SUSTAINABLE PUBLIC TRANSPORTATION IN LARGE CITIES: DEMAND ESTIMATION

TADEÁŠ UMLAUF

Department of Civil Engineering

APPROVED:

Ruey Long Cheu, Ph.D., Chair

Carlos Ferregut, Ph.D.

Prof. Dr. Ing. Miroslav Svítek

Luis David Galicia, Ph.D.

Bess Sirmon-Taylor, Ph.D.
Interim Dean of the Graduate School

Dedication

I dedicate this work to my amazing family and friends who supported me, inspired me, and gave me motivation during my studies.

I would like to dedicate this thesis to the special memory of my grandfather, Walter Umlauf, who was not allowed to study.

This work is dedicated to the memory of my supervisor Doc. Ing. Ladislav Bína, CSc., who encouraged me to enroll in this program and provided me advices and inspiration during my studies in Prague and during writing this thesis. Dr. Bína passed away in March, 2014 just a few days after he provided me valuable suggestions here in El Paso.

I would like to dedicate this work to the memory of my friend, Achim Franz Josef Schweighofer.

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by

TADEÁŠ UMLAUF, Bc.

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Declaration

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This thesis is jointly supervised by the following faculty members:

Ruey Long Cheu, Ph.D., The University of Texas at El Paso

Doc. Ing. Ladislav Bína, CSc., Czech Technical University in Prague

Ing. Tomáš Horák, Ph.D., Czech Technical University in Prague

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Abstract

Public transportation helps to decrease the negative externalities caused by people's mobility. In many countries, the total number of vehicles and traffic has risen many times in the last decades but there is limited space to improve infrastructure in the cities. Large cities all over the world have a lot of issues with congestion, traffic noise, emission of greenhouse gases, and accidents. According to many international examples, sustainable public transportation in combination with synergistic projects (park & ride, kiss & ride, bike & ride) can help to overcome these issues. Therefore new transit modes and routes have been implemented in large cities recently with a purpose to change mode share in favor of transit. Transit networks have been added by faster and more comfortable modes like light rail and bus rapid transit. More transit modes are than integrated into one system to ensure high level of attractiveness for users by easier transfers and simpler fare policies. The matter of sustainability is considered during planning process of every new public transportation improvement project. The environmental aspect combined with transit oriented development is very important aspect of public transportation.

This research is focused on potential ridership estimation for a new proposed transit service. The proposed iterative model uses real data about current ridership as well as demographic and business information along the corridor to predict riderships. The model uses the system dynamics approach to predict the new route ridership generated in service coverage area. Transit assignment procedure is used in two steps to assign riders to the new, existing and modified routes.

The proposed model is applied in a practical case study of BRT implementation along the Alameda Avenue in El Paso, Texas. This research has estimated a daily total BRT ridership of 4,180 riders and the new service implementation would persuade 2,064 persons to use transit instead of other modes.

The proposed iterative ridership estimation model has the potential to be used in large cities around the world, including cities in EU and U.S.

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Chapter 1 Introduction

1.1 Background

People commute to work, hospitals, schools, shopping centers, sport centers, and etc. every day. The standard of living has been rising and with this increasing number of people has been using their own cars to commute, because it is better, faster, more comfortable, and cheaper. In many countries, the total number of cars has risen many times in the last decades but the infrastructure is more or less the same like it was tens of years ago. This is especially the case of big city centers and post-communist countries (like the Czech Republic) where the functional highway network and city bypasses are still missing. The environment in cities is polluted by noise, vibrations, and greenhouse gases. Another problem in cities is parking. Streets in old cities are usually narrow; the capacity of parking is low and there is hardly any space for building new parking lots.

