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This issue of World Transport Policy and Practice is a significant milestone in the life of the journal. It marks 20 years of publication and for anyone with a serious interest in understanding the importance of transport, the links between transport, mobility and accessibility and the links with sustainability, health and quality of life, there is more than enough material here to work on. At the outset we chose to emphasise the word "policy" and that remains a strong focus. 20 years of publication have examined policy in detail, more often the lack of intelligent policy, but always with a keen eye on "this is what we have to do if we want to improve things". There is now no excuse for anyone anywhere in the world to sit at his or her desk on a Monday morning and wonder how to sort things out. The answers lie in our freely available archives.

The very old saying "you can take a horse to water but you can't make it drink" must have been coined by people at the sharp end of sustainable transport. Globally we are drowning in excellent material on sustainable transport and how to correct negative trends and how to produce huge gains for quality of life, health, community, air quality, poverty and accessibility. We know that current transport priorities and spending damage the quality of life of children and older people and we know how to correct that. We know how to de-carbonise transport so that this sector or segment of life actually works to solve problems rather than make them worse. Harry Vallack and his colleagues in this issue have explained how this can be done. We know how to reduce death and injury on the roads and we know how to improve air quality and create lively, viable communities. All these topics have been covered in detail in our last 20 years. The reality is we are just not doing it.

In one important sense the journal has failed. We wanted to improve policy and reveal really good ideas on how to do this to a wider audience because we thought this would help and it didn't. The missing link is willingness to do something and we don't yet know how to nurture and embed

"will" in a wider decision-making, political and societal process.

In the last 20 years over 20 million human beings have been brutally killed in the road traffic environment. Many more than this have died as a result of poor air quality that is dominated by vehicle exhaust emissions. The public policy response has been and still is truly pathetic and is a stain on our so-called civilisation.

Our approach to dealing with failure is the same as that adopted by William Wilberforce and his colleagues in the 20 years of anti-slavery activity leading to the abolition of the slave trade in 1807. Wilberforce was rebuffed, rejected and ridiculed many times but he remained steadfast. He believed slavery was wrong and he redoubled his efforts to eliminate this dreadful scourge. We do not equate our efforts with the abolition of slavery but the negative effects of unsustainable transport are a dreadful scourge and must be eliminated and just as we cannot now imagine why anyone supported slavery in the 1790s so in coming decades we will wonder why anyone supported mass, motorised mobility and cared so little for dead and broken bodies.

So, following the example of William Wilberforce our response to failure is to redouble our efforts. In this issue of World Transport Policy and Practice we present some first class insights, analyses and policy recommendations. We focus on how to de-carbonise our transport systems (Vallack and his colleagues), how to recognise the over-riding importance of transport systems that deliver outcomes benefitting those with hearing, visual and other characteristics that might render transport arrangements more difficult than they need be (Chris Cook). We examine the deeply flawed process of evaluating transport projects (Sudhir Gota) and show that the use of "do-nothing" in transport appraisal is plain wrong and we explore how to develop a deeper understanding of transport issue through a detailed disaggregated approach to age, gender, race/ethnicity and income (John Renne).

In the meantime if any of our readers have any suggestions about how we encourage the horse to drink when we have taken it to the water trough please let us know.

John Whitelegg  
Editor

**Socioeconomics of Urban Travel: Evidence from the 2009 National Household Travel Survey with Implications for Sustainability**

*John L. Renne and Peter Bennett*

**Abstract:**

This article summarizes patterns of mobility for urban travel across the United States based on the 2009 National Household Travel Survey (NHTS). It examines how patterns vary by socioeconomics and highlights policy implications of current mobility patterns for creating a more sustainable society. Key findings include the reaffirmation that over 80 percent of trips in America are made by automobiles. While vehicle ownership is the most significant factor in variations in mode use, income, trip purpose, regional variation, race/ethnicity, gender and age are all factors examined for variation in travel behavior. The paper concludes with recommendations for promoting a sustainable society through shifting transportation priorities.

**Keywords:** NHTS, Socioeconomics, Demographics, Urban Travel, Sustainability, Automobile Dependence

**Policy pathways towards achieving a zero carbon transport sector in the UK in 2050**

*Harry William Vallack, Gary Haq, John Whitelegg and Howard Cambridge*

**Abstract:**

The effective decarbonisation of the transport sector will play a large role in achieving the UK government target of an 80 per cent reduction in greenhouse gases, from the 1990 baseline, by 2050. This paper presents a vision of a 'zero carbon' future for the UK transport sector. It quantifies and assesses the contributions that a range of behavioural, fiscal, spatial planning and technological carbon dioxide (CO<sub>2</sub>) reduction measures can make in assisting the UK to move towards a 'zero carbon' transport sector by 2050. Two scenarios for 2050 are compared: a business-as-usual (BAU) scenario (with continuation of present trends and policies) and a maximum impact (MI) scenario in which all feasible interventions

for achieving a 'zero carbon' UK transport sector are applied. Although road and rail transport could both achieve the zero CO<sub>2</sub> emission target by 2050, emissions from aviation and shipping are more problematic. For the 2050 MI Scenario, the net result from the entire UK transport sector (including international aviation/shipping) is 76 per cent reduction in CO<sub>2</sub> emissions compared with the 2050 BAU scenario. This falls short of a zero carbon target for UK transport and is due to the remaining CO<sub>2</sub> emissions from aviation (56 per cent reduction) and shipping (49 per cent reduction). To improve the overall CO<sub>2</sub> emissions reduction for transport would require more radical interventions or technological innovations for these two sectors than envisaged here. This visioning and back-casting analysis shows that the potential to reduce UK's transport CO<sub>2</sub> emissions is much larger than has hitherto been recognised.

**Keywords:** Climate change mitigation, zero carbon vision, UK transport policy, scenario analysis

**How Accessible Are The Public Transport Networks Of Berlin And London?**

*Christopher Paul Cook*

**Abstract:**

The onus on public transport operators to make their networks fully accessible to all passengers is becoming increasingly important and with an aging population will only grow in the coming years; but how successful are transport operators currently in achieving this aim? How can we measure effectively improvements in access to their networks? and can they ever achieve total success?

The main aims of current British and German transport policy have similar objectives. Key issues include reducing social exclusion and thereby allowing everyone, regardless of their background, employment status or level of disability to play a full and active role in society. This is most often achieved by having excellent and affordable public transport links within a short distance of major housing developments.

