles which pollutes ambient air, especially urban environments. That substance is capable of causing harmful health consequences by limiting oxygen delivery to body’s organs and tissues and in very high concentrations can cause death (WHO, 2015).

Belonging to a group of gases known as oxides of nitrogen, NO_2 is a substance formed from gas exhaust generated by cars, trucks, buses and other fix sources. When present in the air, that substance contributes to the formation ground-level ozone by reacting with sunlight. High concentrations of ozone at the ground level can cause multiple lung problems and respiratory diseases. Moreover, NO_2 contributes to the formation of particular matter. In the case of SO_2, it is an air pollutant generated in places where vehicle fuels have high sulfur content and generates breathing problems and can damage the human respiratory system (United States Environmental, 2016).

Particular matter (PM) forms in the atmosphere and is a complex mixture of solid and liquid particles. Sulfates and nitrates generated by automobiles and other sources combine with ammonia, black carbon, dust and water and that mixture can remain suspended in the air. When this particles have a dimension of 10 microns or less (PM_{10})

they are so tiny that can enter into the lungs, and in dimension of 2.5 microns or less ($PM_{2.5}$) can get into the bloodstream (OECD, 2014).

The UNEP (2006) state that up to 90% of air pollution in major cities of developing countries has been generated by vehicle emissions; due to high number of old vehicles, poor vehicle maintenance, inadequate infrastructure and poor fuel quality. In LA countries traffic was the single major source contributing to total PM_{10} formation totalizing 38% by 2012; share which was the largest compared to other regions across the world (WHO, 2015). Similarly, traffic in all LA countries, but Brazil, contributed 30% for total $PM_{2.5}$ formation by 2012.

2.1.3 Climate change

Road transport is major source of greenhouse gas (GHG) emissions, and carbon dioxide (CO_2) in particular, due to combustion of fossil fuels in motor engines. The use of hydrocarbons, either for transportation or for other purposes, has extended for more than a century, starting with more impetus in 1900 (The Economist, 2001); however, the effects generated by the accumulation of GHGs have been more noticeable in recent decades. The United Nations Framework Convention on Climate Change (UNFCC) officially recognized the climate change issue in 1997 (Barrett, 2003). Nowadays, anthropogenic emissions of GHGs are widely accepted in the scientific community as the principal cause for climate change (Yigitcanlar & Kamruzzaman, 2014). CO_2, in particular, is considered the most harmful of all GHGs because of its contribution to global climate change (Brand & Preston, 2010).

Climate change is the most complex externality that road transport has to deal with (Santos et al., 2010). Stern states that: (1) climate change is a global problem, thus the consequences affect the whole planet regardless where the emissions take place; (2) the effects of climate change are persistent in the long term; (3) there is uncertainty about the scale, form and the time of the effects; (4) it is possible that important changes generated by the rise of global temperatures will be irreversible (Stern, 2006).

The transport sector generated 7.0 $GtCO_2eq$ (14%) of directly attributable GHG global emissions during 2010 (Fig. 1); which represented nearly 23 per cent of total energy-related CO_2 emissions totalizing 6.7 $GtCO_2$ (Sims et al. 2014). Moreover, transport-related GHG emissions have more than doubled comparing 1970 and 2010, fact that denotes that the emissions in that sector have increased faster than in any other energy end-use sector (Sims et al. 2014). Finally, from total direct GHG emissions attributable to transport (7.0 $GtCO_2eq$) approximately 80% were generated by road vehicles in 2010 (Sims et al. 2014).

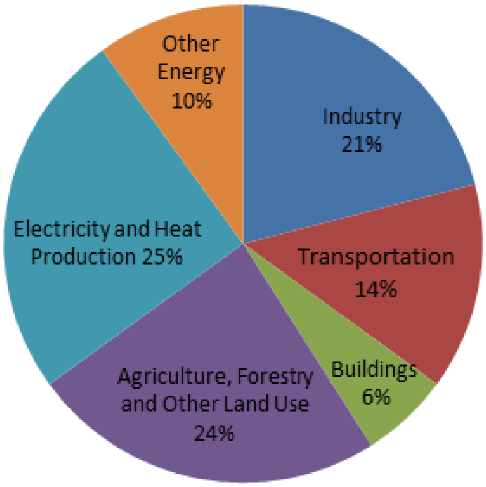

Figure 1: Global Greenhouse Gas Emissions by Economic Sector by 2010 (Sims et al. 2014)

Under a Businesses as usual (BAU) scenario, GHG emissions are expected to increment 50 % towards 2035 and nearly double by 2050 (IPCC, 2014a). That trend implies that mean surface temperature would rise between 3.7°C and 4.8°C by 2100 compared to pre-industrial mean temperatures (IPCC, 2014a); scenario that would carry severe consequences for the natural equilibrium of the planet.

As noticed in figure 1, industrial activity, agriculture and energy generation are also important contributors of GHG emissions at global scale, but, different to perspectives for abatement on those sectors, curving emissions in the transport sector prove to be more costly and harder to achieve (Banister, 2011). Several reasons can be considered for this to happen; countless small emission sources, deep-rooted habits related to car use, high expectations for car ownership in emerging economies, technological limitations for carbon-free vehicles, among others.

Moreover, studies based on life cycle assessment methodology reveal that substantial carbon emissions are embedded in infrastructures that support road transportation, especially during the production of highly energy and carbon intensive materials such as iron, steel and cement. Normally, an extra 63% of on-road emissions from vehicle operations are imputable to transport infrastructures (Chester & Horvath, 2009).

In Latin-American countries, sectors other than transportation have historically been major sources of GHG such as land use, land-use change and forestry, and agriculture (IEA, 2015a). Moreover, energy-related CO_2 emissions in LA are quite lower than the global average. Nevertheless, the transport sector in that region was the largest source of energy-related CO_2 emissions by 2013, approximately 0.4 $GtCO_2eq$ out of 1.1 $GtCO_2eq$ (IEA, 2015a). Projections to 2030 suggest that CO_2emissions in LA will continue to increase, in part, due to increasing car ownership (IEA, 2015a).

2.1.4 Resource depletion

For several decades now, the transport sector has mainly depended on oil products as source of energy, principally because of their extremely high energy density and relative ease of transport and storage. By 1973, 94.3% of the energy requirements of the transport sector came from oil (IEA, 2015b); such dependency has not changed significantly through the years; by 2012 the share of oil as energy source was 93% (IEA, 2015b). Compared to oil, the shares of other sources of power such as natural gas (4%), biofuels (2%) and electricity (1%) were small (Fig. 2).

By 2012, the transport sector was accountable for 27% of the total final energy consumption, share that had not changed significantly compared to the 1974 levels when the energy consumption represented 23 per cent of the total (IEA, 2015b).

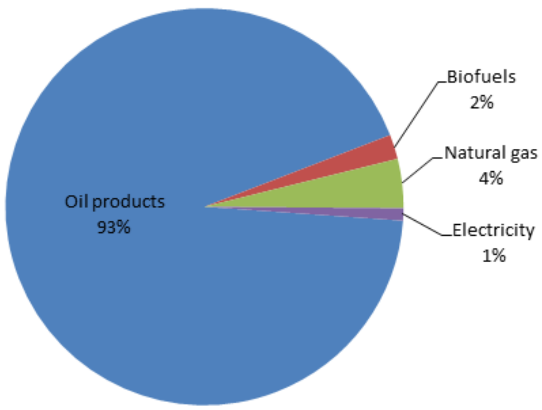

Figure 2: Global energy use for transportation by source in 2012

(Source: IEA, 2015b)

However, the share that the transport sector represents in terms of global oil demand has increased in the last four decades. In 1974, the use of oil products for transport summed up 45 % of the global oil demand; by 2012, that shared increased to represent 64 %

(IEA, 2015b). According to estimations from the OPEC (2016), road transport alone was the largest oil-product consumer by 2015 requiring nearly 39 mboe/d out of a global total demand of approximately 85 mboe/d, outpacing air and rail transportation and other sectors; such as industry, electric generation and household uses.

Furthermore, projections suggest that, regardless the emergence of non-liquid-based vehicles, the consumption of oil products and other liquid fuels is expected to grow at around 1 % rate per annum on the 2025 horizon (BP, 2015a). Under current trends, transportation is going to account 63% of the total growth in world's consumption of crude oil and other liquid fuels between 2010 and 2040 (IEA, 2012). Most of the increase in the use of energy for transportation is expected to take place in emerging countries, especially in India and China, mainly due to economic growth and population explosion (Rodrigue et al., 2013).

Considering that oil is a finite resource, questions about its future availability are always present. The strong oil dependence of the transport sector can be regarded either as a scarcity problem, as reliability issue related with strong price fluctuations or, as a trade issue (Proost & Van Dender, 2012). That argument is reinforced by the fact that more than 50 % of proven oil reserves are concentrated across only 4 countries; Venezuela, Saudi Arabia, Canada and Iran (BP, 2015a), which results problematic for most other countries, especially those not having their own oil reserves,

In most Central and South American countries oil consumption reached levels up to 0.75 tonnes per capita by 2014; which are among the lowest at regional scale. However, countries such as Ecuador, Chile and Venezuela showed higher oil consumption levels, ranging between 0.75 and 1.5 tonnes per capita in 2014 (BP, 2015b). Ecuador and Venezuela apply high subsidies on the internal prices of vehicle fuels; somehow explaining higher levels of consumption of oil products.

2.1.5 Traffic congestion

Increasing levels of car use along with rapid urbanization lead to higher levels of road congestion, and when the infrastructure that supports transport is congested, one more vehicle in the road reduces the travel speed and the travel time reliability of all users (Proost & Van Dender 2012). Urban congestion generates losses of productivity due to the high operating costs incurred by an extensive and spatially inefficient use of private vehicles. For several countries in the European Union (EU) and some states in United

States of America (US) the costs of congestion represents over 0.7 % of the gross domestic product (GDP) per year and millions of gallons of fuel wasted (Hoballah & Peter 2012).

For certain developing cities such costs are even higher. According to Hoballah & Peter (2012), the cost of congestion for Buenos Aires and Mexico City represented 3.4% and 2.6% of the national GDP respectively. But economic loses are larger for Lima, where approximately USD 6.2 billion (representing 10% of GDP) is attributed to congestion; moreover, up to four hours a day are wasted by some citizens when commuting inside that Lima (Hoballah & Peter, 2012).

There is an apparent correlation between urban congestion and pollution. In congested cities, where road speed is low, pollution levels are comparatively higher to cities with fluid traffic flows (Dulal & Akbar, 2013). Traditionally, the response to address traffic congestion used to be the provision of more road capacity; however, it has been widely demonstrated that such measures rather induce more traffic.

2.1.6 Urban expansion

Cities worldwide are responsible for approximately 70 % of global energy consumption and more than 70 % of related carbon emissions (IPCC 2014b). GHG emissions generated in cities are basically determined by four factors: the economic basis of the city, either it is an industrial or a service economy; the land use patterns of the city; the physical arrangement and structure of its transport system; and its waste management system (Dulal & Akbar, 2013). Despite agreeing in some of those factors, for Floater et al. (2014) population growth, income growth and market failures are also determinant factors for the generation of GHG emissions in urban environments.

Land use for the development of urban infrastructures has both direct and indirect environmental impacts (Yigitcanlar & Kamruzzaman 2014). Direct impacts are generated when soils in natural state are transformed into spaces occupied by urban infrastructures which affects the natural ability soils to sequestrate carbon; besides disrupting additional environmental services soils provide and generating more and more impervious surfaces that affect the water cycle. Besides, land use patterns modify the urban form which influences the distances people need to travel inside cities for multiple purposes; which consequently increases emissions of transport-related pollutants. These sequences clearly explain the interaction between land use, transportation and the environment.

2.2 Sustainable mobility systems

2.2.1 The sustainable mobility paradigm

Sustainability is an approach coming up from the awareness that human activities generate major environmental impacts that can cause economic, social and ecological costs. In 1987 the Brundtland Commission formally provided the stepping-stone about sustainability when they pointed that sustainable development “meets the needs of the present generations without compromising the ability of future generations to meet their own needs” (Brundtland et. al., 1987), Based on that concept, sustainability paradigm took shape by incorporating not only certain issues related with resource consumption, but also, economic and social welfare, equity, human health and ecological integrity (Litman & Burwell, 2006).

Sustainable mobility aims to ensure that multiple environmental, economic and social issues are regarded when making decisions affecting transportation activity (MOST, 1999); however, that is not a simple task as transport impacts have implications of different type (Fig. 3).

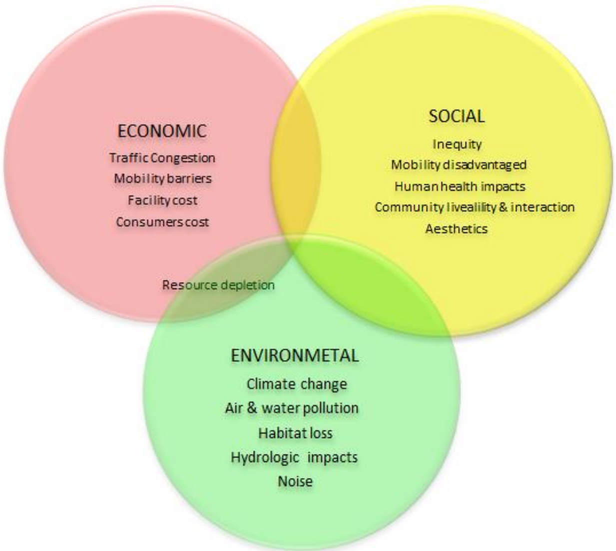

Figure 3: Transport impacts on sustainability

(Based on: Litman & Burwell, 2006)

Therefore, sustainable transport tends to favor integrated actions aiming to balance all three planks by providing a framework and tools for long-term and comprehensive planning. According to ECMT (2006) a sustainable transport system is meant to:

- Allow individuals, firms, and societies to meet their elementary mobility needs in such a way that preserves human and ecosystem health, and promotes equity within and between future generations,
- Be affordable, efficient, offer alternatives for mobility, support a competitive economy and stable regional development, and
- Restrict emissions and wastes within the absorptive capacity of the environment, use renewable sources within the levels of natural replenishment, and use non-renewable resources within the rates of development of renewable substitutes, while minimizing negative effects on the use of land and the generation of noise

And in order to addresses all those aspects, the sustainable mobility paradigm proposes four main objectives (Banister, 2008) namely: avoid trips; modal shift from private to sustainable means of transport; reduce travel distance; and the use of cleaner vehicles. This approach disregard the provision of new road infrastructure as central measure to cope with increasing travel demand; rather, it suggests that the interventions in the supply side of the transport sector should prioritize the provision of infrastructure for non-motorized mobility, a better management of the existing infrastructure and improvements on the PT service. Table1 presents a compilation of some of the specific measures under those four main strategies.

Mobility management strategies seek mainly to influence people's travel behavior in order to reduce total vehicle kilometers traveled (VKT); while cleaner vehicles technologies and most technological innovations point to reduce emissions rates and fuel consumption per unit of distance. For Litman (2013) mobility management strategies generally achieve more planning objectives than cleaner vehicle strategies. However, Moore et al. (2010) state that aiming to reduce VKT is a blunt objective because it basically relies on changing human behavior and settlement patterns to increment PT use and reduce automobile travel instead of directly attending GHG emissions as some cleaner vehicle strategies do. Moore et al. (2010) also point that VKT reduction strategies are among the most costly and least efficient options.

Table 1: Strategies for sustainable mobility

Mobility management strategies			Cleaner vehicle strategies & Technological innovation
Avoid Travel	Modal shift	Reduce travel distance	
Teleworking	Fuel taxes	Land-use policies for new developments	Emission standards
Teleshopping	Congestion pricing	Mixed-use development and sprawl containment	Fuel economy
Teleconferencing	Parking management	Development taxes	Car sharing and Bike sharing schemes
	Fare subsidies	Residential parking restrictions	Fuel quality improvements
	Provision of infrastructure for walking and cycling		Alternative fuels & electrification
	Accessibility Improvements		Bus rapid transit (BRT) systems
	Public transport improvements		
	Car-free districts		
	Physical integration for multi-modal journeys		

(Based on Banister, 2008)

On the other hand, cleaner vehicles consume less energy and reduce emissions, and usually reduce fuel costs, but all those gains are offset by increased ownership costs (upfront and maintenance) to achieve a given level of performance (Litman, 2013). This type of strategies also involves behavioural changes at the moment of making purchase decisions for changing vehicles. Amid the debate on the effectiveness of both types of strategies for prompting sustainable mobility, evidence demonstrates that in order to curve emissions and improve local transport systems comprehensive solutions combining a variety of measures should be devised (Dalkmann & Brannigan, 2007).