The transportation demand is still rising and people want to be mobile more and more. According to Maslow's hierarchy of needs (Maslow 1943) the need of mobility is said to be one of the derived needs. This need is caused by the impossibility of satisfying all other needs at one place. Based on Maslow's hierarchy The Transportation Hierarchy of Needs was introduced in a more recent study (Winters 2001):

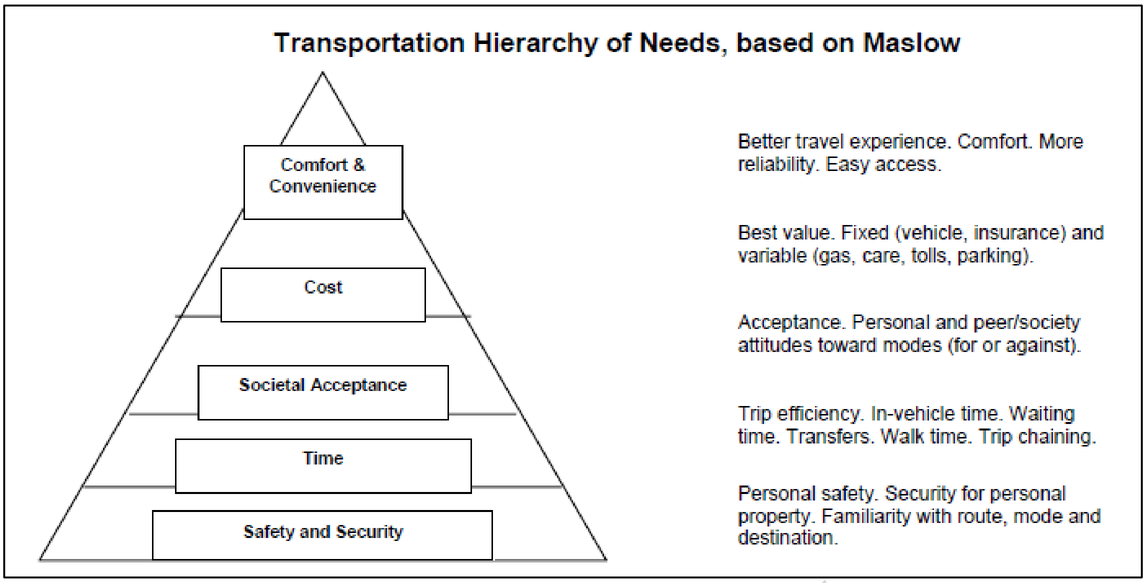

Figure 1.1 Transportation Hierarchy of Needs

Source: Winters (2001)

It is said that people in more developed countries with more Gross Domestic Product (GDP) per capita use passenger cars more often than others. According to Althaus (2012) vehicle density per capita increases with increasing GDP (almost linear rise from 0 vehicles per capita at GDP 0 to 0.3 vehicles per capita at GDP $10,000).

Transportation sector is responsible for almost 30% of energy consumption in Organisation for Economic Co-operation and Development (OECD) countries (IEA 2011) which is connected with a large emission production.

The hypothesis of Environmental Kuznets Curve (Kuznets 1955; Dinda 2004) is used in cases of describing the relationship between environmental degradation and economic growth. The inverted-U shape curve is presented in Figure 1.2. At the low levels of development the degradation increases monotonically up to the stage of industrial economies where the turning point is found. The post-industrial economies are supposed to take the environment into account and to decrease the impact caused by the industrial development. In passenger

transportation this means that the developed countries with high GDP per capita should use more sustainable modes of transportation especially public transportation.