**Keywords:** Accessible Public Transport, Individual Mobility, Staff Presence and Training, Automation, Independence, Measuring Accessibility

### **Changing Do-nothing Baselines for Transport Investments**

*Sudhir Gota, Lee Schipper Scholar*

#### **Abstract:**

In the realm of conducting transport economic and environmental assessments, the option of “doing nothing,” or “no project/investment,” is considered as the baseline of the projects. Potential benefits of the project are always compared to a “do nothing” option before a decision is taken. However, this “do nothing” concept is a myth – “do something” is a reality, and considering this concept in baseline assessments could be a game changer for transport projects. In absence of a particular project or an investment, a suitable alternative would be found and implemented by the authorities. Thus, baselines need to be redefined and ‘without project’ scenario should not be just considered as ‘no improvement’ but, should ideally be considered as to what would ‘most likely’ happen if this project is not executed. By making this change in baseline, fundamentals of transport investment can be strengthened and this can lead to paradigm shift in transport. Considering BRT projects, assessment of transport expansion in the baseline was estimated and found to be a gamechanger in the economic analysis.

**Keywords:** Baseline, BRT, Vehicle kilometers traveled, infrastructure, cost-benefit analysis

# **Socioeconomics of Urban Travel: Evidence from the 2009 National Household Travel Survey with Implications for Sustainability**

*John L. Renne and Peter Bennett*

## **1. Introduction**

The National Household Travel Survey (NHTS) is the only study of transportation mobility for all trip purposes across the United States. The most recent NHTS was conducted in 2009, eight years after the preceding NHTS in 2001. The data is vital in understanding patterns of mobility within American society. This article summarizes the socioeconomics of urban travel based on the 2009 NHTS and examines three key research questions:

1. What are the patterns of mobility for urban travel in the United States?
2. How do these patterns vary by socioeconomic characteristics?
3. What are the policy implications of current mobility patterns for encouraging more sustainable travel behavior?

This is the fifth in a series of articles that examine national urban travel behavior characteristics by socioeconomic groups. Previous articles were written about the 1977, 1990, 1995 and 2001 studies<sup>1</sup> (Pucher, Hendrickson, & McNeil 1981; Pucher & Williams 1992; Pucher, Evans, & Wenger 1998; Pucher & Renne 2003). Similar to the previous articles, this study also looks at patterns of mobility for urban travel and how they vary by socioeconomic groups. Taken as a whole, the entire set of articles reveal trends towards an increasingly automobile-dependent society.

The transportation sector consumes around 70 percent all oil in the United States, a current level that is unsustainable in terms of production and environmental impact (Renne and Fields 2013). The travel behavior of Americans has been shaped by the availability of oil, in turn leading to infrastructure and land uses that can be described as automobile dependent. After the housing market crash in 2008, these development patterns were subjected to new scrutiny, as sprawling land uses were more susceptible to falling value and foreclosures (Leinberger 2009). As a result, local and national policy increasingly em-

phasizes sustainability, which is one of the five U.S. Department of Transportation's (DOT) priorities. Moreover, livability is another national priority for the DOT, which has overlapping goals and objectives to sustainability with respect to the goal of reducing auto dependence and shifting mode shares to transit and non-motorized modes (U.S. Department of Transportation 2012). This policy is driven by President Obama, who stated:

*We'll focus on creating more livable and environmentally sustainable communities. Because when it comes to development, it's time to throw out old policies that encouraged sprawl and congestion, pollution, and end up isolating our communities in the process. We need strategies that encourage smart development linked to quality public transportation, that bring our communities together (January 24, 2010).*

To further these goals, the Obama administration created a new partnership between the US Department of Transportation (DOT), the US Department of Housing and Urban Development (HUD) and the Environmental Protection Agency (EPA) to promote sustainable communities. The success of the Administration's goals in promoting more sustainable and livable transportation systems is contingent upon understanding current travel behavior. Different socioeconomic characteristics will determine how Americans travel behavior would change as a result of these policies. The travel patterns observed in this article should be considered when targeting investment to change travel behavior.

## **2. Literature**

This section summarizes literature relevant to the research questions of this article. It begins with discussion of literature defining transportation and sustainability followed by mobility and automobile dependence. The last section on socioeconomics sets the stage for the data analysis presented in subsequent sections.

<sup>1</sup> Prior to 2001, the National Household Travel Survey was known as the National Personal Transportation Survey (NPTS).

## 2.1 Transportation and Sustainability

The EPA estimates that transportation accounted for 27 percent of all U.S. greenhouse gas emissions in 2008, making it the largest end use source of carbon dioxide (U.S. Environmental Protection Agency 2010). Since 1990, transportation has also been the fastest growing source of carbon dioxide (CO<sub>2</sub>), accounting for 47 percent of the net increase in total U.S. emissions. Transportation also account for the emission of 85 percent of carbon monoxide (CO), 50 of black carbon (BC), 34 percent of particulate matter of 2.5 microns (PM<sub>2.5</sub>), 55 percent of nitrogen oxides (NO<sub>x</sub>) and 41 percent of non-methane volatile organic compounds (NMVOC). With the growing threat of irreversible climate change and its impact on human and natural ecosystems, many public figures, policy makers, and activists have recognized the need to curtail these emissions (Gordon and Burwell 2013).

The global supply of petroleum, the main fuel for transportation, may soon reach peak levels that will be unobtainable in the future (Greene 2004; Newman, Beatley, & Boyer 2009; Gilbert and Perl 2008). High prices and volatility in the petroleum market resulting from peak oil could make current transportation patterns, currently focused on driving, increasingly onerous. Unequal supply and demand, environmental degradation, and the impacts these will have on society indicate that the current transportation system is unsustainable.

Sustainability is defined as the ability to meet the needs of the present without compromising the ability of future generations to meet their needs (World Commission on Environment and Development 1987). This definition easily translates into a transportation context; resource use and impacts of the current system will directly determine the quality of life in the future. Sustainability can be achieved in three different categories: environmental, economic, and social (Kennedy, Miller, Shalaby, MacLean, & Coleman 2005; Sustainable Transportation Indicators Subcommittee 2008; Litman & Burwell 2006; Black, Paez, & Suthanaya 2002).