Several of the measures exposed in table 1 look for voluntary responses from people, i.e. car sharing schemes or PT improvements. Other work on an incentive basis and seeking to lead to rational decisions (in the economic sense) at the moment of making travel decisions, i.e. economic instruments, such as fuel taxes or road pricing. Finally, the most restrictive measures are those that by means of ordinances and legislation establish legal rules (Dalkmann & Brannigan, 2007), i.e. emission standards, traffic restrictions, etc.

2.2.2 Sustainable mobility management strategies

2.2.2.1 Strategies for avoiding travelling

The use of information and communication technologies to work, communicate, shop and execute personal dealings without travelling, are ways through which recurrent journeys taken by personal vehicles might be avoided, and thus urban traffic congestion is reduced as well. But, when it comes to reducing carbon emissions, pollution and energy consumption the effect of working outside a formal working place, known as teleworking, is relative. Any gains derived from that particular strategy depend on emissions generated by staying at home (use of household appliances), the energy mix, the travelling distance that is avoided, and the possibility of rebound effect on car use (Santos et al., 2010).

2.2.2.2 Strategies for modal shift

Stimulating a shift of car users to PT is a commonly regarded as a key policy aiming to reduce energy requirements and environmental impacts of the transport sector. Multiple mechanisms have been proposed in order to encourage modal shift to sustainable means of transport; pricing instruments, development of infrastructure for non-motorized mobility and other “soft” measures that involve improvements in the quality of service of sustainable means of transport. The latter type of measures is going to be analyzed in detail in coming chapters under the context of the city of Cuenca.

Pricing policies in transport, under the principles of welfare theory, are meant to promote economic efficiency by making prices reflect the full cost of providing roads, parking, fuel and insurance (Litman, 2013). And under the sustainable mobility paradigm, it is a matter of equity to make drivers carry the external cost of choosing to travel by private cars.

From that perspective, prices should cover the social marginal cost which is the total cost to society as a whole for taking one further action in an economy. In this case, it is an extra unit of transport activity (Van Essen et al., 2008); for example an extra kilometer travelled or an extra gallon of gasoline consumed. Nash et al. (2001) explains the application of pricing policies, particularly in European Union (EU), has been conceptualized in two moments. Initially, pricing policies aimed to charge users for the utilization of transport infrastructures based on the marginal operation and maintenance cost. But later, the importance of environmental issues led policymaking to address the external costs of transport such as noise, congestion, emissions, accidents, etc.

Nevertheless, pricing instruments have certain limitations as they are not comprehensive in addressing multiple transport externalities at once. For example, fuel taxes are meant to address externalities related with consumption of fossil fuels but that is just a part of the total external cost that car usage imposes to society (Anas & Lindsey, 2011).

But on the other hand, price instruments allow consumers to limit emissions in ways that appeal them the most; investing in technology with higher fuel efficiency, using smaller vehicles, driving less, or adapting driving style (Proost & Van Dender, 2012).

Fuel taxes

The most common example of this type of charges is the application of fuel taxes aiming to limit fuel consumption. Fuel taxes bring advantages when making driving more expensive and reduce kilometers traveled (Parry & Small, 2005) with no risk for rebound effects. Gasoline and diesel taxes have been used in Europe and Japan and at some point have reached over 200% of the product price. Such taxes constitute both a carbon tax and an important consumption tax able to address energy supply issues (Proost & Van Dender, 2012).

Congestion pricing

From the economic point of view, road congestion is the effect generated when the demand for a road reaches its full capacity generating lower speeds of vehicle transit and longer traveling times (Dias, 2015). The costs generated by time delays and extra fuel consumption are borne directly by all motorists, yet an externality is generated since individual motorists increment those costs for other motorist (Anas & Lindsey, 2011). Congestion can be reduced by extending road infrastructure or managing (pricing) the use of road infrastructures. However, extending road infrastructure can increase VKT and consequently fuel consumption and related emissions; reason why it is not regarded a real solution under the sustainability approach.

Congestion pricing requires tolls to charge drivers the cost that congestion generates for other drivers (Dias, 2015). By reducing road usage, those charges ensure that road infrastructure is used by those that value it the most (Proost & Van Dender, 2012). However, pricing tolls according to the marginal social cost principle is not simple. The difficulties come up due to the fact that general cost of a trip fluctuates with fuel consumption and the cost that time has for drivers and passengers (Dias, 2015). Moreover, congestion levels change by time of the day, week and season; thus, toll should be able to adapt to those variations which in practice results difficult (Anas & Lindsey, 2011).

There are few experiences in the application of congestion pricing systems inside urban areas. Singapore was the pioneer when in 1975 that city launched a cordon scheme that restricted three zones in the proximities of the business district aiming to control the traffic flowing to that area (Anas & Lindsey, 2011). In 2003, London implemented a zonal scheme through which motorists are not only charged when entering of leaving that delimited zone, but also, when circulating inside that zone (Anas & Lindsey, 2011). After 10 years of the implementation of that scheme, the transport authority of that city, Transport for London, reported a 10% reduction in traffic volumes from the initial levels and a total reduction of 11% in VKT from 2000 to 2012 (TfL, 2014).

Public transport price

PT displays economics of scale when increments of ridership prompt an increase in the frequency of the service, spacing of stops, density of lines and service reliability (Anas & Lindsey, 2011). Then, ridership growth reduces average operational costs, but also, reduces average user's costs as waiting times are reduced (Basso & Silva, 2013). This configures the so-called Mohring effect (Mohring 1972) which explains that PT fares should consist of a component equal to the marginal social cost together with a subsidy that reflects the positive externalities of bus ride demand (Anas & Lindsey, 2011).

Moreover, the implementation of subsidies on PT fares has been justified on the grounds of efficiency considering those subventions as an instrument to reduce non-charged externalities derived from car use (Dias, 2015) such as congestion, pollution and noise. That argument is based on the fact that car use is a substitute service for PT services (Basso & Silva, 2013). In this case, the reduction of the bus-ride fares by means of subsidies is considered a second-best option since car use externalities are not charged (Anas & Lindsey, 2011; Basso & Silva, 2013). Finally, the application of this type of subsidies has a justification when considering that PT is highly demanded by low income segments; thus, those subventions can have effects on income redistribution (Dias 2015; Basso & Silva, 2013)

Parking management

The availability of a large number of parking spaces and underpriced parking are regarded as important determinants of mode choice, therefore managing parking supply and price are considered effective measures to curve driving and consequently ease traffic congestion (Obermann, 2012). Besides those positive effects, parking management solutions are normally better than increasing the number of parking spaces since they are able to support planning objectives related with land use, compact development, and also restraining the generation of impervious surfaces, and at the same time avoiding environmental and aesthetic damage (Litman, 2016).

For Litman (2016) parking planning and management should aim to;

- Provide optimal parking supply and price;
- Seek the efficient use of parking facilities favoring high priority uses;
- Promote schemes that allow sharing of parking facilities among various destinations (off-street parking);
- Strive to pass the costs of parking directly to users;
- Provide financial incentives to people who reduce their demand for parking.

Parking management and pricing strategies can be framed as general travel reduction actions, which means that they seek to influence travel demand regardless the motive; work, shopping, schooling, etc. Also those strategies can be used more focally for reducing recurrent travel demands generated by workplaces or schooling facilities (Obermann, 2012). In general, there are multiple strategies to manage parking which can be grouped in pricing options and parking-space optimization options. Finally, since parking is a persuasive factor on the decision of using car or not, the display of parking spaces in urban areas have to be carefully planned and managed (Hickman &Banister, 2006).

There are several non-economic measures that seek to discourage car use in a less direct way when compared to pricing policies; however, they have proven certain effectiveness for spurring modal shift. Non-price measures deal with a range of heterogeneous aspects such as investments in transport infrastructure, investments in PT, periodic vehicle checking, awareness campaigns, etc. The main advantage of this type of measures is that they normally benefit non-car users in a direct way through improvements on infrastructures for sustainable mobility.

2.2.2.3 Reducing travel distances

Policy tools oriented to promote high employment and residential densities are able to decelerate urban expansion but at the same time reduce travel distances, car use, and subsequently reduce energy use, traffic congestion, and air emissions. However, the causal relation between residential density and travel distance is still obscure (Proost & Van Dender, 2012). There is evidence suggesting a causal link but it is not as strong as it was believed; mainly because households pick certain locations for living according to their preferences, those preferences and density levels explain transport choices (Bento et al., 2005). Therefore, no significant reduction in transport volumes or energy consumption should be expected from land use planning unless drastic changes in land use patterns take place (Proost & Van Dender, 2012).

Various studies have proven that compact districts –those with high population, building and employment densities-, appropriate road networks and high quality PT services are related with low CO_2 emissions levels (Cervero & Sullivan, 2010). Inside of such districts most destinations for working, education, shopping, etc., are close to residential buildings and can be reached by carbon-free modes or are well-served by PT services. Those are the cases of Hammarby Sjöstad in Stockholm, Sweden; the Rieselfeld and Vauban districts of Freiburg, Gemany; and Kogarah Town Square in Sydney, Australia (Cervero & Sullivan, 2010).

Based in the urban economic theory, Brueckner & Kim (2003) state that spatial expansion of cities, particularly in United States (US), is the product of several forces; population growth; raising household incomes which stimulates the demand for large pieces of land for building houses; heavy investments in new road networks which facilitates commuting and makes living in the outskirts attractive. But urban growth should not be considered as inefficient just based on those forces; rather, urban expansion should be analyzed for the presence of market failures that instill those forces (Brueckner & Kim, 2003). Initially, those distortions are originated from a failure to internalize both the positive externality that open space around cities represent and the negative externality provoked by road congestion. Furthermore, fiscal distortions generated when the cost of developing urban infrastructures is not fully accredited to users which spur urban sprawl (Brueckner, 1997).

Brueckner & Kim (2010) explain some ways to correct the above mentioned market failures. First, development taxes should be imposed in order to internalizing the open-space externalities and decelerate urban sprawl. Second, the traffic congestion externality can be address by charging fees in congestion tolls which are going to increase the cost of commuting which may led to shorter commutes and compact cities. Finally, developers of peri urban projects should be charged the full cost that the development of public infrastructures represents through taxes and fees.

The present urban form, the existing transport systems and buildings, and their corresponding energy consumption patterns and GHGs emissions, have been crafted by past policy decisions and urban planning processes. Besides, transport infrastructures such as roads, highways, railways, etc., are difficult to change once they are in place; reason why, urban transport systems have low adaptive capacities (Yigitcanlar & Kamruzzaman, 2014). Finally, the lifespans of urban infrastructures range from 30 to 100 years (Floater et al. 2014); thus, present policy interventions and urban planning processes are going to determine to a good extend if cities will be able to offer suitable conditions for sustainable lifestyles in the future.

2.2.2.4 Cleaner vehicle strategies & technological innovation

The most typical policy response for curving energy consumption and GHG emissions from road transport has centered on developing and supplying motor vehicles equipped with higher efficiency technologies, and the introduction of low-carbon vehicle fuels. Different to mobility management measures that seek to reduce total car use, cleaner vehicle strategies and related technological innovations are able to reduce emissions in a per-kilometer basis. For Moore et al. (2010) fuel efficiency and traffic signal optimization are more likely to achieve direct reductions in GHG emissions than strategies aiming to increase urban densities or encourage PT ridership growth.

Fuel economy

Most vehicles technologies able to improve fuel economy, particularly two-wheelers and passenger cars, are already in the market and are cost-effective (IEA, 2012b). However, there are a number of barriers of different nature which impede a larger market penetration of such technologies. Therefore, the discussion on cleaner vehicles strategies should not only focus on incentives for the development of more efficient cars, but also, on measures that encourage the use of those technologies (IEA, 2012b).

There is a potential for improving fuel economy of all type of vehicles which ranges between 30% and 50% towards 2030 taking 2005 levels as baseline (IEA, 2012b). However, in certain cases drivers do not have enough and adequate information on those technologies, but also, drivers are skeptical about the idea that such vehicles can actually save them money on fuel costs. Once those market barriers are addressed, drivers are going to get the economic benefits coming from more efficient cars when extra upfront costs are paid back over a few years through fuel savings (IEA, 2012b).

Finally, a common concern related with fuel economy regulation has to do with the so-called rebound effect that occurs when the reduction on the cost of driving encourages car use leading to more congestion and emissions (Proost & Van Dender, 2012). Thus, a policy meant to reduce one externality can exacerbate others.

Emission standards

Seeking to reduce local air pollution derived from road vehicles in urban areas, countries part of the EU and many states in US have enforced emission standards for new vehicles. Those standards have been successively tightened in line with the emergence of improved technologies. This has allowed the levels of air-pollutants generated by road transportation to decrease over the two last decades (OECD, 2014).

Emission standards can be regarded as a strategy to address the above mentioned market failures that give rise to such an important energy efficiency gap in terms of fuel economy. Finally, higher historical fuel economy and stronger standards have been observed in places with high fuel taxes (Proost & Van Dender, 2012).

Alternative fuels & electrification of transport

Policy intervention has tended to provide subsidies to encourage the use of alternative fuels such as biofuels, ethanol and biodiesel via fuel mix mandates (Proost & Van

Dender, 2012). Such policies can help diversifying energy sources in the transport sector but normally the main objective is to curve emissions derived from the combustion of conventional vehicle fuels. However, in multiple cases the environmental and social impacts generated in the production of feedstocks used directly for biofuels, such as corn, sugar cane or palm oil crops, do not justify their use as source of energy. This is why, Proost & Van Dender (2012) state that assessments on the application of such policies reveal poor environmental performance and limited potential for curving emission. Yet, the use of biofuels is decisive to decarbonize road transportation. Technological developments point to produce second generation biofuels; which mainly use organic residues as feedstocks and not crops purposely produced for energy generation.

On the other hand, the electrification of transports nowadays is centered on allowing electric-powered vehicles to run with onboard stored energy (Rode et al., 2014). Multiple advantages come with use of electricity instead of liquid and gaseous fuels as source of power for road transport. For example, radical reductions of local air pollution and noise levels, but also, reduced carbon emission if electricity is generated from renewable sources. Moreover, electric vehicles offer a way out from peak oil prices. However, electric car technologies nowadays are still not able to match the advantages of vehicles equipped with internal combustion engines, particularly in terms of autonomy.

Electric mobility has grown faster in other segments apart from electric cars. Nowadays, in some countries e-bikes represent an important share of daily urban travel. By 2014, only in China more than 230 million e-bikes were sold (IEA, 2015). The principal factors behind such impressive demand have been the small size, maneuverability and agility of those vehicles (Popovich et al., 2014). Such characteristics help reducing travel times particularly under high levels of traffic congestion.

Technological innovations

Central technologies for urban transport have not experienced notable changes in recent decades; the evolution of urban mobility has been rather driven by the innovative use of existing technologies and infrastructures such as Bus Rapid Transit (BRT), car-sharing and bike-sharing schemes (Rode et al., 2014).

Effective car-sharing schemes, by which a car is rented on a per ride basis from an organization which owns and maintains the car, have proven to reduce car ownership (Martin & Shaheen 2011) and have the potential contribute in VKT, since users are more prone to use PT services when not having their own car (Rode et al., 2014).

Urban mobility patterns have been influenced by disruptive technologies coming from outside the conventional automotive sector, mainly in the form of digitalization (Rode et al., 2014). The use of ICT has enhanced urban transport systems by enabling; a more efficient management of transport, more efficient car use and ubiquitous display of travel information.