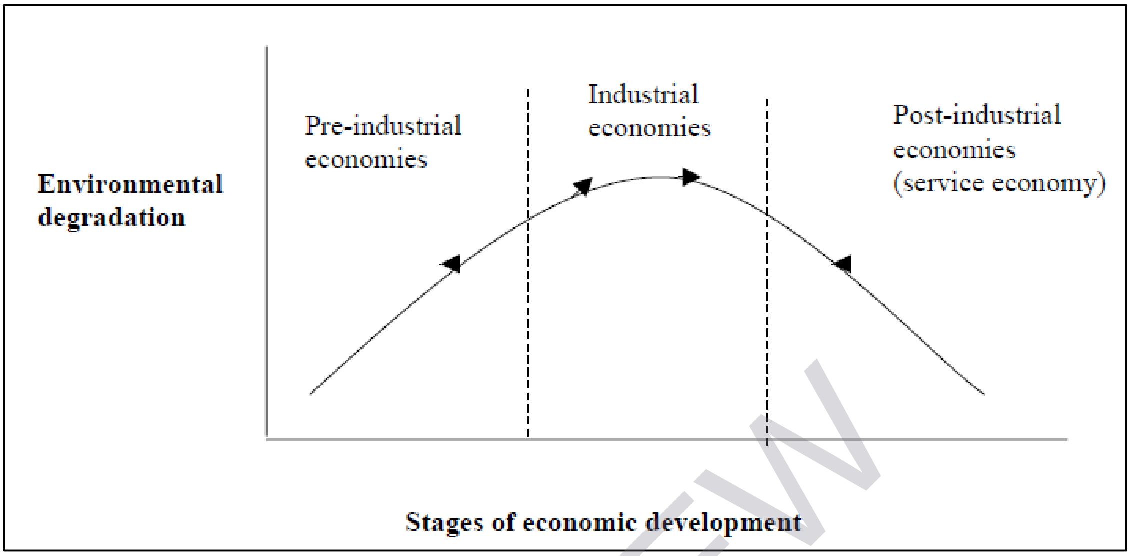

Figure 1.2 The Environmental Kuznets curve

Source: Panayotou (2003)

To compare the real situation and hypothesis concerning the Environmental Kuznets Curve we can take transit mode share and GDP per capita and see if there is a relationship between them. The following table provides the values for selected European countries and U.S. Transit mode shares are computed as the ratio of transit passenger-miles and total passenger-miles for each country.

Table 1.1 Transit and individual mobility (IM) mode share in selected European countries and U.S.

Mode share of Transit 2011		Percentage Transit (%)	Percentage IM (%)	GDP/capita (index)	Ratio (Transit/GDP)
United States	(u)	8.1	91.9	148	0.055
Norway		11.6	88.4	187	0.062
Luxembourg	(e)	16.9	83.1	272	0.062
Netherlands		11.9	88.1	131	0.091
Iceland		12.0	88.0	112	0.107
United Kingdom	(e)	12.5	87.5	109	0.115
Germany		14.0	86.0	121	0.116
Ireland	(e)	15.8	84.2	129	0.122
Finland		14.9	85.1	115	0.130
Sweden	(e)	16.7	83.3	127	0.131
Lithuania		9.2	90.8	66	0.139
Switzerland		22.8	77.2	158	0.144
Denmark	(e)	18.4	81.6	126	0.146
France	(e)	16.2	83.8	109	0.149
Slovenia	(e)	13.2	86.8	84	0.157
Austria		21.1	78.9	129	0.164
Poland		10.9	89.1	65	0.168
Italy	(e)	17.2	82.8	100	0.172
Belgium	(e)	20.5	79.5	119	0.172
Spain		19.0	81.0	99	0.192
Cyprus	(e)	18.3	81.7	95	0.193
Portugal	(e)	15.2	84.8	78	0.195
Malta	(e)	18.3	81.7	86	0.213
Greece	(e)	18.4	81.6	79	0.233
Estonia	(e)	15.9	84.1	67	0.237
Croatia	(d)	15.4	84.6	61	0.252
Slovakia		22.7	77.3	73	0.311
Czech Republic		25.6	74.4	80	0.320
Latvia		21.6	78.4	59	0.366
Romania	(e)	18.3	81.7	47	0.389
Bulgaria	(e)	19.4	80.6	46	0.422
Hungary	(e)	36.6	63.4	66	0.555
Macedonia	(e)	24.5	75.5	35	0.700
Turkey	(e)	40.6	59.4	52	0.781