The impact transportation has on the environment includes local air pollution and greenhouse gases as an end product, but transportation systems also consume vast amounts of resources. Fossil fuels are a finite power source, and the extraction of the oil in the future will become treacherous and costly, in what Gilbert and Perl (2008) term the era of extreme oil.

Economic sustainability must balance the costs and benefits of a transportation system, while taking into consideration long-term and indirect impacts. Individual costs, such as gas prices, vehicles and maintenance, tolls, and transit fares are a major determinant in transportation choices (Sustainable Transportation Indicators Subcommittee 2008). As this cost structure changes, modes become comparatively more and less attractive.

The benefits and costs of a transportation system are not always provided in an equitable distribution; social sustainability addresses these unequal impacts. Moreover, Environmental Justice relates to the situation when environmental damage caused by transportation often occurs in communities unable to prevent it. The costs and availability of travel can limit the ability of some people to make necessary trips, leading to a lower mobility for the poor (Sanchez & Brenman 2007). Lastly, transportation choices can impact the ways in which a community interacts, leading to conflict and isolation (Litman & Burwell 2006). A growing body of literature addresses the concept of transport and social exclusion, which not only includes safety and disability access, and access to jobs, but also "access to major social needs and inclusion" (Stanley & Vella-Brodrick 2009, p. 90). However, these and other authors note that more work is needed to better understand how transportation benefits can be equitably distributed across society, especially to marginalized communities.

A great deal of attention has been paid to the role of technology in achieving a more sustainable transportation system. National policies have targetted the fuel economy of the automobile fleet, resulting in significant reductions in greenhouse gas emissions (Greene & Schafer 2003).



However, changes in vehicle technology do not address all of the consequences of automobile dependence. Problems relating to traffic congestion, active living, urban vitality, and spatial mismatch remain unsolved as automobiles become more fuel efficient (Renne & Fields 2013).

## **2.2 Mobility and Automobile Dependence**

The transportation system in America has significant room for improvement in all three dimensions of sustainability. Increasing the number of trips people make, has been the dominant paradigm in planning decisions. The automobile maximizes personal mobility, and highway expansion, traffic management, and new vehicle technologies are all designed to support this system (Cervero 2001). Changing this focus to accessibility, the coordination of transportation and land use to maximize the number of travel opportunities for all, engenders the planning solutions that lead to a sustainable transportation system. Compact development, increasing transit systems and non-motorized infrastructure, and vehicle sharing are some strategies for increasing accessibility (Cervero 2001; Goldman & Gorham 2006).

American cities do not compare favorably to cities around the world with respect to sustainable mobility; our cities are mainly automobile dependent. In a sample of urban areas, Americans traveled more kilometers per capita in private vehicles, and owned more private vehicles per capita, than residents of Australian, Canadian, European, and Asian cities (Kenworthy & Laube 1999). High rates of vehicle ownership and distance traveled in the United States were also observed in previous versions of the NPTS (Pickrell & Schimek 1999). In wealthy Asian cities, 59.6 percent use transit to travel to work, in addition to 20.3 percent of people who walk (Kenworthy & Laube 1999).

Between 2005 and 2008, gasoline prices spiked in the United States, making the cost of driving more expensive. A small but significant increase in transit ridership was recorded during the spike (Lane 2010). Although the new ridership was mostly accounted for by those already

living near transit, the growth was greater in cities generally thought of as more automobile dependent. Gas prices alone cannot radically reduce automobile dependence, however, because people are more inclined to continue using their current mode (Weis, Axhausen, Schlich, & Zbinden 2010). In the 2001 NHTS, automobile availability was found to be a strong predictor of transit use by an individual (National Center for Transit Research 2007; Pucher & Renne 2003).

The quality of transit service also plays a role in the mode choice of individuals. Different modes are better suited for different travel distances. According to the National Transit Database, average local bus trips are the shortest at 4.6 miles, and commuter rail trips are the longest at 30.1 miles (Yu & Machemehl 2010). There is also a strong relationship between the distance people live and work from transit, and their likelihood to use transit (Lane 2010). Both of these quality variables dictate the travel time people experience, a major factor in enjoyment of a commute (Páez & Whalen 2010). There is some intrinsic enjoyment of commuting, but this decreases with travel time. Transit shelters and infrastructure play a role in the enjoyment of a commute as well. These amenities can increase the visibility of transit stops; cognitive awareness of transit is yet another factor in the likelihood of an individual to use transit (Mondschein, Blumenberg, & Taylor 2007). In fact, accessibility is a function of awareness of travel options as well as their existence.

Urban form can have profound effects on transit ridership and is also a factor in non-motorized active transportation. A recent meta-analysis calculated elasticities across many variables and studies in an examination between of travel and the built environment. Findings reinforce the importance of urban form in travel outcomes, but note that travel variables are generally inelastic with respect to changes in the built environment (Ewing & Cervero 2010). Density and land use mix both have a positive impact on transit use and walking, and reduce the number of trips made by single occupancy vehicles (Frank & Pivo 1995). Compact and mixed-use development also has an impact on reducing

distances traveled, and ultimately greenhouse gas emissions from transportation (Transportation Research Board 2009).

### **2.3 Socioeconomics**

Socioeconomics play a major role in the mode choice of Americans. Economics, system design, and accessibility all contribute to different demographics choosing different modes for daily travel. Socioeconomics also influence the type of urban environment people live in, which in turn influences travel behavior (Stead 2001). Many studies find income, race, gender, and age to have an influence on mode share.

Income is an important variable for transportation mobility as many of the costs of travel are paid by the traveler themselves. Automobile dependence in the American transportation system has made vehicle ownership a necessity for most people, but vehicle ownership is lower among low-income households (Giuliano, Hu, & Lee 2001; Babey, Hastert, Huang, & Brown 2009). Vehicle ownership is a significant variable that corresponds with a drop in mode share for bicycles, but it also correlates highly with socioeconomic variables such as income and race (Parkin, Wardman, & Page 2008). Low-income households are more likely to live close to bus routes, especially those owning one or zero cars (National Center for Transit Research 2007).

Differences in travel behavior between men and women have lessened over the years while more women have entered the workforce, yet some differences remain. Women are still more likely to make trips related to domestic activity, while men make the majority of work trips, and the majority of single occupancy vehicle trips (Schaffer & Schultz 2008). Men make up the majority of bicycle commuters, and use bicycles more frequently than women (Twaddle, Hall, & Bracic 2010).