2.2.3 Barriers for sustainable mobility systems

The transition towards sustainable mobility has to overcome a number of barriers of different type; organizational, technical-operational and external (Table 2). But among them, defining the roles organizations play at the moment of effecting those that transition prove to be the most complex (Stough & Rietveld, 2005) when for example, inside transport agencies the planning process and the execution of policies are not understood. Rodrigue et al., point that the difference between policy and planning root on the fact that the former is usually related to strategies and goals whereas the latter is related with concrete actions (Rodrigue et al., 2013). In some cases the planning process is developed separately of any direct policy context, but also, policies might be framed without any direct implications on planning.

Another aspect that should be recognized for the development of sustainable mobility systems is that land use and transport planning are mutually supportive (te Brömmelstroet & Bertoline, 2008). Perhaps the main argument explaining the need for integrating those two domains in order to reorient current travel patterns is that VKT per capita increase as cities sprawl and average densities drop because of longer trips; more motorized trips that strengthen car dependency; and lower average vehicle occupancy (Cervero, 2001). Besides, PT requires high densities in order to operate efficiently and better compete with cars; which is difficult when current or potential users are spread over wide land areas. But in practice, the integration of these two domains has proven to be difficult. According to te Brömmelstroet & Bertoline, there is a number of barriers in realms of governance such as: the existence of separate planning bodies; different financial arrangements; differences in planning objectives, distinct information and knowledge, etc.

Technical and operational barriers are those related with the development of infrastructure necessary for sustainable mobility system. They are relatively easier to address in the short and medium terms and entail predictable actions for implementation once institutional barriers are surmounted (Stough & Rietveld, 2005).

Addressing organizational barriers might be a complex task; however, solutions can be devised at the local level and among a reduced number of stakeholders. But on the other hand, certain external barriers, particularly those related with poor policy integration and unsupportive regulatory frameworks between national and local governments, result much more difficult to surmount from the perspective of local authorities.

Table 2: Barriers to the implementation of sustainable transport strategies

Organizational
Lack of inter-departmental working
Divided responsibilities
Spatial boundaries
Lack of revenue funding
Lack of qualified and skilled staff
Increasing number of stakeholders
Technical
Difficulties to generate and use indicators
Poor data management
Inability to model and appraise instruments
External
Inconsistency in national, regional and local priorities
Poor public acceptance of certain measures
Short termism in decision making

(Source: May, 2009)

3 METHODOLOGY

3.1 Theoretical background

The literature review done in the preceding chapter has been useful to learn and have certain insight about transport planning and policy making. The present study has identified multiple policies and measures to promote the development of sustainable mobility systems. It has been noticed, some strategies are able to achieve sustainability goals, more specifically curving car use, in the short-to-mid terms such as taxes on the cost of driving and non-pricing measures mainly in the form of investments on massive and non-motorized mobility infrastructures.

On the other hand, measures aiming to reduce travel distances, which consequently reduce certain levels of car use, through urban planning might be able to generate changes in the long run since promoting compact urban development and mixed land use are lengthy processes. Another aspect noticed through the literature review is that some policies and decisions that influence the development of sustainable mobility systems are part of the attributions of local authorities and others are prerogatives of national governments and legislative bodies.

This theoretical background has provided elements to better understand the implications of the sustainable mobility targets of the City of Cuenca. Henceforth, the main objective of the present study is to propose a plan for encouraging a 10% modal shift from cars to PT in the 2025 horizon; which is one of the targets of the local authorities of Cuenca.

3.2 Guidelines for modal shift

The sequence of steps that the present study proposes in order to successfully implement a sustainable mobility plan are explained in figure 4. Since the focus is provoking car drivers in Cuenca to use PT services, after substantiating the modal shift target, existence of potential barriers able to hinder the completion of the proposed plan is addressed. Then, a brief analysis of the key events in transport planning and policymaking in Cuenca is undertaken in order to determine how successful they have been for promoting sustainable mobility. Next, an analysis of the determinants of both car use and PT ridership is provided.

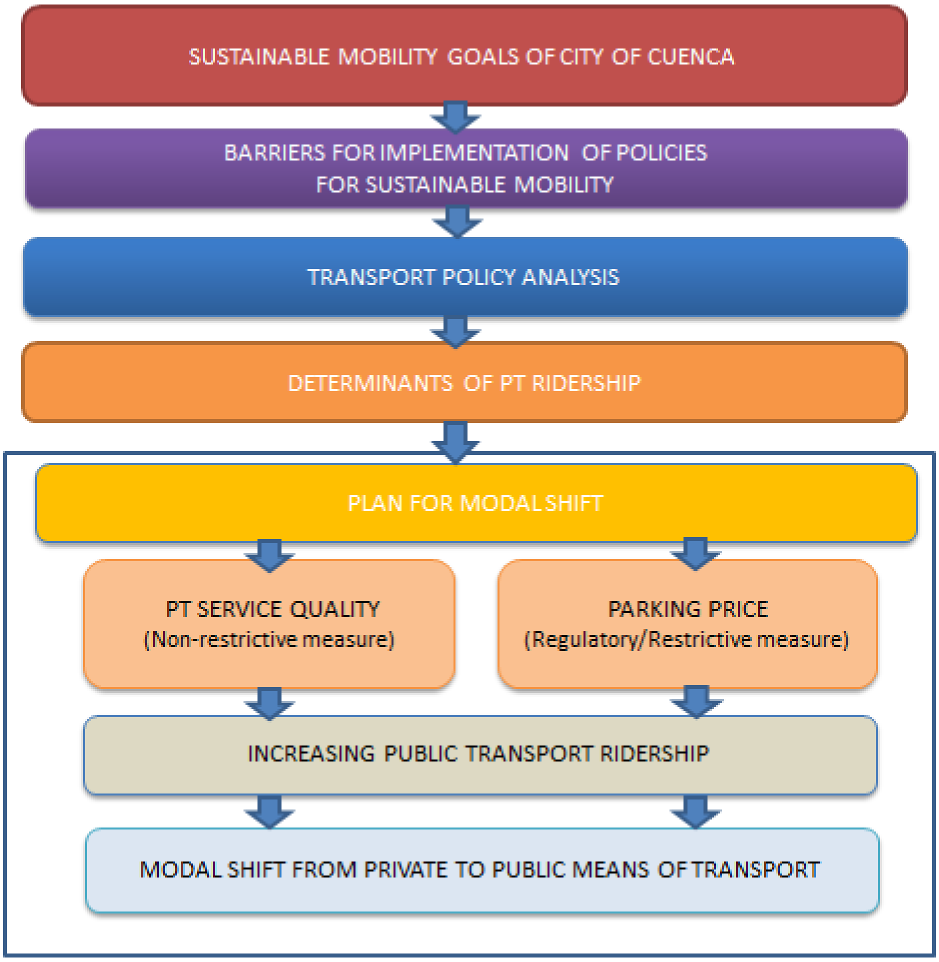

Figure 4: Modal shift schematics

After assessing the feasibility of different instruments for prompting modal shift, this study proposes improvements in the PT service quality of Cuenca, particularly conventional bus services, as central strategy for offering citizens a good transport alternative to cars and an easy-to-use service. Other factors are also going to be analyzed as concomitant measures for prompting modal shift in Cuenca. As can be noticed in figure 4, a restrictive measure for car use is proposed additionally to non-restrictive ones. In this case, the objective is to discourage car use by increasing parking prices; which is expected to increase PT ridership.

By improving the quality of urban PT several aspects of the sustainable mobility paradigm can be addressed, namely; improved mobility options for the transport disadvantaged; reduced car use and urban traffic congestion; reduced GHG's emissions associated with car dependence, etc.

3.3 Analysis tools

Since demand elasticities are the most common means for examining the impacts on demand of various changes in PT provision within a consistent framework (Currie & Wallis, 2008), to determine the sensitivity of PT ridership to changes in multiple service features estimations employing values of elasticities are going to be performed for the case of Cuenca. Besides, the plan for higher quality PT in Cuenca consider improvements in certain factors based on perceptions of citizens about the present PT in that city.

Perceptions of service quality

The perceptions of travel quality have a critical influence on travel behaviour (Currie & Wallis, 2008). In this sense, at least two surveys have been carried out in Cuenca in order to assess certain service quality aspects of PT. Those surveys reveal that most citizens are quite satisfied with aspects related with service quantity of conventional bus system in Cuenca; however, many aspects directly related with service quality are not well regarded by respondents. Then, the necessity to propose actions to improve the service quality of conventional bus service in Cuenca arises as a fundamental factor for improving perceptions of citizens on PT.

Scenario modelling

PT ridership growth and GHG reductions coming from the introduction of the plan proposed through this study are going to be modeled. Distances required to model avoided car trips were estimated from local studies. Different usual car trip routes in Cuenca were modeled using referential GHG emission parameters levels for Non-OECD countries as Ecuador.

4 CASE STUDY

4.1 Characteristics of the city of Cuenca

The Canton Cuenca, which encloses both urban and rural areas, is the capital of the province of Azuay and is regarded as the third most prosperous in Ecuador. Besides, urban Cuenca is the largest city in the south of that country (Fig. 5). The canton Cuenca is partitioned in 15 urban parishes, which constitute the city, and 21 rural parishes across a total surface area of 3665.33 sq. km.

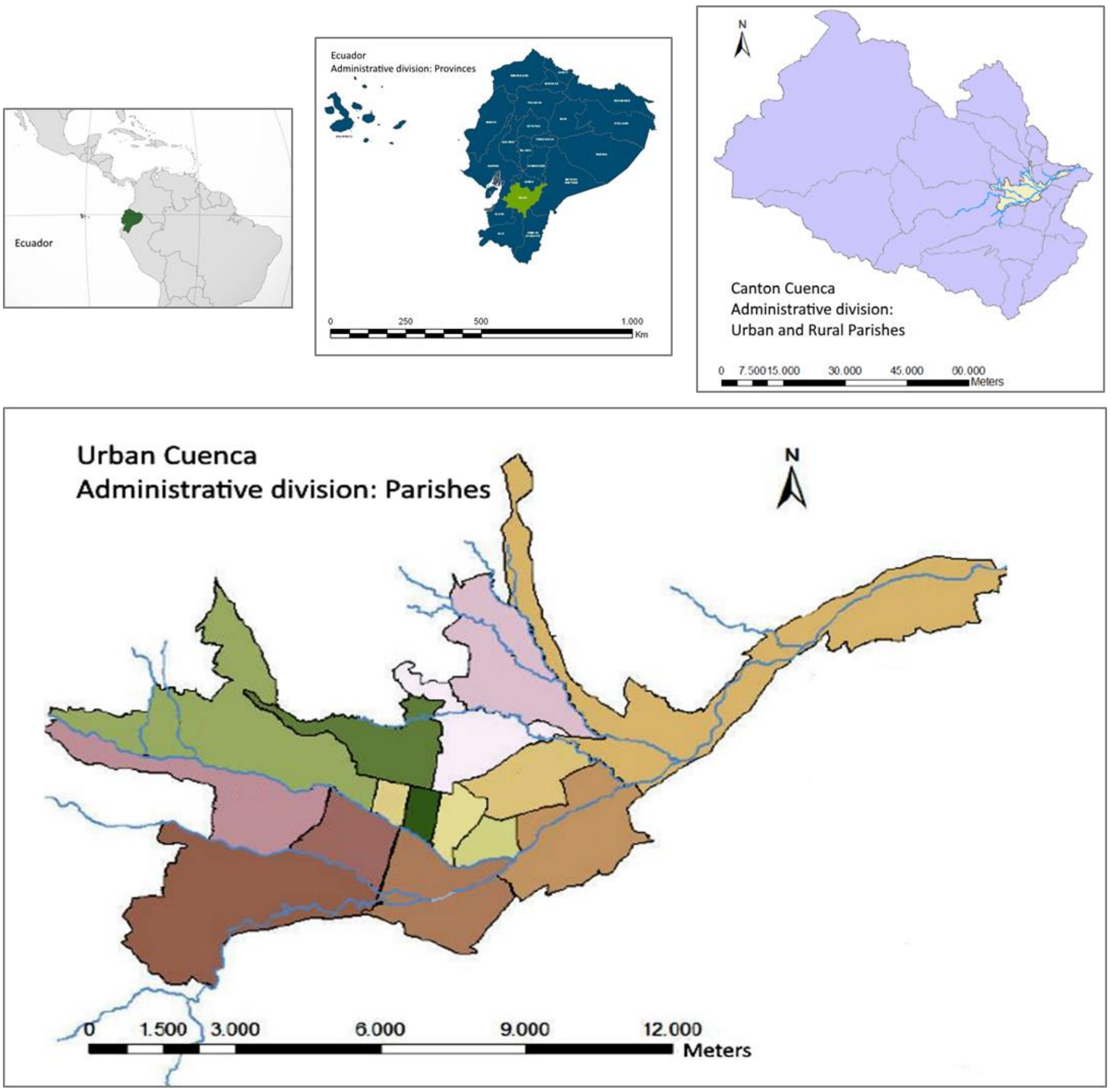

Figure 5: Localization of Urban Cuenca

(Source: noticiasecuador.com (1) (2); INEC 2010a (3) (4))

The population of that canton was estimated in 580,000 people by 2015 (INEC, 2013) but approximately 92% of the total population of the canton interacts in the urban area (GAD-C, 2015). Cuenca has experienced a process of urbanization considering that in 1950 its population represented 50% of the population of the whole province; while, nowadays it represents approximately 70% (IDOM 2013).

Considering a total surface area of 3665.33 sq. km, the population density of the canton for 2013 was around 158.24 people per sq. km. The urban Cuenca is denser though, it reaches almost 4730 inhabitants per sq. km when counting 350,000 persons over a 74 sq. km surface (GAD-C, 2015). The density of urban Cuenca is higher than the densities of major cities in Ecuador; the metropolitan district of Quito has 1,619.14 inhabitants per sq. km and Guayaquil has 2,291.15 inhabitants per sq. km (INEC, 2010); however, denser land use is desirable for efficient provision of public services.

Several factors explain densities and land use patterns in canton Cuenca. Firstly, a dispersed and unplanned physical expansion of the urban area; secondly, the high number of single-family houses and the corresponding lack of vertical expansion in the city (Fig. 6); finally, the existence of many vacant pieces of land across urban Cuenca, totalizing approximately 7.6 sq. km which represents 10% of the total surface area of urban Cuenca (IADB, 2014).

When it comes to building density approximately 75% of the existing buildings in Cuenca are single-family houses of one or two floors and host more than half of the citizens of Cuenca. Only 14.35% of the buildings in the city are 3 or 4 stories and less than 500 buildings are 5 stories or more, most of them located on medium to high-value zones of the city (IDOM 2013).

Figure 6: Urban landscape of Cuenca

(Source: www.livingamdg.com/blog/living-in-cuenca)

In Cuenca, the construction sector tends to develop private condominiums, suburban neighborhoods and only-residential zones (IDOM, 2013); disregarding criteria about mixed land use and compact urban development. Successive municipal administrations of Cuenca, in charge of the urban planning affairs of the canton, have been ineffective in planning and controlling the urban expansion especially since the 80's when the urbanization process started to be problematic (IDOM, 2013). As resultant, the urban morphology of Cuenca draws a tentacle-shape pattern (Fig. 5) which increases travel distances among different points of the city compared with urban development following circular patterns.

4.2 Mobility patterns in Cuenca

About 480,000 trips in urban Cuenca are taken by means of motorized vehicles; mainly automobiles and buses. The other 215,000 trips are taken by means of non-motorized modes; biking or walking (GAD-C, 2015). Conventional bus, which is presently (2016) the only means of massive PT available in Cuenca, represents 31% of the total modal share in that city (Fig. 7).