Note: e=estimated d=definition differs u=computed from other source (no letter)=official data

Source: Eurostat (2013a, 2013b) and RITA (2013)

We can plot a scatter graph of transit mode share versus GDP per capita to see if there is a trend. The graph is provided in Figure 1.3

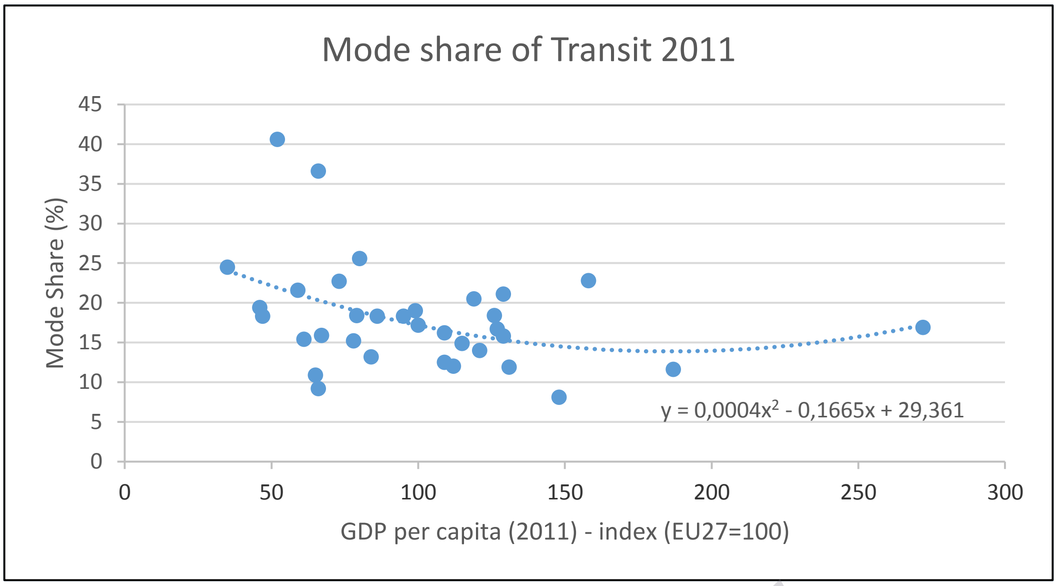

Figure 1.3 Mode share of transit for countries in Table 1.1

Source: European Commission (2013a, 2013b) and RITA (2013)

It can be seen from the above table that there have to be also other factors influencing the mode share. We can see that rich countries have smaller transit share/GDP ratios than poorer ones. Therefore we can say that there is strong evidence for rejecting the hypothesis connected with the Environmental Kuznets Curve.

Transit modal split can be very different for two cities in the same country. For example, in New York, the mass transit constitutes 23% of all trips (U.S. Census Bureau 2010; NYDOT 2009) but in El Paso, Texas it is only about 2% (El Paso MPO 2012). High transit mode shares are reached in following European cities: Madrid 40% (EMTA 2012), Paris 34% (EMTA 2012), Prague 43% (TSK HMP 2013), Vienna 36% (Wiener Linien 2010).

Some cities in South America recently implemented Bus Rapid Transit (BRT) systems and it seems to be the ideal mean of transit for large cities in developing countries. The transit modal splits for Curitiba, Brazil is 45% (ICLEI 2011) and the TransMilenium BRT system in Bogota, Columbia constitutes 62% of all journeys (Camara de Comercio de Bogotá 2008).

These are proves that appropriate transportation planning combined with modern ideas and the sufficient investment can lead to good transit mode share in cities.

According to the International Association of Public Transport (UITP 2009), urban passenger transportation produces about 34% of CO_2 emissions due to transportation in 27 European Union countries (EU-27) and 8.5% of total CO_2 emissions in EU-27. From this amount (transportation related CO_2 emission), only 10% of CO_2 is produced by public transportation and the rest is caused by passenger cars. This CO_2 production ratios are similar at the global scale.