As more of the baby boomer generation is reaching retirement age, transportation systems in the United States must prepare for new challenges (Burnett & Lucas 2010). Although elderly populations lose some mobility, which is related to work

travel, they continue to use automobiles at rate similar to their younger cohorts (Giuliano, Hu, & Lee 2003; Colia, Sharp, & Giesbrecht 2003). With aging populations, automobile dependence cannot persist due to diminished driving ability. Elderly drivers are less likely to use transit as walking access distance increases in comparison to their non-driving cohorts (Hess 2009).

The socioeconomic characteristics of travel in American cities are essential to creating a transportation system that is sustainable and accessible. A new paradigm of government action, financing, infrastructure building, and place-based planning is necessary for this system to be successful (Kennedy, Miller, Shalaby, MacLean, & Coleman 2005). Sustainability is not an end result of a process as much as a process itself; the goals needed to create sustainable systems must not become more important than the principles behind them (Goldman & Gorham 2006).

### **3. Methodology**

The decennial census and American Community Survey gather journey-to-work travel data as well as socioeconomic demographics, but more information is needed to fully understand a transportation system. The National Household Travel Survey (NHTS) is a comprehensive look at all types of daily travel in the United States, and aims to help policy makers make informed planning decisions. Administered by the Federal Highway Administration, the NHTS is conducted as a telephone survey of households across the country. The survey collects demographic information and transportation characteristics, but also asks respondents to keep a travel diary of a 24-hour period. This type of survey was first conducted in 1969 as the Nationwide Personal Transportation Survey (NPTS), and repeated in 1977, 1983, 1990, and 1995. In 2001, the survey became the NHTS with the incorporation of the American Travel Survey (ATS) and long-distance travel data (Federal Highway Administration 2010).

Statistical analysis of the NHTS data was conducted. Descriptive statistics were taken of the sample data, and were normalized using a weight variable provided with-

in the NHTS data. This analysis focused on urban travel; households identified as “not in an urban area” were excluded, while those in urban areas, urban clusters, or in an area surrounded by urban areas remained. Additionally, urban travel is distinctly different from long-distance intercity travel, so trips longer than 75 miles were excluded from the analysis.

Mode share was an extremely important measure for analysis. The NHTS asks respondents to identify one mode of transportation for each trip taken from a list of over twenty options. In this study, seven different options for motor vehicles were combined into an automobile category. A separate variable was used to separate single occupancy vehicles (SOV) and high occupancy vehicles (HOV). There were six different modes classified as transit<sup>2</sup>, and additionally differentiated as bus and light rail, metro/subway/heavy rail, and commuter rail. Bicycle and pedestrian modes were used separately, and also combined into a non-motorized category. School bus and taxicab modes were also used, and the remaining modes combined into an “other” category. The survey methodology allows researchers to examine up to five access and five egress modes, however, for the purposes of this paper, we have examined the primary mode of travel. This

allows for consistency in comparing the results of this study to previous articles in this series. Moreover, a detailed examination of access and egress modes is beyond the scope of our analysis.

#### 4. Travel Trends in the United States

Since 1960, the U.S. Census has gathered information on the journey-to-work characteristics of Americans through the use of a supplemental survey (Table 1). Although the methodology of this survey has changed, a general trend of increased automobile dependence emerges. From 1960 to 2000, the mode share for automobiles rose from 66.9% to 87.9%, most drastically in the 1960s and 1970s. This increase corresponds with a drop in transit use from 12.6% to 4.7%, and a drop in walking from 10.3% to 2.9% (U.S. Census Bureau 2000).

Since 2002, journey-to work sample data has been available for each year from the American Community Survey (ACS). For each year, the mode shares reflect a pattern similar to the 2000 Census (Table 2). Although the ACS mode shares only cover an 8-year period, they may reflect a new trend. The small differences and slight decrease in automobile share from year to year indicates that automobile depend-

Mode of Transportation	Census Year				
	1960	1970	1980	1990	2000
<b>Total Auto</b>	66.9	77.7	84.1	86.5	87.9
SOV	na	na	64.4	73.2	75.7
HOV	na	na	19.7	13.4	12.2
<b>Public Transit</b>	12.6	8.9	6.4	5.3	4.7
<b>Walk</b>	10.3	7.4	5.6	3.9	2.9
<b>Bicycle</b>	na	na	0.5	0.4	0.4
<b>Work at Home</b>	7.5	3.5	2.3	3.0	3.3
<b>Other</b>	2.6	2.5	1.1	0.9	0.8
<b>All</b>	100.0	100.0	100.0	100.0	100.0

**Table 1: Trends in Mode Share for the Journey to Work (1960-2000)**

(percentage of workers by weekly usual means of transportation)

Source: US Decennial Census, Supplemental Survey: Journey to Work, 1960-2000.

Note: Only the 1960 Census worktrip survey included a category called “not reported”, which accounted for 4.3% of all 1960 responses. To make the 1960 distributions comparable with those of later years, which do not include an “unreported” category, the 1960 reported modal shares were scaled up by a factor of 1.045 so that their total would equal approximately 100%.

<sup>2</sup> Transit included local public transit, commuter bus, commuter train, subway/elevated train, street car/trolley, and special transit-people w/disabilities. These categories were used in previous versions of this paper; there are other modes in the NHTS that could be classified as transit.

ence may have reached a limit. Increases in walking and working from home have accounted for most of decrease in automobile use. Bicycle shares are impossible to determine because of a change in methodology combining them with motorcycle, taxicab, and other modes in 2004 (see Table 2, note).