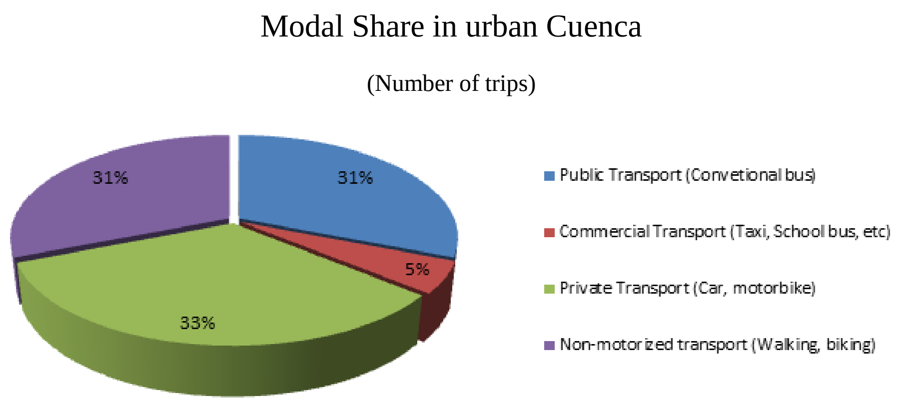

Figure 7: Modal share of urban trips in Cuenca

(Source: GAD-C, 2015)

In Cuenca, about 27% of total PT trips are taken for commuting, but also, people uses that mode of transport for shopping, personal dealings and going to school; in proportions of approximately 20% each. When it comes to the use of private vehicles in working days, around 42% of the trips are made for working purposes. Attending school, accounts 12% of the trips either as driver or as passenger. But the rest of the trips made by private car during working days, 46% of the total, correspond to activities that can be considered as non-habitual, and in many cases having non-fixed schedules, such as personal dealings, recreation, shopping and medical care.

According to the mobility plan of Cuenca (PMEP), approximately 700,000 trips are taken in Cuenca during working days (GAD-C, 2015). Half of those trips inside urban Cuenca are made for attending habitual tasks such as working and studying. Leisure and shopping motivate around 30% of the trips and personal dealings and health care make people travel 19% of the times.

When it comes to distribution of trips in terms of destinations in working days, the PMEP reveals that the historical center of Cuenca attracts 26% of total urban trips and the sector called “El Ejido” 14%. Those two attached zones (Fig. 8) are occupied by several patrimonial and administrative buildings but also educational institutions, banks and hospitals which constitute important trips attractors.

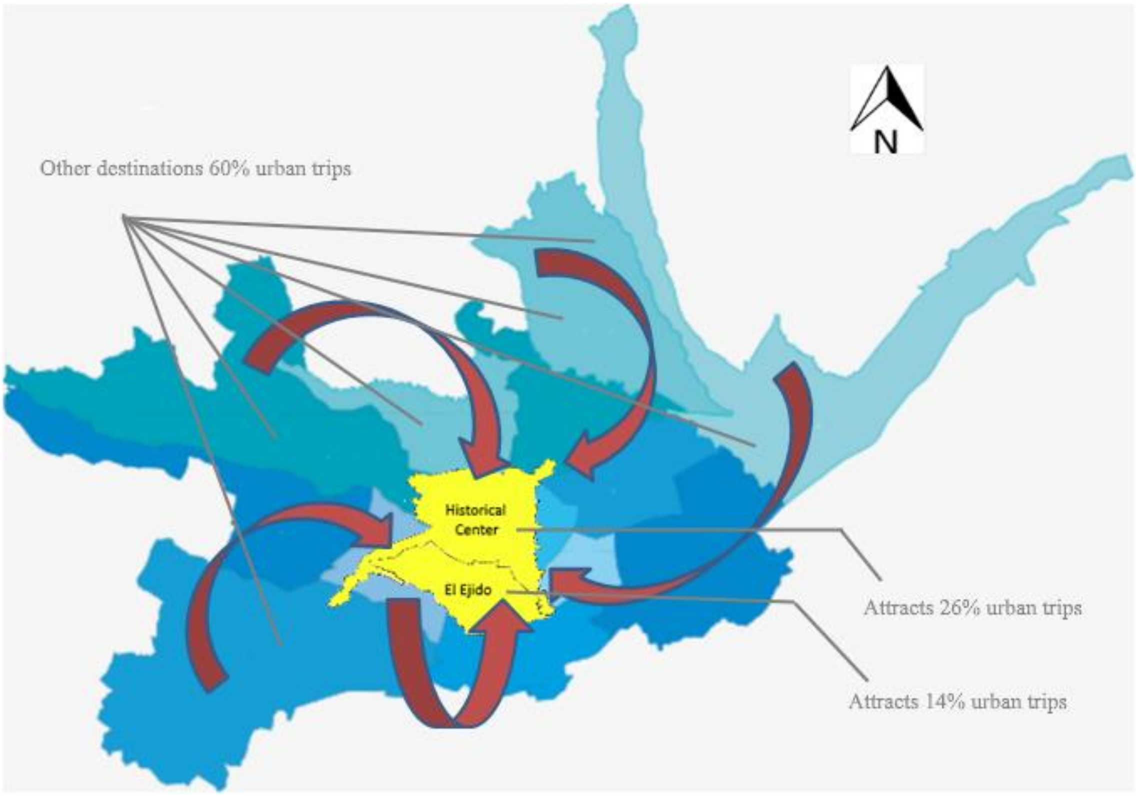

Figure 8: Main trip attractors in urban Cuenca
(Based on a map from GAD-C)

The remaining 60% the trips made in urban Cuenca are distributed among many other destinations. Among them, the sector of the biggest market of the city, called "Feria Libre," sums up 6% of total urban trips.

4.2.1 Transport-related Greenhouse gas emissions

In Ecuador, transport-related CO_2 emissions have been escalating steadily and its share respect to economy-wide emissions keeps growing. By 1990, that sector accrued around 6.8 $MtCO_2eq$ (Fig.9) representing over 23 % of total emissions for that country. More recently, by 2010 transport-related emissions totalized 15.23 $MtCO_2eq$ which represented a 125 % increase from 1990's levels and 28 % of total national emission. Under a Business as Usual trend (BAU), GHG emissions are expected to double towards 2030 compared to 2010's levels totalizing 31.2 $MtCO_2eq$; which will represent 36 % of economy-wide emissions (SLOCAT, 2016).

Under a low-carbon scenario[1], proposed by SLOCAT, transport-related GHG emissions in Ecuador are projected to increase nearly 51 % by 2030 taking 2010 levels as baseline; which would represent 26 % less emissions respect to the BAU scenario (SLOCAT, 2016). Nevertheless, according to the goals set under the international climate agreement know as Intended Nationally Determined Contributions (INDCs) established by the U.N. Framework Convention on Climate Change Conference (UNFCCC) of the Parties (COP21) held in Paris in December 2015, the transport sector in Ecuador should be able to maintain its emissions near to the 2010 levels towards 2025 (red line in figure 9). Thus, not even the low-carbon trend is going to be enough to curb transport emissions at levels INDCs requires towards 2030.

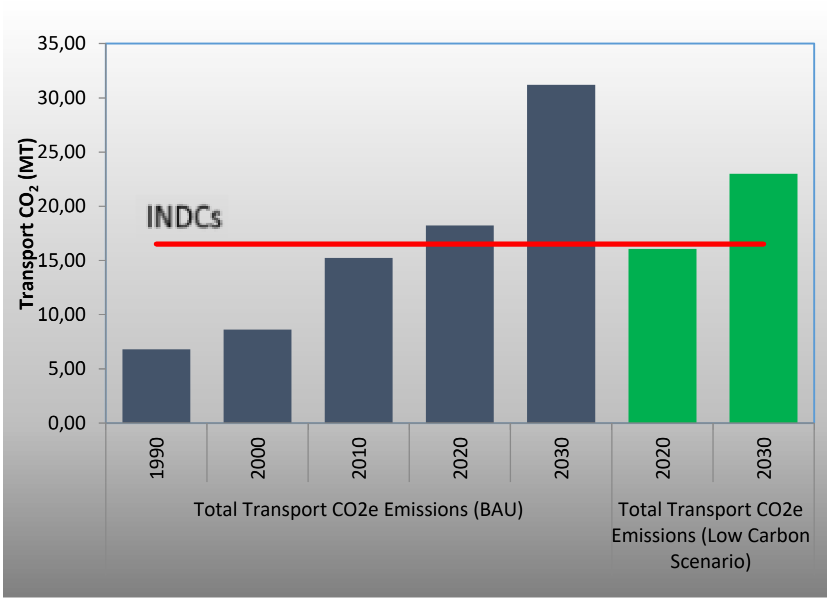

Figure 9: Projected Transport GHG Emissions in Ecuador

(Source: SLOCAT, 2016)

At the local level, total GHG emission in the canton Cuenca accrued 2.42 tCO_2eq per capita by 2009 (IADB, 2014), level slightly higher than both national average that reached 2.36 tCO_2eq per capita and the average levels of developing countries in LA and the Caribbean, 2.23 tCO_2eq per capita (World Bank, 2016). Carbon emissions attributed to the transport sector in the canton Cuenca totalized 662,687 tCO_2eq by 2009 (Fig. 10); which represented 57 % out of 1.18 $MtCO_2eq$ emitted in total in the canton (IADB, 2014).

[1] Based on available potential mitigation studies (SLOCAT, 2016)

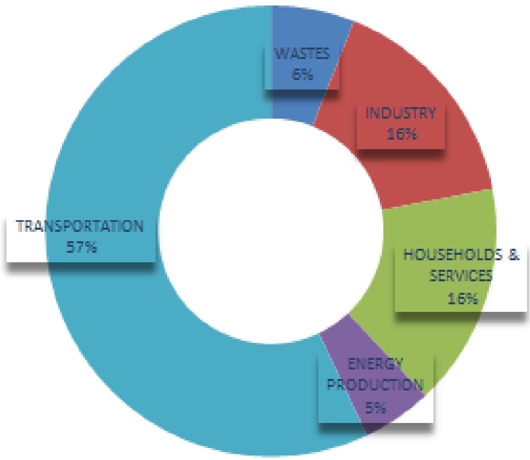

Figure 10: GHG Emissions per sector in canton Cuenca by 2009 (% in tCO2eq)

(Source: IADB, 2014)

Moreover, based on the trends of growth of the car stock and in the number of travel kilometers per year, the transport was accountable for 60 % of total CO_2 emissions and 68 % of NOx emissions (GAD-C; 2015).

4.2.2 Sustainable mobility goals of the City of Cuenca

Antecedents

In a recent study of Inter-American Development Bank (IADB, 2014) the mobility in Cuenca was labeled as “low sustainability” mainly due to the high levels of traffic congestion, more noticeable at the city center, and which are mainly generated by increasing rates of motorization, 0.33 vehicles per person according to the estimations of that institution, and considered high for a developing city in the LA context. Average motorization rates in LA reached 0.176 cars per person by 2014 (OICA, 2016). Another argument is that transport is the largest source GHG emissions in the canton, 57 % of total emissions (Fig.10). Only light-duty vehicles (LDV) account approximately a third of total transport-related emissions which reached 600,000 tCO_2 by 2009 (IADB,2013).

Several economic, social and environmental indicators of sustainable mobility for the case of urban Cuenca are summarized in table 3. And even when that list is not exhaustive, according to the information available all indicators related with car use such as noise, air quality, climate change emissions, etc., are worse than others; which reinforces the fact that car use is worsening living conditions in that city.

Table 3: Summary of sustainable mobility indicators of Cuenca

SUSTAINABLE MOBILITY INDICATORS OF CUENCA BETWEEN 2012 AND 2015					
Indicator	Description	Type	Direction	Percentage	Source
User satisfaction	Portion of population that considers time spend for commuting inside Cuenca as adequate	Economic	More is better	67%	CCCV (2015)
Commute time	Average door-to-door commute travel time	Economic	Less is better	10-20 min	CCCV (2015)
Electronic communication	Portion of population with Internet service	Economic	More is better	52%	INEC (2013a)
Modal share	Portion of travel made by efficient modes (non-motorized, PT)	Economic	More is better	62%	IMC (2015)
Affordabilty	Portion of household expeditures devoted to transport	Economic-Social	Less is better	14,60%	INEC (2013b)
User rating	Portion of the population considering accesibility to PT for hadicapped users as adequare	Social	More is better	26%	CCCV (2015)
Safety	Per capita crash disabilities and fatalities	Social	Less is better	0,0033	IMC(2015)
Climate change emissions	Portion of GHG emission from transportation respect to overal emissions	Environmental	Less is better	57%	IADB (2013)
Air pollution	Portion of total emissions of air pollutants (CO and NO2) imputable to road transport	Environmental	Less is better	92%/72%	IMC (2015)
Air quality	Portion of population that considers air quality is getting worse by motor vehicle smoke	Environmental	Less is better	81%	CCCV (2015)
Noise pollution	Portion of population that considers traffic noise too loud	Environmental	Less is better	48%	CCCV (2015)

(Based on Litman, 2016)

Notes

- Commute time: 38% (biggest share) of the respondents of a survey carried by CCCV (2015) spend between 10 and 20 minutes commuting in Cuenca
- Electronic communication: % of population of the province of Azuay having access to an Internet connection in 2013
- Air pollution: most air pollutants levels are normally under the WHO thresholds however road transport contributes disproportionally CO and NO2 emissions
- Affordability: monthly percentage of national household consumption expenditure in Ecuador calculated between 2011 and 2012 (INEC- ENIGHUR 2012) without specifying modes or purposes of journeys
- Safety: calculated from a total number of reported accidents; 1876 by 2014 and a projected population of 569416 persons in Cuenca for 2014 (INEC, 2013)
- Climate change emissions: GHG emissions in the Canton Cuenca by 2009 per economic sector

4.2.3 Potential barriers for the implementation of plans for sustainable mobility in intermediate cities in Latin America

Previously, at the end of section 2 of this master thesis, several barriers of different nature that impede the development of plans and strategies for sustainable mobility systems were briefly stated. In the literature several studies have exposed the existence of those impediments when it comes to provoke a modal shift (Batty et al. 2015); barriers that impede PT ridership growth (Currie & Rose, 2008); the existence of barriers in the United Kingdom (UK) context and the development of a set of decision-support tools designed to help overcome those barriers (May, 2009); and barriers to integration of land use and transport planning (te Brömmelstroet & Bertolini; 2008). However, to the best of the author's knowledge, the assessment of barriers that hinder fruition of plans and strategies aiming to promote sustainable mobility in the context of intermediate cities[2] in LA, like Cuenca, has not widely investigated. And even when the existence and analysis of those barriers is not the main purpose of this thesis, a general overview in this sense is provided next.

Several experts working in urban and transport planning and sustainable mobility in LA cities where consulted in order to have an insight about the factors that typically impede the completion and success of sustainable mobility initiatives inside local governments in intermediate cities; however, four concrete answers were obtained (Annex 1). And even when the number of answers is small, the high level of expertise of respondents made the information obtained valuable. Two of the respondents have certain insight about transport planning and policy-making in Cuenca; however, their responses were not specific for that city.

The specific question addressed to the interviewees was:

Once local governments in intermediate cities in Latin America define plans and strategies for sustainable mobility, what are the factors inside those governments that hinder the achievement of defined objectives?

[2] An intermediate city, beyond its size, it has a role in the urban system by ensuring basic services to both urban and rural population and provides a variety of social services, economic opportunities, and specialized services such as universities, hospitals, industries, etc. (UCGL, 2013)

The responses can be broadly grouped in three segments: barriers related with politic aspects, barriers related with lack of financial resources, and finally those related with organizational and technical aspects. The respondents were designated as R1[3], R2[4], R3[5] and R4[6] (see footnote).

When it comes to politic affairs the main problem, according to R1 and R4, is that when ruling periods in local governments finish, the next authorities in charge redefine the priorities of cities according to their own political agendas and devote funding to new projects. Then, for R3, existing plans aiming to promote sustainable mobility are dismissed or their objectives are postponed i.e. when initially aiming to provoke a modal shift towards 2020 later it is put off to 2030. R4 explains that this lack of commitment to long term planning is in part motivated by a lack of citizen involvement which otherwise would help to control the actions of local governments respect to long term objectives defined for cities. Moreover, R1, R3, and R4 coincidence that there is a lack political commitment inside local governments since tough decisions, as imposing pricing policies to car use, can generate conflicts with certain stakeholders and carry political repercussions. Finally, R2 points that a strong barrier at this level is that local politicians lack understanding about the real problems of the cities they are in charge of.