In Figure 1.4, the relationship between CO2 emissions from passenger transportation and mode share of transit, walking, and cycling is shown. It can be seen that in North American cities, where mode share of cars exceeds 70%, the level of CO2 emission from passenger transportation per capita is bigger than in European or some Asian cities such as Tokyo, and Hong Kong.

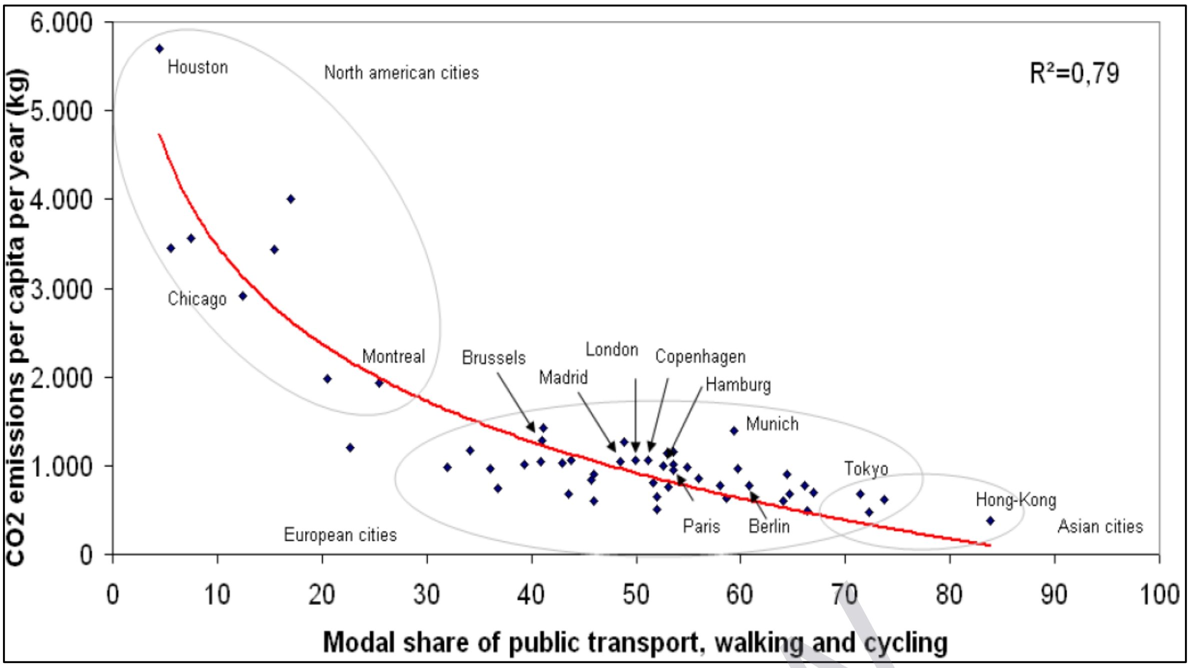

Figure 1.4 CO_2 emission from passenger transport: correlation between mobility pattern and CO_2 emission

Source: UITP (2009)

From Figure 1.4, we can infer that using public transportation in cities is in general more environmental friendly than using passenger cars. The services provided by public transportation have to reflect the demands in the city in order to be successful. Public transportation is partly financed by public sources and therefore the investment should be done smartly.

This thesis focuses on public transportation systems with a view on sustainability. To attract the market (ridership), public transportation should provide a comparable alternative to passenger car in terms of travel time, price, and comfort. It seems to be more reasonable for cities to invest funds in public transportation than to build new roads and then solve big environmental issues like air pollution, noise, vibrations, and all other negative externalities.