1.6% in 2001, before rising to 2.0% in 2009. Non-motorized transportation represented a higher share than any year before in 2009, with 10.5% for walking and 1.0% for bicycling. The methodology of the NPTS and NHTS has changed between years, but remained largely identical from 2001 and 2009. A trend of a thaw in auto-

Mode of Transportation	2002	2003	2004	2005	2006	2007	2008	2009
<b>Total Auto</b>	87.8	88.2	87.8	87.7	86.7	86.5	86.2	86.1
SOV	77.4	77.8	77.7	77.0	76.0	76.1	75.5	76.1
HOV	10.4	10.4	10.1	10.7	10.7	10.4	10.7	10.0
<b>Public Transit</b>	5.0	4.8	4.6	4.7	4.8	4.9	5.0	5.0
<b>Walk</b>	2.5	2.3	2.4	2.5	2.9	2.8	2.8	2.9
<b>Bicycle</b>	0.4*	0.4*	na	na	na	na	na	na
<b>Taxi, Motorcycle, Bicycle, or Other</b>	na	na	1.4*	1.6*	1.7*	1.7*	1.8*	1.7*
<b>Work at Home</b>	3.5	3.5	3.8	3.6	3.9	4.1	4.1	4.3
<b>Other</b>	0.8*	0.7*	na	na	na	na	na	na
<b>All</b>	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

**Table 2: Trends in Mode Share for the Journey to Work (2002 - 2009)**

(percentage of work trips by means of transportation)

Source: U.S. Census Bureau, American Community Survey, Means of Transportation to Work for Workers 16 Years and Older, 2002 - 2009.

Note: The American Community Survey in 2002 and 2003 used mode categories similar to the 2000 Census. The ACS from 2004 to 2009 used a Taxicab, Motorcycle, Bicycle, or Other Means category in place of the Bicycle and Other categories.

Over a similar period as the Census, 1969 to 2009, the National Personal Transportation Survey (NPTS) and National Household Travel Survey (NHTS) have been used to collect detailed information on the travel habits of Americans (Table 3). These surveys report on trips of all purposes, not just work trips. The trends from these surveys do not completely correspond with the Census data. The mode share for automobiles is over 80% for each year, and displays more variability than an upward trend. Transit shows a pattern of a shrinking mode share from 3.2% in 1969 to

mobile dependence is visible in 2009. This could have been due to high gas prices present during the data collection period.

## 5. 2009 NHTS Results

### 5.1 Trip Purpose and Modal Choice

When travel is related to work, Americans are most likely to use an automobile. The next most utilized mode is transit (see Table 4). The automobile is used for 89.6% of work trips, 73.9% of the time in single occupancy vehicles (SOVs). In contrast, shopping trips are also taken mostly by

Mode of Transportation	1969 (1)	1977	1983	1990	1995	2001	2009
<b>Auto<sup>2</sup></b>	81.8	83.7	82.0	87.1	86.5	86.4	83.6
<b>Transit</b>	3.2	2.6	2.2	2.0	1.8	1.6	2.3
<b>Walk<sup>2</sup></b>	na	9.3	8.5	7.2	5.4	8.6	10.5
<b>Bicycle</b>	na	0.7	0.8	0.7	0.9	0.9	1.0
<b>Other<sup>3</sup></b>	5.0	3.7	6.5	3.0	5.4	2.5	2.6

**Table 3: Trends in Mode Share for Daily Travel in the United States (1969-2009)**

(percent of trips by mode, all trip purposes)

Source: Federal Highway Administration, Nationwide Personal Transportation Surveys 1969, 1977, 1983, 1990, and 1995; and National Household Travel Survey, 2001 and 2009.

Note: Unlike all subsequent tables, these NPTS and NHTS modal split percentages are for daily, local travel in aggregate for the entire USA, both urban and rural, as reported by the FHWA in their own NPTS and NHTS reports. Our own tabulations, from Table 3 onward, include only local trips in urban areas.

1. The 1969 NPTS did not sample walk and bike trips, thus artificially inflating the modal split shares of the motorized modes compared to the NPTS surveys in later years. To ensure some degree of comparability, we adjusted downward the reported motorized shares of trips in 1969 by 10%, using the percentage of walk and bike trips in 1977. That is why the column adds to 90% and not 100%. Our adjustment is rough, but otherwise, the 1969 and later NPTS modal split distributions would be completely incomparable.

2. The decrease in auto mode share from 1995 to 2001, and the corresponding increase in walk mode share during the same period, are due to a change in surveying methodology that captures previously unreported walk trips. Light Electric Vehicles, like golf carts, were included in the Auto category.

3. The "other" categories includes mainly school bus trips, which account for roughly 2 -3% of all trips in each of the survey years. It also includes taxicabs, ferries, and airplanes.

automobile (87.6%), but fewer in SOVs (40.6%). The mode share for the automobile is lower for social and recreation trips (79.0%) and school and church trips (69.9%), with the majority of those trips being taken in automobiles with more than one passenger.

east coast areas exhibit a mix of bus, light rail, heavy rail, and commuter rail, yet the transit use in the western part of the United States is almost entirely bus and light rail.

Mode of Transportation	Trip Purpose			
	Work and Work Related	Shopping and Services	Social and Recreation	School and Church
<b>Total Auto</b>	89.6	87.6	79.0	69.9
SOV <sup>1</sup>	73.9	40.6	28.6	18.7
HOV <sup>2</sup>	15.6	47.0	50.4	51.2
<b>Total Transit</b>	4.7	2.8	1.8	3.0
Bus and light rail <sup>3</sup>	3.0	2.4	1.4	2.4
Metro/subway/heavy rail <sup>4</sup>	1.2	0.3	0.3	0.5
Commuter rail <sup>5</sup>	0.6	0.1	0.1	0.1
<b>Total Non-motorized</b>	4.8	8.8	18.2	11.8
Walk	3.9	8.3	16.6	11.0
Bicycle	0.8	0.5	1.7	0.8
<b>School Bus</b>	0.1	0.0	0.2	14.6
<b>Taxicab</b>	0.2	0.3	0.2	0.2
<b>Other</b>	0.7	0.5	0.6	0.5
<b>All</b>	100.0	100.0	100.0	100.0

**Table 4: Variation in Mode Share by Trip Purpose**  
(percentage of trips by means of transportation)

Source: Calculated by the authors from the 2009 NHTS.

Notes: In order to isolate urban travel, the sample was limited to residents of urban areas and trips of 75 miles or less.

1. SOV (single occupancy vehicle) includes vehicles with driver and no passengers.
2. HOV (high occupancy vehicle) includes vehicles with two or more occupants.
3. Light rail also includes conventional streetcars.
4. Metro/subway/heavy rail includes elevated rail and rail rapid transit.
5. Commuter rail includes suburban/regional rail systems and short-distance service provided by Amtrak.