Cities with rapidly increasing populations correspondingly have important increments in mobility demands; which require ongoing investments on the infrastructures that support transportation. For R3 and R4 the lack of financial means to improve or maintain existing transport infrastructure and provide infrastructure for massive and non-motorized transportation is a serious issue when aiming to promote sustainable mobility systems in intermediate cities in LA. R4 mentions that normally much of the available funding in LA countries is devoted to major cities as they apparently have bigger problems than intermediate cities. Then, the latter just have enough money to solve their most pressing needs but none for long term planning and the implementation of project and programs for sustainable mobility. R4 mentions that the lack of financial means is also directly related to the lack of willingness of local policymakers for

[3] R1: Alejandro Rodríguez, PhD

[4] R2: Dr. José Luis Cañavate

[5] R3: Rodrigo Días, MSc

[6] R4: Harvey Scorcia, MSc

imposing pricing mechanisms to car use; revenue that in other parts of the world, especially in certain EU cities, is used to finance infrastructures for sustainable mobility. Finally, R1 asserts that public entities in LA are inefficient by nature. Then, when local governments have financial means to invest in mobility projects sometimes those resources are not used in the most efficient way.

Opinions about barriers related with organizational and technical aspects inside local governments of intermediate cities in LA are diverse. However, the main coincidence among all interviewees is an almost general lack of institutional capacity and capability. R4 points that it is about a lack of both skilled and sufficient personnel for properly planning and executing what the plans dictate; which at the same time is related with the lack of financial means to hire such workers. R3 agrees with that statement and adds that the high levels of staff turnover impede the formation of specialized working teams. R2 considers that besides lack of institutional capacity and capability in many cases an important barrier is that directors in high level positions related with mobility and urban planning inside local governments are not committed at all with the objectives of the cities which is accompanied by highly inefficient organizational structures.

Moreover, R1, R3 and R4 mention that normally objectives proposed by local governments and derived from planning processes lack foundation. This means that the objectives are set but normally the type of actions required for achieving them are not defined. R1 mentions that normally there are no technical basis and defined budgets in order to achieve the proposed targets. R3 in this sense mentions that when it comes to defining long term objectives local governments do not define intermediate objectives that allow citizens monitoring the progress of the main target. Moreover R3 and R4 mention that in some cases the vision and main objectives are defined; however, the institutional, regulatory and financial changes required for those purposes are non-explicit.

Several of the most common barriers mentioned in the literature were mentioned by the interviewees. R3 and R4 mentioned that the lack of cohesion between land use planning and transport planning is the basically a norm in cities in LA. R3 and R4 also mention that normally there is a lack of reliable and updated indicators that can help to effective decision-making. Finally, comparing the barriers that the literature highlights, specially coming from studies undertook in developed countries, with the barriers of intermediate cities in LA above mentioned, perhaps the main difference lies in the lack of maturity of political systems at the city level in the LA context; which is aggravated with a lack of involvement and knowledge from citizens that can function as control mechanism. When it comes to lack of financial means for the development mobility infrastructures it is obvious that it represents a bigger limitation for developing cities in LA than for developed cities in other parts of the world. But beyond that, many barriers related with organizational and technical aspects seems to be quite common in many parts of the world when it comes to promote sustainable mobility initiatives.

4.2.4 Transport planning and policymaking in Cuenca

In table 4 the key events of transport planning and policy-making in Cuenca during the last two decades are listed. Several steps forward have been taken in that city under the vision of developing a sustainable mobility system. Among them, it is the coming introduction of the tram system as a new mobility option in 2017, the decentralization of urban road transport management in 2013, and the development of the mobility plan for the city released in 2015.

Table 4: Recent key events in Transport Planning and Policymaking in Cuenca

1999	**On-road parking charges started**
	"aiming rotation on-road parking spots"
1999	**Plan for a sustainable traffic system for a pilot city**
	"PT integration"
2001	**Integrated network of PT for the City of Cuenca**
	"PT integration"
2003	**Last increment in the price of regular gasoline and diesel (National policy)**
	"indefinite subsidization of transpor
2003	**Plan for Sustainable Transport in Cuenca**
	" determine the size of the bus fleet"
2003	**Last increment in PT fares (National policy)**
2004	**Standardization buses for urban PT services**
	"buses currently operating"
2012	**Approval of the execution of the tram system proposed by Major Paul Granda**
	"higher capacity than other PT options"
2013	**Municipality in charge planning, regulating and controlling traffic, road transport**
	" full autonomy"
2014	**Cuenca Sustainable City: Action Plan**
	"GHG emission targets" "tram as tool for urban development" "land use and transport planning approach"
2015	**Program for Safe Transport (National policy)**
	"security camaras onboard PT" "panic alarm"
2015	**Mobility and Public Spaces Plan towards 2025**
	"modal shift"
2016	**Municipality provides financial compensation to PT operators**
	"keep fares subsidiezed"
2016	**Start trials for WiFi provision and LCD screens in PT services**
2017	**Expected opening of the tram system**
	"several delays"

However, after having an overview of the potential barriers that intermediate cities in the LA context normally face for implementing strategies to promote sustainable mobility systems in the prior section, the analysis of the conditions that the city of Cuenca presents in terms of transport planning and policymaking in order to achieve its mobility and environmental targets can be assessed in terms of what are considered the pillars of sustainable mobility and the elements that are erected upon those pillars. According to Kennedy et al. (2005) more sustainable urban transportation generally requires four pillars: effective management of land use and transport; stable funding; strategic infrastructure investment; and careful neighborhood design. But from the interviews carried to experts working in LA cities, it can be noticed that institutional capacity and capability is another pillar as well as the existence of a solid transport and land use authority. Then, adapting such pillars to the context of LA cities they can be arranged in the following way:

1. Integrated strategy between land use and transport planning
2. Institutional capacity and capability
3. Integrated transport and land use authority
4. Stable financial capacity in the short-medium and long term

In the particular case of the city of Cuenca there is no integrated strategy between land use and transport planning as the study of the IADB (2014) called "Cuenca Ciudad Sostenible" recognizes (p. 70). Then, it is difficult to think that urban Cuenca is going to offer high levels of accessibility in the coming future and it is probable that the city will have difficulties at the moment of coping with increasing mobility demands. When it comes to institutional capacity and capability of the organizations in charge of mobility affairs in Cuenca there is no evaluation available providing hints to better know if those entities will be able to carry out the actions required to achieve the mobility targets of the city; neither the PMEP is explicit about the necessity of undertaking organizational and institutional changes in that sense.

The role of the transport authority in Cuenca (EMOV-EP) is limited to the management and control of the transport activity (Municipal ordinance 295 from March 4th 2010). Then, it is difficult to think that there are models that can relate transport planning with the economy growth or decline of different sectors of the city, the location of households and jobs, or migratory patterns inside the city. Finally, the lack of stable funding for developing mobility projects is perhaps the most evident problem of the city of Cuenca as it will be further explained when talking about subsidies for PT and the recurrent problems that the municipality currently has in order to afford the implementation of the Tram system (El Tiempo, 2016). Moreover, there are no defined pricing mechanisms that can serve stable as sources of revenue for maintaining and investing in transport systems.

The integration of PT services is regarded as a fundamental element of sustainable mobility; which can be constructed upon the existence of the above mentioned pillars. Fully integrated PT transport systems seems to be the model for achieving efficiency in urban mobility and accessibility as they are able to capture most of the demand of PT services by offering multiple options and at the same time avoiding inefficiencies e.g. line overlapping, as well as tending to an optimal allocation of resources. Perhaps the foremost examples are the integrated transport systems existing in London and Madrid.

It can be noticed from table 4, that the notion of sustainability in transport planning of the City of Cuenca was first incorporated in 1999 with the Plan for a sustainable traffic system for a pilot city sponsored by the IADB which aimed to implement an integrated PT system. Several other related plans were released in 2001 and 2003; however, the integration of the only PT service operating in Cuenca, conventional-bus service, has been difficult. By 2016, more than 15 years after the introduction of the first attempt for aligning PT under the concept of sustainability, the integration of PT is minimal. The only advances have been the integration of one corridor (line 100) allowing transfers by paying a single fare.

4.2.5 Modal shift target of Cuenca

In 2011 the Municipality of Cuenca commissioned the execution of a mobility plan for the city (PMEP) which was completed by 2015. Such plan first identified multiple issues affecting mobility of the citizens in Cuenca; urban sprawl, car is at the top of the mobility hierarchy; high shares of motorized mobility; lack of infrastructure for non-motorized mobility, among others, and defined a general objective for mobility in Cuenca towards 2025. Then, the city aims to define a new mobility model for the urban area in order to: achieve equitable modal shares, provide citizens mobility options, and guarantee safeness, effectiveness, quality and environmental conservation.

In order to achieve the general objective several targets were also defined in the PMEP, but, perhaps the most explicit in terms of sustainable mobility points to encourage a modal shift of 10% from car use to PT by 2025 and based on the modal share estimated for 2015.

Focusing on the strategies that the PMEP enlists in order to provoke a modal shift, the necessity for improving PT services and better parking management come up. Moreover, the concepts of mobility management of both supply and demand are generally explained. Finally, the PMEP describes several projects that may have an effect on prompting a modal shift such as the construction of segregated lanes for the conventional-bus system as well as the implementation of IT systems that will allow monitoring bus operation in real time, and to estimate de demand for PT services. However, there are not defined plans for modal shift neither the transport policy making process in Cuenca has been addressed. Therefore, the present study looks for proposing a plan that can help that city to achieve such mobility target.

4.3 Determinants of PT ridership

4.3.1 Exogenous influences

Urban PT in Cuenca has been losing modal share to car use in recent years. By 1990, around 50% of the urban trips were made by conventional bus services; more recently, in 2015, only 31% of the trips were taken by those means (GAD-C, 2015). On the other hand, rates car ownership in Cuenca has been growing steadily in recent years; around 10 % per year. Several factors explain PT ridership levels in Cuenca. Some of them are exogenous which are not under the control of local transit agencies and PT operators; namely:

Car ownership

According to the local transport agency (EMOV-EP), approximately 160,000 vehicles were registered in 2013 in Cuenca. And the annual growth of the car fleet is around 10% (IADB, 2014).In the city of Cuenca the motorization rate is 280 vehicles per 1000 people taking an urban population of 570,000 persons for 2014 (INEC, 2013). Comparatively, the car stock in Ecuador totalized nearly 2.19 million units by 2014 (AIHE, 2015) and considering a total population of 16 million people, the national motorization rate corresponds to 136.39 cars per 1000 people. Besides, the annual increase of the national car fleet was 7 % in average between 2010 and 2014 (AIHE, 2015).

There are some factors socio-economic factors that explain the escalating rates of car ownership observed in recent decades in Cuenca. In first place, car ownership is often positively related to income levels (Bamberg et al., 2003). In that respect, many families living in the Cuenca have been receiving significant remittances from relatives working abroad, especially in US and EU, which have inflated disposable household incomes. Only in 2014, families in Cuenca received USD 415 million in remittances (BCE, 2015). Some of those moneys have been used for acquiring cars; which in part explains increasing motorization rates. Moreover, this phenomenon might have been influencing the perceptions of many people in Cuenca in the sense that car ownership and use is a requisite in order to fit socially in that city regardless actual needs.

But on the other hand, the central government of Ecuador has progressively restricted the importation of both assembled cars and parts for assembling cars inside of the country by determining quotas since 2011 as part of a set of macroeconomic measures (El Comercio, 2016a). Such policies along with higher taxes on new vehicle have been restraining car ownership in Ecuador. Besides, car dealers reported that between January 2015 and May 2016 sales of brand-new cars had sharply fallen; allegedly because of the economic crisis that Ecuador has been facing due to the fall of oil prices and some natural disasters, which affects the national economy and somehow prevents people from asking loans for acquiring new cars (El Comercio, 2016a).

Moreover, it would be difficult that car fleet continues to growth at an annual 10% because the market would be saturated in question of a few years; considering that by 2014 the number of cars was 160,000 (GAD-C,2015) and at that rate the car stock would double its size in just seven years. Such an increment seems unlikely for a local economy part of a county that is struggling to grow; in Ecuador the national GDP rose 0.3% during 2015 and is projected to be negative for 2016 (El Universo, 2016). All those factors suggest that the growth of the car fleet of Cuenca by now is decelerating; which seems to be an opportunity for stimulating the use of sustainable modes of mobility.

Cost of driving a car

When assessing PT ridership growth, several models normally include fuel prices as an influencing factor; most of them have found little of as small relationship of those prices and PT ridership though; manly because expenditure on fuels typically represents a relatively small share of total car travel costs (Taylor & Fink, 2003). That being said, some particular facts about prices of transport fuels in Ecuador seem to be relevant in order to understand the dynamics of PT ridership and car use.

While globally the prices of vehicle fuels have experienced continuous fluctuations in recent years (Fig. 11), in Ecuador the distributor's price of fuels for road transportation have basically not changed since August of 2003 (Petroecuador, 2013) due to the application of subsidies by the central government. And that stabilization policy is expected to continue holding fuel prices unchanged since recently, June 2016, the central government even increased subsidies. Then, the consumer's price is as low as USD 1.46 per gallon of regular gasoline called "Extra", up to USD 2.29 per gallon of high-octane gasoline called "Super", and the Premium diesel is USD 1.02 per gallon. As it is obvious, in that country there are no taxes on fuels apart from the valued-added tax (VAT).

When the retail prices of gasoline and diesel do not fully reflect their market prices neither the external costs generated by the use of those energy vectors, especially with the application of subsidies, private car use turns to be less restrictive. In several countries where the state is the owner of domestic oil stocks, as it is the case of Ecuador, fuel subsidies have been financed through oil trade revenues under the notion of promoting household income redistribution.

Fuel subsides in Ecuador for a long time did not have a clear definition for their existence and were assumed as implicit; implying that supply price was suppressed (Mendoza, 2014). But, more recently the justification for those subventions has been based on the fact that the country, even though exports oil, needs to import gasoline and diesel to cover the internal demand of those fuels due to low internal refinement capacity. Therefore, fuels subsidies nowadays are regarded as explicit since the government directly spends money on them.

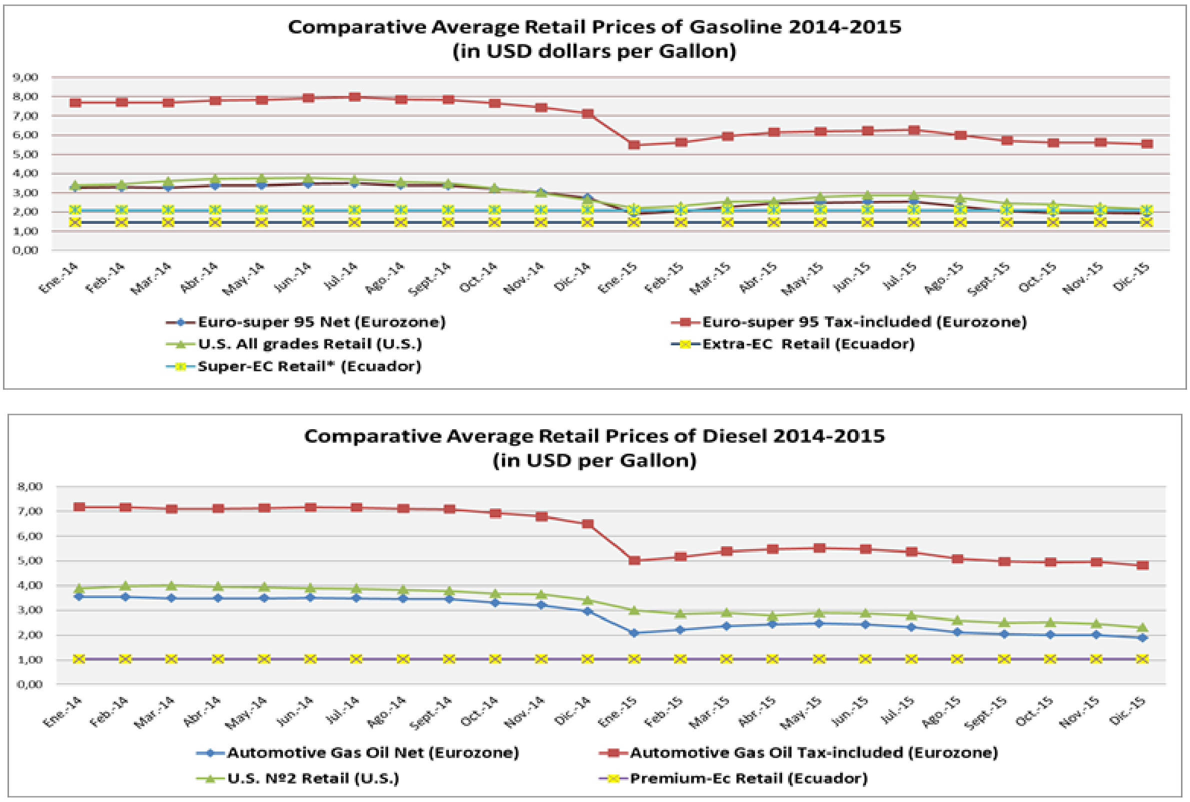

Figure 11: Comparative average retail prices of Gasoline and Diesel 2014-2015

(Sources: EU Commission, Weekly Oil Bulletin 2014-2015; US EIA, Petroleum & other liquids 2014-2015)

Any attempt to cut fuel subsidies in Ecuador have generated social unrest expressed through protests and strikes and might have carried severe consequences in terms of political stability, facts that have made those subventions almost untouchable for several regimes. Moreover, the severe inflationary effects that might by generated by higher domestic energy prices and their effects on the competitiveness of national exporters (IMF, 2013) make those subsidies hard to remove. Under such circumstances the application of fuel taxes as a measure for restricting car use seems still distant.