1.2 Thesis Objectives

The thesis has the following objectives:

1. To review the problem of urban congestion and its externalities;
2. To review different sustainable public transportation systems and its role in solving urban traffic congestion;
3. To develop a model of demand estimation for sustainable public transportation including Service Equity Analysis (SEA);
4. To demonstrate the application of the demand estimation model and SEA using real data along a major transit corridor in El Paso, Texas;
5. To provide recommendations for decision makers for easier implementation of the proposed demand estimation model in cities, including European cities.

1.3 Thesis Outline

This master thesis is organized into following chapters:

- Chapter 1 deals with the introduction and research objectives.
- Chapter 2 reviews transportation problems in large cities, including congestions and negative traffic externalities. The conflict between private cars and transit is presented as well as basic public transportation concepts.
- Chapter 3 provides the definition of sustainable public transportation, reviews public transportation systems in large cities and literature closely connected to sustainable transportation.
- Chapter 4 proposes the model of demand estimation for sustainable public transportation in large cities and describes all its features as well as procedure and requirements for SEA.
- Chapter 5 applies the proposed model in a practical case study. The proposed BRT along the Alameda corridor in El Paso, TX is used for this case study.

- Chapter 6 concludes this thesis and shows some potential opportunities for future work. This chapter also summarizes all requirements which are needed for implementing the demand estimation procedure or similar ridership estimation model for sustainable transit in other cities, including European cities.

Chapter 2 Current Transportation State in Large Cities

2.1 Overall Situation

Probably every city in the world has its own transportation policies for parking, infrastructure planning, public transportation, and many others. Traffic problems in the different cities differ a lot, but in general all cities have issues with the high level of passenger cars in their streets which is caused by increasing transportation demand and/or insufficient level of public transportation.

2.1.1 Congestions

This issue of congestion occurs especially in the morning and afternoon peak hours. The difference between peak and off-peak hour's traffic congestion differs among cities (TomTom 2012a, 2012b). These studies also present the average delay per hour driven in peak hours and the total annual delay of an imaginary 30 minute commute.

Table 2.1 shows the situation in selected cities in North America and Europe. The percentage shows the difference between travel time during non-congested periods and travel times in peak hours. For example a driver can take a trip which takes 30 minutes in non-congested period and but in morning peak hours it takes 46.8 minutes (an increase of 56% caused by morning peak hour congestion). The studies are based on real data from users of navigation systems.

Table 2.1 TomTom Congestion Index for selected cities

City	Country	Morning Peak	Evening Peak	Delay per hour driven in peak period	Annual delay	Ranking within the continent by average congestion delay
Los Angeles	USA	56 %	77 %	40 min	92 h	1
Vancouver	Canada	51 %	65 %	34 min	83 h	2
Houston	USA	41 %	65 %	32 min	80 h	8
New York	USA	32 %	41 %	22 min	61 h	15
Calgary	Canada	17 %	22 %	11 min	35 h	16
Detroit	USA	18 %	28 %	14 min	43 h	25
Istanbul	Turkey	84 %	125 %	64 min	118 h	1
Warsaw	Poland	93 %	91 %	55 min	110 h	2
Stockholm	Sweden	67 %	78 %	43 min	96 h	10
Vienna	Austria	58 %	53 %	31 min	78 h	12
Prague	Czech Republic	60 %	43 %	31 min	78 h	21
Madrid	Spain	41 %	30 %	20 min	57 h	51

Source: TomTom (2012a, 2012b)

From the table above we can see that in North American cities the congestions during the evening peak are worse than in the morning peak. There is also a general conclusion that in European cities the travel times during peak hours rise more than in American cities.

In the IBM 2011 Commuter Pain Survey (IBM 2011) more than 8,000 drivers from 20 cities worldwide were asked about the frustration of traffic, especially daily commuting. Drivers in Los Angeles, Mexico City, India, China, Singapore, and Johannesburg listed stop-and-go traffic as their biggest commuter pain. The respondents also perceive the negative impacts on their health while 42% declared increased stress, 35% reported more anger and 16% respiratory and sleeplessness issues. The results of this study are shown on the Figure 2.1.