Transit has the greatest mode share for work trips, at 4.5%, and the least for social and recreation (1.5%). Within the different types of transit, bus and light rail is used for many different purposes, while heavy rail and commuter rail are predominantly used for work trips. These rail modes traditionally serve established corridors in transit dependent cities such as in the northeast – their use for work commuting is a product of a long history and a way of life.

## 5.2 Regional Variation in Mode Share

Each region of the United States offers a unique profile of cultural differences, transportation options, geography and variation in historical and urban design, which impact mode share (see Table 5). Using the U.S. Census regional divisions, the 2009 NHTS highlights these differences. The Middle Atlantic has the highest transit mode share at 7.0%, followed by the Pacific and New England, at above 2%. In comparing these regions, the older

Walking accounts for a high of 17.9% of trips in the Middle Atlantic region, and a low of 6.1% in the East South Central. Walking consistently ranks highest in regions that also feature high mode shares for transit, indicating higher intensity urban design, as well as travel related to accessing transit. Bicycling was highest in the East South Central region at 1.9%, as well as the Pacific region (1.5%), where many cities are known for bicycle use. The mode shares between regions were tested for significance, and the observed bike mode share values had a 95% confidence interval of at most +/- 0.25%, making differences between high and low regions significant (see Table 5, note 2).

## 5.3 Economic Factors in Urban Travel

Motor vehicle ownership is heavily impacted by income class (Table 6). 21.4% of households earning less than \$20,000 do not own a vehicle; this number drops to 6.1% and less than 2% for the subsequent higher income classes. A similar

Mode of Transportation	New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific
<b>Total Transit</b>	2.7	7.7	2.3	0.8	2.0	0.6	1.2	1.1	3.1
Bus and Light rail	2.0	4.4	1.9	0.7	1.7	0.6	1.1	0.9	2.8
Metro/subway/heavy rail	0.5	2.6	0.2	0.0	0.2	0.0	0.0	0.0	0.1
Commuter rail	0.2	0.7	0.2	0.1	0.1	0.0	0.0	0.1	0.1
<b>Total Non Motorized</b>	14.6	18.5	12.2	10.2	10.8	8.0	8.7	10.8	15.2
Walk	14.1	17.9	10.8	9.1	9.8	6.1	7.8	9.5	13.7
Bicycle	0.5	0.6	1.4	1.1	1.0	1.9	0.9	1.3	1.5

**Table 5: Regional Variations in Mode Shares for Transit, Walking, and Bicycling** (percentage of trips by mode)

Source: Calculated by the authors from the 2009 NHTS.

Notes:

1. In order to isolate urban travel, the sample was limited to residents of urban areas and trips of 75 miles or less.

2. Although the NHTS sample size is large, the number of users of low share modes in certain regions could be small enough to make differences in mode share insignificant. A 95% confidence interval was created for each value in this table. No mode share varied by more than one percent, and most had less than a 0.25% margin of error. Thus, we can say with 95% confidence that the noticeable regional variations are not due to chance.

declining percentage structure is observed for single vehicle ownership, from 45.8% of those earning less than \$20,000 to 7.1% of those earning over \$100,000. The pattern is reversed for higher numbers of vehicles; two vehicle households are common in most income classes, and three or more vehicles rises from 9.2% for those earning under \$20,000 to 44.4% for those earning over \$100,000.

In 2009, the U.S. Census Bureau used poverty thresholds ranging from \$10,289 to \$47,744, depending on the size of the family, with most thresholds in the \$20,000 to \$40,000 range (U.S. Census Bureau 2009). Many households earning less than \$20,000 are under the poverty line, yet over three quarters of them own at least one vehicle. Any income higher than \$20,000 almost guarantees owning at least one vehicle.

hicles (HOVs). HOV travel is slightly more common than driving alone for one- and two-vehicle households, and only three or more vehicle households make more trips in SOVs than HOVs.

Transit use is heavily impacted by vehicle ownership. In zero-vehicle households, transit is used for 23.6% of all trips, but in one-vehicle households only 3.1%. When two or more vehicles are present, transit use drops to below 1%. For zero-vehicle households, the predominant transit mode is bus and light rail, at 18.8% of all trips. Zero-vehicle households also use taxicabs more, at 2.5%.

When no vehicle is present, the most common mode of transportation is walking, at 41.1% of all trips. Pedestrian travel declines as the number vehicles owned increases, from 41.1% for zero-vehicle

Vehicles Per Household	Household Income					
	Less than \$20,000	\$20,000 to \$39,999	\$40,000 to \$74,999	\$75,000 to \$99,999	\$100,000 and over	All
0	21.4	6.1	1.9	1.0	1.4	5.3
1	45.8	38.2	23.0	11.3	7.1	23.5
2	23.6	38.0	45.5	51.8	47.2	42.2
3 or more	9.2	17.8	29.7	35.9	44.4	28.9
<b>Total</b>	100.0	100.0	100.0	100.0	100.0	100.0

**Table 6: Vehicle Ownership by Income Class**

(percentage distribution within each income class)

Source: Calculated by the authors from the 2009 NHTS.

Notes: The sample was limited to residents of urban areas. Vehicles include passenger cars as well as station wagons, passenger vans, sport-utility vehicles, pickup trucks, light trucks, motorcycles, mopeds, and recreational vehicles. This data include only residents of urban areas and urban clusters.

Differences in travel behavior also occur as a result of vehicle ownership (see Table 7). Automobile use jumps from 25.2% to 79.2% between zero-vehicle and one-vehicle households, and continues to gain mode share as more vehicles are added. In zero-vehicle households, most automobile travel is done in high occupancy ve-

households to 7.5% for households with three or more vehicles. Although bicycling also decreases in the same fashion, it exhibits a relatively small mode share in each category; even households without a motor vehicle use a bicycle for only 2.3% of all trips.