Normally, the demand for fuel is almost non-sensitive to changes in its price (almost perfectly inelastic in the short run); therefore, increasing fuel prices has a negligible impact over both reductions in private vehicle use and increments in PT usage (Cosgrove & Gargett, 2007; Currie & Wallis, 2008). In consequence, price elasticity of demand of road transport fuels in Ecuador has been determined in 0.01; implying that consumption of those energy vectors is basically not changing with respect to increments in the price (Mendoza, 2013).

In general, energy subsidies have multiple economic, social and environmental consequences. In the context of the present study the most relevant issues are those related with fiscal imbalances which displace priority public investments; accelerated resource depletion; inefficient fuel consumption; increasing emissions of air pollutants and GHG gases; inequality as subsidies are mostly benefiting high-income households (IMF, 2013).

In the specific case of Cuenca, the costs related with car ownership are allegedly higher than in other Ecuadorian cities due to the existence of several charges and taxes imputed by local and regional governments at the moment of registering cars. There are approximately eight charges between insurances, green taxes, car inspection, and other conceived mainly for raising funds as it is usual with fixed charges; which are not as efficient for internalizing external cost of driving as charges imputed in a per trip basis.

Urban Sprawl

Spatial factors such as land use and urban form are regarded to influence PT ridership in at least two different ways. Firstly, availability and price of parking influence the relative utility of automobile use (Taylor & Fink, 2003). And secondly, due to urban sprawl actual or potential PT users are dispersed through a wider service area of PT which affects the efficiency of PT operations. In that sense, a study carried by Spillar & Rutherford claim that total ridership will growth as population density increases since a greater number of people have access to PT (Spillar & Rutherford, 1998).

Between1950 and 2010 the city of Cuenca expanded its surface area more than 7 times, at rate of approximately 1.2 sq. km per year. Comparatively, its population grew nearly 4 times in the same period (IDOM 2013).But it has been the levels of population density which has shown a downward trend; in 1950 there were 8044 people per sq. km in urban Cuenca steadily falling to nearly 4547 people per sq. km by 2010 (Table 5).

Table 5: Historical density levels in Cuenca based on the urban footprint growth

	1950	**1962**	**1982**	**2001**	**2010**
Population	82.451	82.629	152.406	277.374	331.888
Surface (sq.km)	10,24	15,95	41,03	55,64	73
Density (people/sq.km)	8048,08	5179,69	3714,95	4985,26	4546,6

(Source: IDOM, 2013)

Moreover, the urban perimeter of Cuenca between 1987 and 2002 grew 2.36 % per year. Later, in the period ranging from 2002 to 2005 the urban footprint growth was 1.57%, but it was between 2005 and 2010 that the city expanded at a more accelerated pace, at a yearly average rate 4.12 %, considered as too high for cities the size of Cuenca (IDOM 2013).

4.3.2 Endogenous influences

There are a several factors determining PT ridership and car use which can be influenced by local transit authorities; namely:

Public transport price

Fare levels have been widely regarded as an influencing factor for PT ridership growth. In that sense, a study by Sale on several PT systems in US points that a stable reduction of PT fares was an important factor explaining ridership uplifts; however, those gains are not as large as those accountable to increased services (Sale,1976). On the other hand, the provision of PT services in most cases is only viable at a financial loss (Currie & Rose, 2008); due to low usage rates or in order to keep fares stable. That fact discourages private investment in PT unless governments offer subsidies.

Until 2012, regulation of urban PT services, including fare setting, was an attribution of the central government for all cities in Ecuador. Between 2003 and 2012 PT fares at national level kept unchanged at USD 0.25 for the conventional bus service. To compensate any fare increments required by PT operators, most private, the central government, particularly since 2010, granted them several subventions in the form of tax exceptions, bonus and monthly outlays (El Comercio, 2014).   .

Starting in 2013, all affairs related with transportation inside the canton Cuenca by decree became an attribution of the local municipality (GAD-C, 2015). However, PT fares in city Cuenca have not changed from 2003 levels until now, 2016. Therefore, all financial compensation, particularly the monthly payment formerly granted by the central government, should be managed by the city; which represents a disbursement of more than USD 2.85 million per year. But financial constraints of the municipal budget make such compensation hard to cope with (El tiempo, 2016). According to estimations from PT operators in Cuenca, in order to cover the real costs of PT and generate profits for them PT fares should be set at USD 0.42, which represents a 65% increment from the current price (El Comercio, 2015). Finally, such an increase in the fares of PT is still calculated considering a highly subsidized price of transport fuels; without subsidies, fare increments required by PT operators would be even higher.

Based on the Linear Expenditure System first introduced by Stone in 1954, Cisneros et al., (2000) determined the price elasticity of conventional-bus service demand in -0.3453 ceteris paribus for Ecuador (Cisneros et al., 2000). That value is quite similar to -0.40 which is the fare price elasticities of PT synthesized from metadata analysis of international cases (Currie & Wallis, 2008). In 2000, when that study by Cisneros et al. was conducted, real incomes were lower and the share of PT users could be different to the current levels. Nevertheless, that value of elasticity is, at best, appropriate for predicting how a change in the fares is going to affect ridership in the short run; up to 2 years (Litman, 2016). If fare increments of 65% requests by bus operators were accepted, and assuming an elasticity value of -0.3453 keeping other variables equal, a reduction of approximately 22% in the demand of PT might come in the next 2 years of the increment.

In sum, the current price of PT in Cuenca does not reflect the actual cost of the provision of that service. Fares have remained constant mainly due to the application of financial compensations coming from the central government and later assumed by the municipality, but also, due to the existence of huge subsidies for transport fuels at national level. Under that state of affairs the application of subsidies on the price of PT as an instrument for increasing PT ridership in Cuenca is not feasible; rather, a sharp increment in fares seems to be imminent; as consequence a decrement in ridership is probable if the prices of substitutes do not increase in similar proportions.

Quality factors of the PT service in Cuenca

Models aiming to determine the levels of PT usage and to propose uplifts should include measures of PT service quality – reliability, comfort, and convenience – and service quantity; but usually, only the latter is measured (Taylor & Fink, 2003). Among the factors under the control of PT agencies, quality improvements of PT service prove to be highly effective for increasing PT ridership especially when directed to specific segments of the population (Taylor & Fink, 2003)

Some of the most relevant features of the conventional bus service in Cuenca are exposed in table 6.

Table 6: Attributes of bus service in Cuenca

Attributes	
Frequency	24 conventional-bus lines pass in intervals between 5 and 20 minutes in a typical day (16 in intervals of 10 minutes or less, but, during weekends the frequency increases to 30 minutes for certain lines)
	2 integrated-bus lines pass in intervals of 5 minutes in a typical day
Velocity	In average the velocity of the buses when operating ranges between 15 and 17 km per hour
Bus stops (location)	92% of the population has a bus stop at 300 meters or less from their homes (the remaining 8% corresponds to people living in rural areas)
Bus stops (quality & accessibility)	Poor accessibility and convenience of the bus stops "particularly" in the peripheries of the canton (lack of sidewalks to access bus stop and lack of roofed bus stops)
Fare payment	Fares can by prepaid through e-cards or on-board with coins
Exclusive bus lanes	2.9 km of segregated bus lanes
Physical attributes of the buses	
Age of the fleet	9 years in average
Capacity of the buses	Each bus can carry between 60 and 90 passengers (above 50% of them sitting)
Accessibility of the buses	All buses of the existing fleet are high-floor buses requiring three steps
Information	Buses are equipped with led panel boards providing information about the stops
Security	Buses are equipped with video cameras connected to a centralized monitoring system and GPS systems

(Source: GAD-C, 2015)

The perceptions of the citizens of Cuenca with respect to certain attributes of the conventional bus service are inferred from the results of a survey on the quality of living in Cuenca performed jointly by CCCV and IADB which are summarized in table 7.

Table 7: Citizens' perception on quality attributes of conventional bus service in Cuenca

Percentage of respondents who are "Satisfied" and "Very satisfied" with the bus service with respect to given attributes		
Attribute		**%**
Frequency	How often buses pass during the day	63
	How often buses pass at night	26
Accessibility	The degree to which PT is available for handicapped individuals	26
Price	The monetary cost of travel	86
Information	How much information is provided about routes	46
Comfort	How comfortable the journey by bus is and the cleanliness of the vehicles	53
Driver attitude	How drivers handle users	30
Routes	Coverage of the bus network	52

(Source: CCCV, 2015)

Moreover, the study carried by CCCV (2015) concludes that individuals who take the bus for traveling to work or school spend more time than people who use other means of transportation in Cuenca. Then, PT travel time represents an important barrier when aiming to attract more commuters to use public bus services.

Public transport provision: introduction of the tram system

The light rail system, currently under construction, called Tranvía de los 4 ríos de Cuenca is expected to start operating in 2017. It is a single-line system crossing the city from northeast to southwest (fig.12) with a longitude of 10.7 km (total 21.4 km for two directions) and passing through some of the spots with higher mobility demands of the city - industrial park, the airport, the bus station, the historical center, the biggest market in town, etc. The frequency of that service is planned within a six-minute headway in peak hours. And its capacity is 300 passengers per ride and 120,000 passengers per day (GAD-C, 2015).

The tram is expected to be the backbone of an integrated transport system for Cuenca; however, the physical characteristics of the bus fleet currently operating that city do not match those of the tram system. Perhaps the main incompatibility is that entries and exits of existing buses are opposite to tram stops; requiring users to cross the street when taking off the bus to take the tram and vice versa. That aspect will make the physical integration of those two modes of PT difficult.

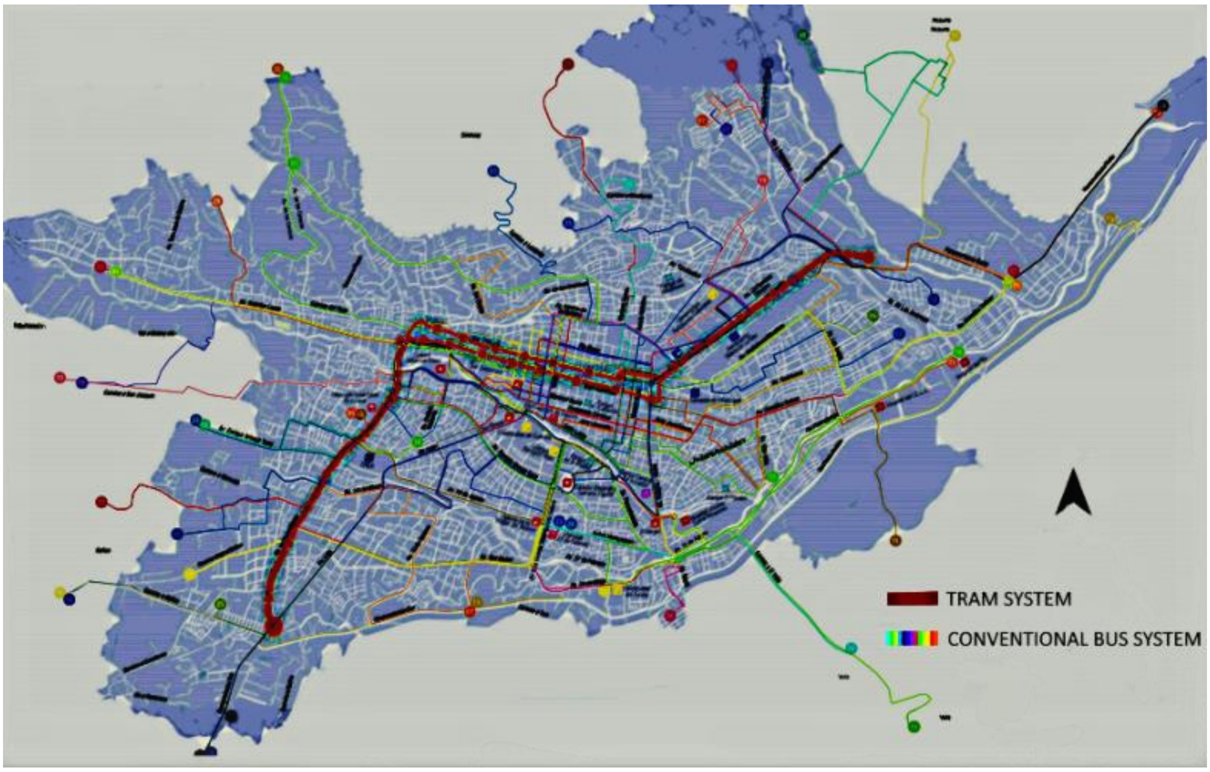

Figure 12: Public transport system in Cuenca

(Based on maps from cuenca.gov.ec)

Even if the tram operates separately from the conventional bus-services, that system is going to increase the supply of PT and provide a new transport option for certain routes. Studies suggest that in certain cases the introduction of tram systems have generate PT ridership growths up 8% when compared to conventional on-street bus (Currie & Wallis 2008). Moreover, reductions on in-vehicle time can be expected when traveling by tram depending on the type of way that the system uses; segregated right of way or on-street (Currie & Wallis 2008). For the case of Cuenca, most of the tram's route is going to have a segregated right of way which constitutes an advantage over other modes of transport in terms of travel time.

Parking management

Parking management and pricing are normally controlled by public agencies different to those in charge of managing PT; therefore, they are considered as exogenous influences of PT ridership. Nevertheless, in the case of Cuenca a single agency (EMOV-EP) is in charge of the management of both parking and PT; then, in this case it is an endogenous influence on PT ridership.

The PMEP provides some references about the distribution and use of parking spaces across Cuenca. There exist 28,280 on-road parking spaces across the urban area representing 1.2% of the total area occupied by streets. Approximately 2,340 on-road parking spaces are priced and with regulated turnover (GAD-C, 2015). Presently, the on-road parking fee in Cuenca is USD 0.50 per hour. Since the historical center and El Ejido are the main trip attractors in Cuenca (as seen on fig. 8), most on-road priced parking (93%) is concentrated on those two contiguous zones of the city.

The rates of occupancy of priced on-parking spaces range between 50% and 80% depending on the zone; however, during certain periods of the day they may overflow. Their turnover is approximately 0.85 vehicles per hour. From the total demand for priced on-road parking, approximately 40% of the vehicles occupy those spaces for 10 minutes or less. Finally, 15% of drivers parking their cars on priced spaces for 10 minutes or less skip the use of parking cards which is the payment method.

When it comes to commercial parking, there are nearly 6,270 spaces across the city. Similar to the distribution of on-road parking, the historical center and El Ejido concentrate 88% of spaces available in parking lots. According to the PMEP, nearly half parking spaces available at the historical center of the city are not regulated; 27% of total spaces available in parking lots (GAD-C, 2015). More than 1400 parking spaces available inside privately-owned buildings in the historical center are regarded as “fixed parking” as they are rented in a monthly-basis to workers (83%) and the other part (17%) to residents of that sector; therefore the turnover rate of commercial parking is lower, 1.9 vehicles per day, compared to on-road parking.