Mode of Transportation	Total Number of Vehicles in Household				
	0	1	2	3 or more	All
<b>Total Auto</b>	25.2	79.2	85.5	89.1	81.9
SOV <sup>1</sup>	3.5	38.6	38.3	46.1	38.7
HOV <sup>2</sup>	21.7	40.6	47.3	43.1	43.2
<b>Total Transit</b>	25.5	3.4	1.2	0.6	2.8
Bus and light rail <sup>3</sup>	20.6	2.3	0.8	0.5	2.1
Metro/subway/heavy rail <sup>4</sup>	3.9	0.8	0.2	0.1	0.5
Commuter rail <sup>5</sup>	1.0	0.3	0.1	0.1	0.2
<b>Total Non-motorized</b>	43.4	14.9	11.0	8.4	12.9
Walk	41.1	13.6	9.9	7.5	11.7
Bicycle	2.3	1.3	1.1	0.9	1.1
<b>School Bus</b>	2.0	1.5	1.8	1.2	1.6
<b>Taxicab</b>	2.5	0.2	0.1	0.0	0.2
<b>Other</b>	1.5	0.8	0.4	0.6	0.6
<b>All</b>	100.0	100.0	100.0	100.0	100.0

**Table 7: Impact of Auto Ownership on Mode Share**

(percentage of trips by means of transportation)

Source: Calculated by the authors from the 2009 NHTS.

Notes: In order to isolate urban travel, the sample was limited to residents of urban areas and trips of 75 miles or less.

1. SOV (single occupancy vehicle) includes vehicles with driver and no passengers.

2. HOV (high occupancy vehicle) includes vehicles with two or more occupants.

3. Light rail also includes conventional streetcars.

4. Metro/subway/heavy rail includes elevated rail and rail rapid transit.

5. Commuter rail includes suburban/regional rail systems and short-distance service provided by Amtrak.

Similar patterns of automobile dependence are clear when examining the modal choices of each income class (see Table 8). While each of the higher income classes make over 80% of all trips by automobile, only 69.9% of trips by households making less than \$20,000 are taken by automobile.

Transit ridership is the highest for low-income households, at 6.8%, with the

great majority of this travel being taken on bus and light rail. Transit's mode share exhibits a declining percentage with income, dropping to just above 1% for high-income households. Transit use by higher income classes is a factor in the mode shares of metro, subway, and heavy rail. In this case, households earning less than \$20,000 use it the least, which could be a product of the incomes necessary to even live in cities with such systems.

Mode of Transportation	Household Income					
	Less than \$20,000	\$20,000 to \$39,999	\$40,000 to \$74,999	\$75,000 to \$99,999	\$100,000 and over	All
<b>Total Auto</b>	69.9	81.5	84.7	85.7	83.9	81.9
SOV <sup>1</sup>	28.2	38.2	42.7	40.7	39.4	38.6
HOV <sup>2</sup>	41.7	43.3	42.0	45.1	44.5	43.3
<b>Total Transit</b>	7.3	3.3	1.9	1.4	1.7	2.8
Bus and light rail <sup>3</sup>	6.8	2.5	1.2	0.7	0.9	2.1
Metro/subway/heavy rail <sup>4</sup>	0.3	0.6	0.5	0.4	0.6	0.5
Commuter rail <sup>5</sup>	0.2	0.2	0.2	0.2	0.2	0.2
<b>Total Non-motorized</b>	19.5	12.9	11.1	11.0	12.1	12.9
Walk	18.3	11.6	10.0	10.1	10.9	11.8
Bicycle	1.1	1.3	1.1	0.9	1.2	1.1
<b>School Bus</b>	2.0	1.8	1.5	1.4	1.3	1.6
<b>Taxicab</b>	0.7	0.1	0.0	0.1	0.3	0.2
<b>Other</b>	0.7	0.4	0.7	0.4	0.6	0.6
<b>All</b>	100.0	100.0	100.0	100.0	100.0	100.0

**Table 8: Mode Share by Income Class**

(percentage of trips by means of transportation)

Source: Calculated by the authors from the 2009 NHTS.

Notes: In order to isolate urban travel, the sample was limited to residents of urban areas and trips of 75 miles or less.

1. SOV (single occupancy vehicle) includes vehicles with driver and no passengers.

2. HOV (high occupancy vehicle) includes vehicles with two or more occupants.

3. Light rail also includes conventional streetcars.

4. Metro/subway/heavy rail includes elevated rail and rail rapid transit.

5. Commuter rail includes suburban/regional rail systems and short-distance service provided by Amtrak.

For the lowest-income households, most of the discrepancy in automobile use is accounted for in walking trips. Those earning less than \$20,000 walk 18.3% of the time, compared to an average of 12.9% for all incomes. Bicycling exhibits a similar mode share of around 1% regardless of household income. Taxicabs show higher mode shares in the lowest and highest income classes, with almost no use by the households in between.

Overall, Table 8 shows a sharp division between the lowest income households and all others. Each income class other than those earning less than \$20,000 exhibits a similar profile of automobile use, transit ridership, and non-motorized travel. This pattern suggests a shift in transportation choices once a household is able to earn more than the bare minimum, a shift towards automobile dependence.

The population and type of transit system of an urban area plays a major role in the travel patterns of its residents (see Table 9). Generally, within each income class, the mode share for transit increases as metropolitan area population increases. The largest difference, however, is shown between cities of 1 million or more people without subway or rail (1.6% for all income classes), and similar sized cities with subway or rail (6.3% for all income classes). In fact, large cities without rail transit systems show very little increase in transit mode share over cities of 500,000 to 999,999 residents (1.6% versus 1.4%). In areas of all sizes, transit ridership decreases with higher income. Even in large rail cities, transit ridership is lowest for households making over \$100,000 (2.9%). To further illustrate the travel choices of different income classes, Table 10 breaks down the users of each mode by income.

Although households earning less than \$20,000 are least likely to be automobile users (12.4%), the distribution within the mode does not follow an income related pattern. In fact, the distribution of automobile users more closely resembles the distribution of all trips taken, indicating that driving is the predominant mode regardless of income.

Transit ridership is once again skewed towards the lowest income households, making up 39.5% of all trips. Each subsequent income class makes up a smaller portion of transit trips, except for the wealthiest, at 12.9%. The details of transit's income dynamics lie in the types of transit used. Bus and light rail are used 49.9% of the time by households earning less than \$20,000, yet on heavy rail systems, they make up only 9.3% of all trips, the lowest of any income class. Heavy rail and commuter rail users' income is more equally distributed with the exception of the lowest income group being under-represented among heavy rail users. However, heavy rail systems are located in cities with the higher costs of living. There is a pattern of the highest income group having higher rates of heavy and commuter rail usage than middle-income groups, which underscores the traditional use of these systems by work commuting to wealthy neighborhoods.