In sum, there is no evidence over any formal model for parking management in Cuenca. The scheme used for on-road priced parking has been in place for more than 15 years; however, there is no evidence on the effectiveness of that scheme for easing traffic congestion or car use in Cuenca. And in the cases of private parking lots and residential parking, there are not explicit regulations for them in that city.

5 PLAN FOR MODAL SHIFT IN CUENCA

5.1 Background

In the preceding chapter multiple factors influencing PT usage in Cuenca were analyzed and even when multiple aspects should be addressed in order to achieve the mobility targets; however, as initial step the plan proposes improvements in service quality provided by conventional buses in order to offer a more appealing alternative of sustainable mobility to the citizens who travel by private car. Such hypothesis is based on two factors:

- As seen in table 7, important number citizens do not have a positive perception on the quality of PT services in Cuenca
- The modal share of PT is by itself an indicator of quality of PT services (TRB, 2014); which in Cuenca is somehow low (31% by 2015)

As seen in table 4 sporadic measures have been taking in Cuenca in order improve certain aspects of the PT service such as on-board security cameras or the trials for providing Wi-Fi on-board; however the effects of those measures for ridership uplifts might be negligible when applied in isolation. Then, the main objective of this plan is to maximize PT ridership by making a package measures related mainly with the quality of PT services. To that purpose, the plan describes five components: (1) stating with improvements of service quality factors of the conventional-bus service; (2) restricting car use through parking pricing measures; (3) definition of key indicators for controlling purposes are defined; and (4) projections of the effects of the present plan

5.2 Improvements of service quality factors of the conventional-bus system

5.2.1 Availability

A set of factors able to lead to PT ridership unfits (Table 8) is analyzed in the context of Cuenca. Most of those factors related with availability, except information availability, have to do with PT services quantity rather than service quality; however some actions in that regard are going to be proposed.

Table 8: Factors determining the quality of PT service

1) Availability		
Is public transport an option for making a particular trip in Cuenca?		
Inferences based on people's perceptions		
Spatial availability	∞	Fair
Temporal availability	✘	Poor
Information availability	✘	Poor
Capacity availability	∞	Fair
2) Convenience & Comfort		
Once public transport is available		
Would citizens of Cuenca want to use it?		
Citizens ponder several factors to make a decision on using public transportation such as:		
Affordability	✓	Good
Time required for journey	✘	Poor
Accessibility	✘	Poor
Cleanliness	✘	Poor
Driver friendliness	✘	Poor

(Based on: TRB, 2014)

Spatial availability

In urban Cuenca, the spatial coverage of PT service with respect to the urban area is 77.5 %, and in relation to urban population is 92%: the latter considering the number of citizens having a bus stop within 300 meters from home (GAD-C, 2015).When the urban area is covered in a range of 75-90%, as it is the case of urban Cuenca, it can be consider that most destinations within high-density areas are served (TRB, 2014). However, there are some deficits in terms of PT coverage in zones with low densities in Cuenca. The implementation of park-and-ride facilities located at (peripheral) points where PT services are available can encourage drivers to use PT for the final section of their trip. Besides, giving travelers the option to take bikes on-board PT vehicles might help to provide PT services to a greater number of citizens and spur multimodal journeys.

Temporal availability

There are two determinants of the temporal availability of the PT service; frequency and service span (TRB, 2013). From the user's perspective, the frequency of PT service in Cuenca is somehow satisfactory during the day but deficient at night. According to EMOV-EP, the nominal frequency of the service on weekdays ranges from 5 to 20 minutes regardless the hour of the day; however the service is irregular at night. But, PT service is also patchy during weekends when frequencies range between 5 and 30 minutes depending on the route. Then, the problem obviously roots on both a lack of compliance from the operators and lax control from the authority in charge of the supervision of this aspect of the service.

Moreover, the nominal PT service span in Cuenca is 16.5 hours during weekdays, starting at 6 am and ending at 22:30 pm. However, operators cut the service 1.5 hours before in summer, then available until 21:00 pm, allegedly motivated by reductions on the demand for the service due to student's holidays (El Mercurio, 2015). The service span during weekends is reduced to 8 hours for certain lines.

The poor perception that an important number of citizens have in respect to the frequency of the PT service in Cuenca can be improved, firstly, if the transport agency defines timetables and span of the service for each line in agreement with the operators. But also, mechanisms for a continuous control on the compliance of the defined shifts particularly at night and during the weekends need to be adopted directly by that authority instead of letting operators to self-control the frequency and span of the service.

Information availability

Commonly, users of PT in Cuenca arrive to bus stops without knowing the exact time at which buses are going to pass; as there are no schedules publicly available to stick to. In principle, that is not a major problem when headways are no longer than 10 minutes (TRP, 2014) during the day, which is the case of 16 out of 28 bus lines serving in urban Cuenca. But, when headways are longer than 10 minutes users should be provided with information on the schedule and span of service; thus, allowing them to plan their activities according to a timetable of PT services.

Besides making available schedules and span of the PT services, users should receive information on how to use PT services, bus stops and transfer stations and payment methods (TRB, 2014). The widespread availability of all that information has the potential for attracting those segments of the of the population using other means of transportation, but also visitors and occasional users, not putting down benefits this might represent for habitual users.

Multiple means can be used to inform current and potential users according to their age, level of education, access to technology, physical impediments, etc. Nowadays the most usual means are:

- Handouts displaying schedules, maps, fares and delivered in multiple locations
- Information posted at bus stations and stops, on-board and other strategic locations
- Audible and visual information thought for users with visual and hearing impediments
- Personnel from transit agencies providing information on PT services at bus terminals and other points
- On-line information provide through the web and smartphone apps
- Real time passenger information

Currently, conventional buses operating in Cuenca provide on-board information about the names of each bus stop they pass; however, bus stops themselves do not display their names. Then, it is necessary to put names to the bus stops and display that information in bus stops and in other sources of information in order to provide geographical references to citizens about bus routes (Fig.13). Moreover, bus stops should display the numbers of the routes passing in order to inform non-habitual and new PT users about the travel options they have.

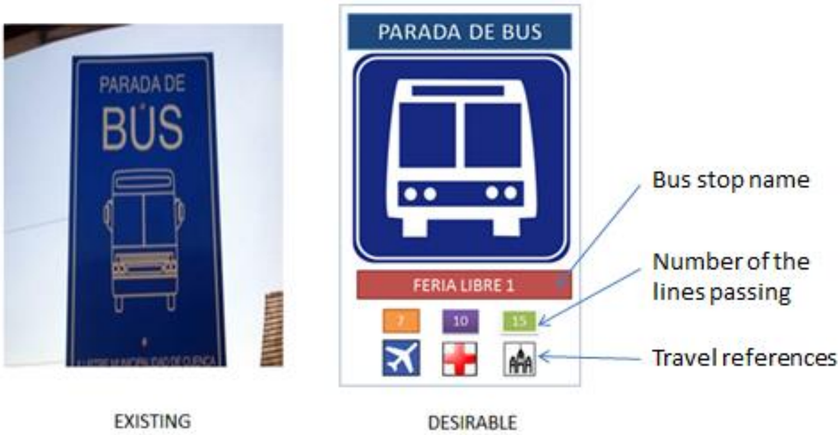

Figure 13: Desirable bus stop signs

Capacity availability

Information available on the relation between supply and demand of PT services in urban Cuenca is inconsistent. According to the PMEP, the capacity of the conventional-bus system totalizes approximately 320,000 passengers per day, however, the demand for those services in urban Cuenca sum nearly 400,000 passengers (GAD-C, 2015). Regardless that mismatch is a matter of lack of capacity or a miscalculation; the PT services in Cuenca are going to be notably incremented with the introduction of the tram system in 2017. According to official sources, the new system is going to have a capacity of 120,000 passengers per day.

5.2.2 Comfort & convenience

Accessible busses

Several facts suggest that the poor accessibility of the existing bus fleet is a major barrier for higher PT ridership levels in Cuenca. Boarding conventional-buses normally requires three steps which is difficult to surmount for handicapped and seniors users. But buses in Cuenca also are uncomfortable and dangerous for children, people carrying babies or packages, and for all users in general.

The tram system of Cuenca is going to improve accessibility as its vehicles are low-floor; however, it is a single route service which is going to cover just a part of the PT demand in that city. Therefore, the introduction of more low-floor transport options is still a necessity in Cuenca. In table 9, different transport systems offering such feature and which have been introduced in the three main cities of Ecuador are compared in terms of cost and capacity.

Table 9: Comparison of costs and capacities of different PT options for cities

Transport system	Capacity (passangers/vehicle)	Capital cost (USD/km)
Metro rail Quito (2016)	1500	89 millon (1)
BRT Metrovia Guayaquil (2006)	160	2,7 millon (2)
Electric Tram Cuatro Rios de Cuenca (2016)	300	+20 millon (3)
Low-floor Bus Euro VI for Cuenca (2016)	80	0,25 millon per unit (4)

(Sources: (1) Alcaldia de D.M. Quito, 2016; (2) COHA, 2009; (3) El Tiempo, 2016; (4) Civitas , 2014)

Further extending the light-rail system or introducing a metro rail in Cuenca, besides adding unnecessary capacity and having low flexibility when route changes are required, would result prohibitively expensive amid the enormous investment that city is making in the tram system. In the case of BRT systems, several experiences, i.e. Metrovia of Guayaquil in Ecuador, demonstrate that those are cost effective options; however, both costs and the development of the required infrastructure would result problematic for Cuenca. Citizens have shown a lot of resistance to the introduction of the tram system in part due to the inconveniences generated by the construction of the infrastructure it requires. Therefore, the introduction of low-floor buses would be a more feasible option for improving accessibility as well as other service quality aspects of PT service in Cuenca. Besides, the need for replace the existing bus fleet with low-floor buses equipped with doors on both sides is fundamental when aiming to have an integrated PT system in that city.

Evidence coming from several cities in different countries in Europe (Jupiter Project) points that among different types of measures adopted for increasing ridership, the one with highest performance in terms of cost-effectiveness was the introduction of low-floor buses (Currie & Wallis, 2008). A study by Balcombe et.al. (2004) in the context of the urban surface transport in Great Britain found that low floor buses might lead to ridership growths in an average of 7% assuming that all the bus fleet is replaced. Besides, the introduction of low floor buses might reduce journey times as users have to be negotiated just one step for boarding and alighting that type of vehicles (Balcombe et.al., 2004).The introduction of low floor vehicles for PT is important for attracting new users, but, it is not enough to keep them if not accompanied with other improvements, such as higher efficiency, cost, convenience and comfort (Currie &

Wallis 2007). Therefore, the multiple measures proposed through this plan should be applied as a package in order to have lasting PT ridership increments.

Finally, other aspects of PT accesibility should not be disregarded. For example, accesible bus stops can help to improve the demand of PT services by implementing barrier-free access routes; particularly better sidewalks and ramps.

Comfort and cleanliness

Almost half of the citizens in Cuenca do not have a positive impression regarding the comfort and cleanliness of the bus service. There are several reasons which can motivate this to happen:

- Uncomfortable sets not provided with headrests
- Litter inside the bus and at the bus stops
- Since the buses serving the city are privately owned, operators “decorate” those vehicles with stickers and ornaments at will
- Unpleasant odors and noise
- Lack of ventilation

Considering all those inconveniences, improving the image of the PT in Cuenca is a must in order to raise PT usage. Therefore, contracts between bus operators, the municipal transport agency and other key stakeholders should be subscribed in order to guarantee passengers certain levels of comfort and appearance when using PT services.

The so-called Quality Partnership Schemes used in UK have proven to be effective in regulating aspects related with PT service quality (Davison & Knowles 2006). In those contracts the local authority is legally bounded for providing and maintaining facilities to enhance the attractiveness of the bus service; and on the other hand, bus operators are legally responsible for providing an improved service through high standard vehicles, customer service and established frequency (Davison & Knowles, 2006).

Such schemes can be used in Cuenca to standardize the bus service by forbidding both the personalization (with stickers and ornaments) that operators normally make to the vehicles. Also other aspects related with the comfort of the seats, the cleanliness and ventilation of the buses might be regulated under those contracts.

But also, high quality bus shelters can help to attract more users to PT services (Fig 14). The existent bus shelters in Cuenca offer protection to few people which result problematic at peak hours and under variable climatic conditions, besides they are not illuminated which provokes a sensation of insecurity to users when waiting for PT at night. High quality shelters at bus stops provide a more pleasing waiting environment and in Cuenca would help to improve the image of PT services.

Figure 14: Desirable bus shelters for Cuenca

Finally, some aspects related with the attitude and poor driving skills of many motorists have damaged the image of PT in Cuenca. Only 30% of the citizens are satisfied by the way drivers handle passengers; thus, this is one of the worst aspects of the PT service in that city. Moreover, the severity of acceleration and braking of the motorists generates uncomfortable movements to passengers. And even though the municipal agency in charge of PT management in Cuenca (EMOV-EP) has provided training to bus drivers, those problems persists. Then, the local transport agency should establish mechanisms to directly intervene in the selection of bus drivers; regardless buses operating in Cuenca are privately-owned. To that purpose, evaluations should be executed in order to assess customer service and driving skills of bus drivers then allowing only those who comply with given standards to operate conventional-buses in Cuenca.

5.3 Restricting car use

The measures proposed above aim to provide a more attractive mobility option and appeal to voluntary responses from drivers in order to shift modes of transport; nevertheless, they do not influence car use in a direct way. Therefore, instruments aiming to discourage car use in a more forceful way need to be considered in parallel with those improvements for PT services at the moment of prompting higher levels of

PT ridership in Cuenca. Parking management can support different policy objectives related with land use, land cost, multiple environmental issues, reduce traffic congestion, energy consumption, etc. (Litman, 2016a). But, effective management of parking supply can also help to provoke modal shift to PT in three ways; (1) removing a given amount of parking in city centers; (2) increasing parking cost within city centers; and (3) providing park and ride facilities (Batty et al., 2015).

The on-road parking scheme in Cuenca has focused on enforcing high parking turnover, particularly in streets of the historical center and El Ejido which are main car trip attractors; however, that scheme can also help promoting the use of PT services by avoiding some of those car trips. To that purpose, some specific measures are proposed:

1. Improve enforcement of on-road parking charges

Abolition of the so-called "ten-minute grace period" drivers assume they have for parking for free in priced on-road spots, measure which would charge/avoid a significant number car trips going towards highly congested zones in Cuenca. For removing those "bad" habits, the local transport agency should make clear car drivers, through information campaigns, there is no grace period on priced on-road parking.

2. Extending priced on-road parking

According to PMEP, there are several zones in urban Cuenca attracting important quantities of car trips because on-road parking is free; only El Ejido and Feria Libre together attract approximately 18,000 car trips to free parking streets (GAD-C, 2016). Then, extending the priced on-street parking system across those two particular zones, which have acceptable PT service coverage, would help avoiding car trips and other associated issues.

3. Differentiated on-road parking pricing

Even when the average occupancy of priced on-road parking in Cuenca reaches 80% in working days, on certain zones parking demand often overflows (GAD-C, 2015). Therefore, higher parking prices should be charged on those zones in order to promote more efficient use of on-road parking and to make drivers switch to other modes.

4. Interventions on commercial parking schemes

The historical center and El Ejido concentrate approximately 90% of total priced parking demand in Cuenca (ICM, 2015). Therefore, many privately-owned pieces of land and buildings on those two zones have been used for commercial parking; which is seemed as a profitable business for the owners of those states, but carry multiple external costs for the entire city by encouraging car use. In order to correct such imbalance, the municipality of Cuenca should impose (annual) financial contributions to the owners of commercial parking business; obviously, such extra costs would be transferred to drivers who opt for using that type of parking. Besides, the introduction of new privately-owned parking schemes in Cuenca should be allowed under parking and mobility planning directives and not only driven by private business opportunities.

Parking charges are part of the out-of-pocket costs for drivers which can influence decisions respect to making a trip or not, shifting the destination of a trip and shifting mode for a trip (Ottosson, et al., 2013). Free or cheap on-road parking encourages car use and makes drivers cruise around searching for vacant parking spots generating traffic congestion, harmful emissions, fuel waste, noise, etc.

Since there are no publicly-available estimations of price elasticity of car trips respect to parking prices for Cuenca, determining the effects of parking price increments in terms of potential avoided car trips is quite difficult. However, the application of those four measures, as a package, might influence drivers' decisions about using cars for going to the historical center and El Ejido; which attract approximately 40% of total trips taken in Cuenca (GAD-C, 2015).

5.4 Definition of key indicators and performance tracking

Certain environmental indicators might be defined in order to track the performance of the actions proposed through this plan; however, the most relevant indicator is PT ridership levels since the main objective of the plan is to increment the use of massive means of transport in detriment of car use. PT ridership is at the end is an intrinsic indicator of the quality of PT. The conventional-bus system operating in Cuenca is able to collect fares through electronic payment cards which might facilitate the measurement of demand for those services.

5.5 Estimations of the effects of the plan for modal shift in Cuenca

5.5.1 Outlines

The potential effects of the plan for modal shift for rising PT ridership and reducing GHG emissions in urban Cuenca are projected in this section. All the improvements related with comfort, information provision, high quality bus shelters, etc. are meant to be fully implemented by the end of 2018. They are meant to achieve a 4% increment (Currie & Wallis, 2008) in the ridership of the conventional bus services. On the other hand, the progressive introduction of Low-floor buses is meant to start in 2018 and replace the complete bus fleet by 2025 generating a 7% ridership increment in the ridership of the conventional bus system. The PT ridership increments generated by the introduction of the tram system were added to those generated by the implementation of the plan above proposed.

5.5.2 PT Ridership growth

The 2015 modal share in Cuenca was assumed as base line for these projections; 224,000 trips per day taken by cars and 217,000 trips by PT which represents 32% and 31% respectively of a total of 700,000 trips taken inside of Cuenca every day. Four scenarios for projecting PT ridership trends towards 2025 were modeled (Fig.15) and which are better explained in Annex 2. The BAU scenario represents a trend on which the modal share of PT estimated by 2015 (31%) remains unchanged through 2025; assuming that local mobility demands increase linearly with the population growth of urban Cuenca which has been around 2% in recent years (GAD-C, 2015). Under this scenario the number of trips of other modes increases in the same proportions to represent the same share as in 2015.

The TRAM scenario represents increments in PT ridership driven by the introduction of the tram system in Cuenca starting in 2017; however, the total impact of that new mode of transport was calculated by the end of 2018 due to uncertainties about its actual date of opening. According to the PMEP, the PT ridership that the corridor on which the tram is going to start operating is approximately 65.000 trips per day; which for TRAM scenario can be considered as an “at best” scenario because it corresponds to the ridership of the few conventional bus lines (2 lines as feeders and one line that operate as a trunk line) which are integrated both physical and in fares. This assumption is made on the basis that the tram system is supposed to be the trunk line of the existing integrated system. The increments on PT ridership provoked by the introduction of the tram system were assumed to be 8% (by the end of 2018 for the case of Cuenca) as Currie & Wallis (2008) observed for cases having certain similarities but in other context.

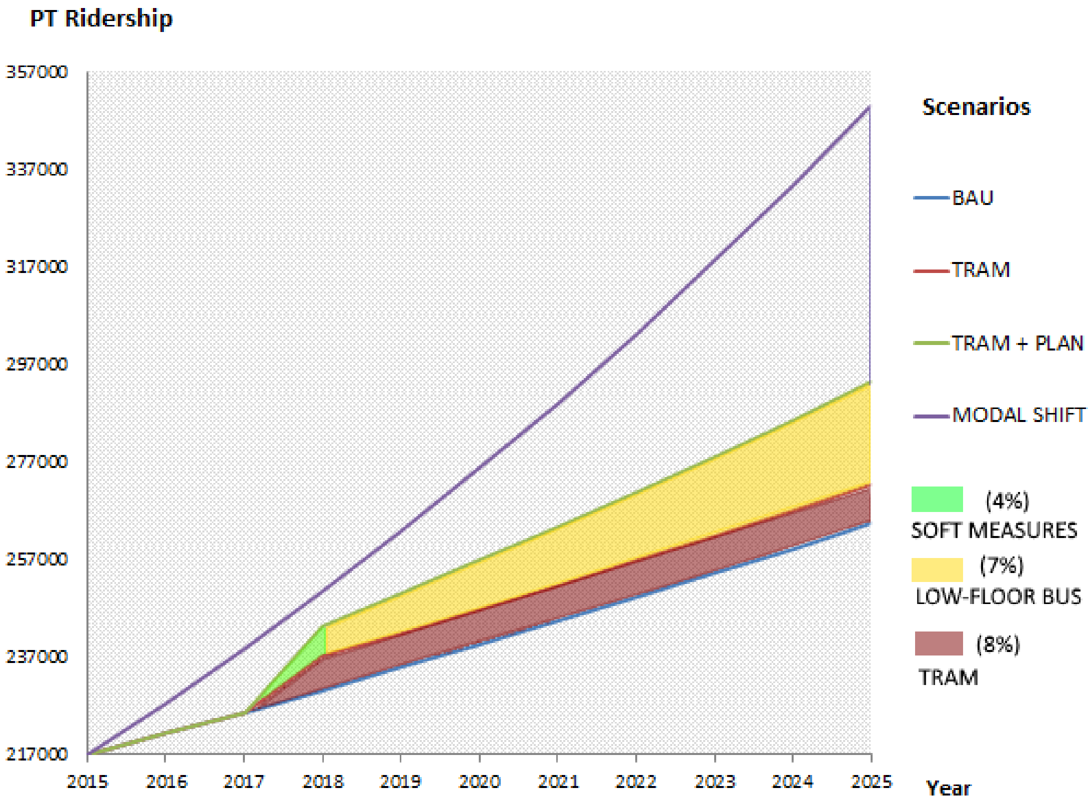

Figure 15: Projected PT ridership growth in Cuenca towards 2025

Even when there are not local studies or from other similar context that can help quantifying the impacts that measures proposed in this plan may have in terms of PT ridership growth for Cuenca for modelling purposes it is assumed that bus improvements associated with cleanliness, facilities, information, comfort are likely to increase PT ridership only marginally, up 4% (Currie & Wallis, 2008) by 2018. Besides, it is assumed that introduction of low-floor buses might lead to progresive ridership growths totalizing 7% once all the bus fleet is replaced by 2025, as some studies for UK suggest (Balcombe et.al., 2004). The scenario exposing the PT ridership growths of the plan proposed in this thesis together with the introduction of the tram system was designated as TRAM+PLAN scenario.

Finally, the MODAL SHIFT scenario represents the 10% modal shift target that the municipality of Cuenca aims to in the PMEP from 2015. This scenario was modeled considering that a 10% switch between car trips and PT ridership by 2025 implies a modal share of 41% of trips taken by PT means and a corresponding reduction of car trips to 22% by the end of that year and taking the 2015 modal share as baseline. In order to achieve such target, the annual PT ridership growth required is approximately 5% assuming that local mobility demands increase linearly with the population growth as above mentioned. On the other hand, this implies that trips taken by private cars in urban Cuenca should decrease approximately 1.75% per year in order reduce its modal share to 22% by 2025. As can be observed in figure 15, the TRAM scenario and the TRAM+PLAN scenarios come short in rising PT ridership at the levels that the 10% modal ship aims for.

5.5.3 GHG reductions

As one of the sustainability targets of Cuenca is to maintain the 2009 levels of total local GHG emissions (1.18 $MtCO_2eq$) through 2030 (IADB, 2014), it is relevant to determine how higher quality measures proposed in the present plan might contribute for that objective. All the assumptions and calculations for modelling GHG emission are explained in Annex 3. In figure 16 the BAU scenario represents GHG emissions generated by the transport sector in urban Cuenca under estimations of the IADB (2014) by 2025. Other two scenarios were modeled in the study released by IADB; the CEMx scenario represents avoided GHG emissions coming from the introduction of national policies aiming to change the national energy matrix and which basically maintain local emissions of 2009 levels through 2025; and under the SMART-GROWTH scenario avoided GHG emission in Cuenca would shrink more than 50% respect to the 2009 levels which implies development under the concept of smart growth and sustainable mobility.

For modelling potential GHG reductions coming from the implementation of the plan proposed in this master thesis and the introduction tram system (TRAM+PLAN scenario) as well as the effect of the 10% modal shift target (MODAL SHIFT scenario), 10 typical car trip routes in urban Cuenca were modeled based on distances provided by local studies (Palacios & Vinueza, 2015). To consider that the PT ridership growth provoked by the implementation of the plan and the introduction tram would directly correspond to car trips avoided and not also to PT ridership increments generated by walking trips shifting to PT under the existence of a better service is perhaps a too optimist assumption; however, such a scenario was modeled in order to visualize the magnitude of the changes required in order to achieve the environmental goals of the city of Cuenca.

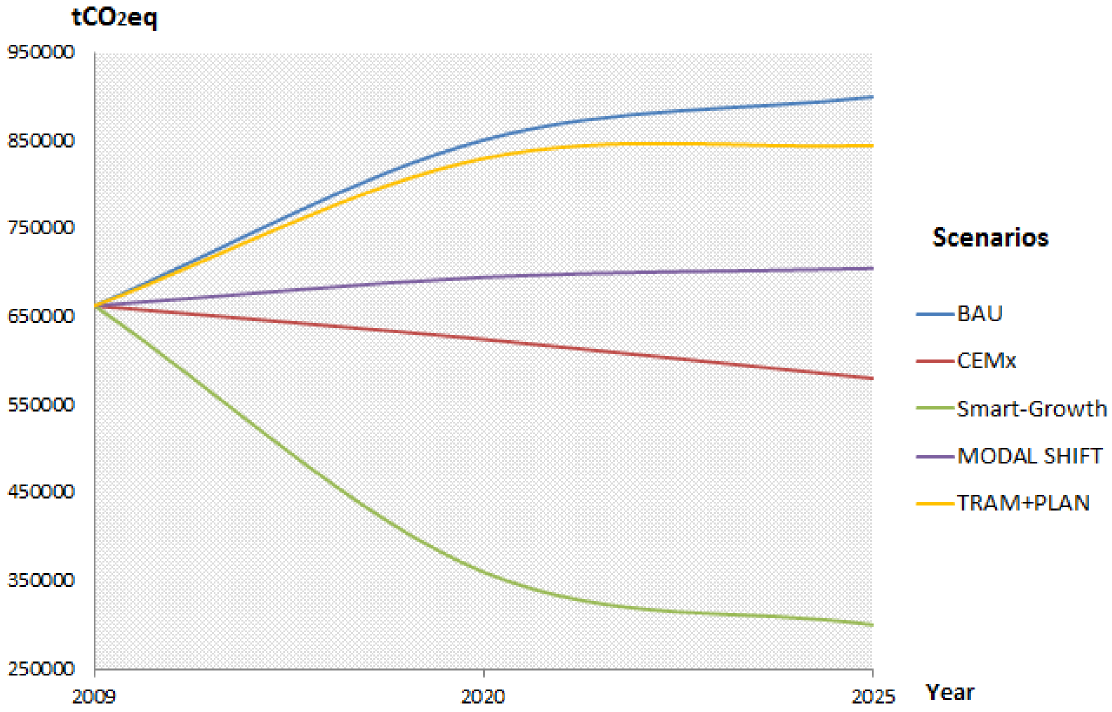

Figure 16: Effects of higher quality measures for PT services on total GHG emissions from the transport sector in the canton Cuenca towards 2025 (tCO2eq/year) (Based on IADB, 2013)

Again, the 2015 modal share in Cuenca was assumed as base line; 224,000 trips per day taken by cars and 217,000 trips by PT which represents 32% and 31% respectively of a total of 700,000 trips taken inside of Cuenca every day. The MODAL SHIFT represents a reduction in GHG emissions coming from a minimum of 85,000 car trips avoided per day. That number of car trips was calculated considering an annual 2% increment in mobility demand in Cuenca by 2025 from the 2015 levels. Finally the TRAM+ PLAN scenario represents a reduction of GHG emissions coming from a reduction of 28,800 car trips per day by 2025.

6 CONCLUSIONS & FURTHER RESEARCH

The present master thesis analyzed the transport patterns of the Ecuadorian city of Cuenca and proposed a plan for improvement under the sustainable mobility paradigm. In agreement with prior studies, it was found that current transport patters in Cuenca give rise to several issues; particularly in terms of environmental degradation, social exclusion, generated by exacerbated car use, poor quality of PT service and ineffective urban planning. Some initial steps have been taken in that city in order to address those issues; improving PT services, through introduction of the tram system, and also with the execution of a plan for mobility and public spaces. However, certain structural changes are necessary in order to reorient mobility in Cuenca towards a more sustainable model. The rapid pace of urban expansion observed in that city calls for the integration of municipal agencies for urban planning and transport in order to prompt policies aiming to more compact and mixed-use urban development; which is would reduce travel distances and facilitate the use of sustainable modes of transport.

On the other hand, it is indisputable that high subsidies on the prices of vehicle fuels provided by the central government of Ecuador have generated unrestrained car use in all that country. And even when those subventions are not handled by the local authorities of Cuenca, there are other mechanisms for restricting car use at the local level such as parking management and pricing, which so far have not been effectively implement in that city. Another factor generating mobility issues in Cuenca is the poor quality of its PT services; particularly in terms of accessibility, reliability and comfort. In that sense, the introduction of the tram system will partly addresses those issues; as it is capable of covering a fraction of the PT demand in urban Cuenca. Therefore, further actions need to be considered in order to achieve mobility and environmental goals that the city pursues.

The present study proposed a plan for increasing PT use by improving the service quality of the convention-bus system. But also, some changes in parking prices were considered in that plan as a complementary measure able encourage PT ridership by restricting car use. By modelling the effects that such plan may have on the mobility patters of Cuenca towards 2025, it was found that higher-quality PT service measures along with the introduction of the Tram system would be able to avoid at most 28,800 car trips per day out of a minimum of 85,000 car trips per day that the 10% modal shift target aims for. And when it comes to curving GHG emissions, such measures along with the introduction of the tram would avoid approximately 13,200 tCO_2eq per year; which constitutes a relatively small contribution for turning back to 2009 GHG emissions levels of the transport sector (673,000 tCO_2eq) towards 2030 when by now emissions are estimated around 800,000 tCO_2eq per year (IADB, 2014).

The contribution of the plan proposed in this study is limited respect to environmental aspects of the sustainable mobility paradigm; significant gains would come in terms of social sustainability tough, particularly with the introduction of low-floor buses. Nowadays, the difficult accessibility of the bus feet currently operating in Cuenca prevents several segments (seniors, handicapped, children, etc.) of the population from using PT. Low-floor buses, besides offering an appropriate mobility option for those groups and for citizens in general, would allow an effective integration of different modes of mobility in that city. When it comes to economy sustainability of the measures proposed in the plan, experiences in other parts of the world suggest that, for example, the introduction of low-floor buses is among the most cost-effective options for increasing PT ridership.

Through this study it was corroborated that drastic changes are required to reverse unsustainable travel patterns, particularly in urban Cuenca. The impact of potential interventions for modal shift from local authorities is going to be limited if not supported by national policies that can restrict fuel consumption in vehicles, principally cutting subsidies. Besides, modal shift is a complex task that requires coordinated and long term involvement not only of national and local governments, but also, of the community and other stakeholders.

Finally, much scientific effort is required in order to better understand of current mobility patterns in Cuenca and propose policies and measures leading to a sustainable mobility system for that city. Improving quality factors of PT services would be an initial step in order to offer a sustainable mobility option to multiple segments of the population of Cuenca; however, in order to encourage modal shift, as local authorities aim for, many aspects related to the determinants of PT ridership and car use that need to be investigated in depth. Estimations of price elasticities of demand of transport-related goods and services in Cuenca would be a good start for analyzing feasible pricing policies.

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