Walking trips are taken more often by low-income households, while bicycling follows a distribution similar to the overall trips sample. As was observed in Table 8, taxicabs are primarily used by the lowest and highest income classes.

Metropolitan Area Population	Household Income					
	Less than \$20,000	\$20,000 to \$39,999	\$40,000 to \$74,999	\$75,000 to \$99,999	\$100,000 and over	All
50,000 - 199,999	2.7	0.5	0.5	0.5	0.3	0.8
200,000 - 499,999	4.6	1.0	0.6	0.2	0.3	1.1
500,000 - 999,999	6.1	1.5	0.8	0.5	0.5	1.6
1 million or more without subway or rail	6.1	2.2	1.2	0.7	0.9	1.8
1 million or more with subway or rail	16.5	9.6	5.6	3.9	3.7	6.9
Not in an urbanized area	1.2	0.7	0.2	0.1	0.5	0.5
Nation	7.3	3.3	1.9	1.4	1.7	2.8

**Table 9: Transit's Mode Share by Urban Size and Household Income**  
(percentage of trips by transit)

Source: Calculated by the authors from the 2009 NHTS.  
Note: The metropolitan statistical area (MSA) totals in this table differ slightly from our other urban totals because MSAs by definition include entire counties, parts of which can be rural.



Mode of Transportation	Household Income					
	Less than \$20,000	\$20,000 to \$39,999	\$40,000 to \$74,999	\$75,000 to \$99,999	\$100,000 and over	All
<b>Total Auto</b>	12.4	19.2	27.1	16.1	25.1	100.0
SOV <sup>1</sup>	10.6	19.1	29.0	16.2	25.0	100.0
HOV <sup>2</sup>	14.0	19.3	25.4	16.0	25.2	100.0
<b>Total Transit</b>	37.8	22.4	17.5	7.4	14.9	100.0
Bus and light rail <sup>3</sup>	46.6	22.9	14.7	5.4	10.4	100.0
Metro/subway/heavy rail <sup>4</sup>	9.3	21.9	26.8	13.5	28.6	100.0
Commuter rail <sup>5</sup>	17.4	17.9	23.3	14.0	27.3	100.0
<b>Total Non-motorized</b>	22.0	19.3	22.6	13.1	23.0	100.0
Walk	22.7	19.1	22.4	13.2	22.7	100.0
Bicycle	14.6	21.5	25.6	12.6	25.8	100.0
School Bus	18.5	21.9	25.3	13.5	20.8	100.0
Taxicab	42.5	10.9	5.6	7.0	34.0	100.0
Other	16.1	14.1	33.1	10.5	26.2	100.0
<b>All</b>	14.5	19.3	26.2	15.4	24.5	100.0
<b>Overall Sample Distribution</b>						
Households	22.3	22.8	25.2	12.3	17.4	100.0
Persons	18.0	20.3	25.7	14.2	21.7	100.0
Trips	14.5	19.3	26.2	15.4	24.5	100.0

**Table 10: Income Distribution of Each Mode's Users**

(percentage composition by income class)

Source: Calculated by the authors from the 2009 NHTS.

Notes: In order to isolate urban travel, the sample was limited to residents of urban areas and trips of 75 miles or less.

1. SOV (single occupancy vehicle) includes vehicles with driver and no passengers.
2. HOV (high occupancy vehicle) includes vehicles with two or more occupants.
3. Light rail also includes conventional streetcars.
4. Metro/subway/heavy rail includes elevated rail and rail rapid transit.
5. Commuter rail includes suburban/regional rail systems and short-distance service provided by Amtrak.

The unequal nature of mode choice and income, illustrated above, has a direct impact on the travel distances of Americans (see Table 11). Average trip length is shortest for households making less than \$20,000, at 5.1 miles, and longest for those making more than \$100,000, at 7.0 miles. Across all income classes, the average automobile trip was between 6.3 and

7.7 miles long, showing little variation. Much greater differences in trip length exist in the data for transit modes. Transit trip length more than doubles, from 5.6 to 11.8 miles, as household income increases. Heavy rail trip length is the only transit mode with little variation between lowest and highest income, but those making \$20,000 to \$39,999 travel the longest

Mode of Transportation	Household Income					
	Less than \$20,000	\$20,000 to \$39,999	\$40,000 to \$74,999	\$75,000 to \$99,999	\$100,000 and over	All
<b>Total Auto</b>	6.3	6.7	7.3	7.6	7.7	7.2
SOV <sup>1</sup>	6.1	6.4	7.4	7.9	8.2	7.4
HOV <sup>2</sup>	6.5	7.0	7.2	7.3	7.3	7.1
<b>Total Transit</b>	5.7	7.5	8.0	8.8	10.8	7.6
Bus and light rail <sup>3</sup>	5.6	6.7	7.2	7.5	10.0	6.7
Metro/subway/heavy rail <sup>4</sup>	7.5	9.4	7.1	7.5	7.7	7.8
Commuter rail <sup>5</sup>	9.4	14.9	16.8	17.2	22.3	17.2
<b>Total Non-motorized</b>	0.8	0.8	0.8	0.9	1.0	0.8
Walk	0.7	0.7	0.7	0.7	0.7	0.7
Bicycle	1.7	1.4	1.9	3.2	3.1	2.2
School Bus	4.7	4.5	5.6	5.2	6.2	5.3
Taxicab	4.3	7.2	3.6	6.5	5.8	5.3
Other	5.5	6.7	9.4	7.4	8.8	8.0
<b>All</b>	5.1	5.9	6.6	6.8	7.0	6.4

**Table 11: Average Trip Length by Mode and Income Class**

(in miles)

Source: Calculated by the authors from the 2009 NHTS.

Notes: In order to isolate urban travel, the sample was limited to residents of urban areas and trips of 75 miles or less.

1. SOV (single occupancy vehicle) includes vehicles with driver and no passengers.
2. HOV (high occupancy vehicle) includes vehicles with two or more occupants.
3. Light rail also includes conventional streetcars.
4. Metro/subway/heavy rail includes elevated rail and rail rapid transit.
5. Commuter rail includes suburban/regional rail systems and short-distance service provided by Amtrak.

distance (9.4 miles). This might be due to long transit commutes in New York City, where these incomes would be considered low, and affordable housing is only available at considerable distance. Commuter rail also shows a spike at this income level, as well as significantly longer trip distances for the highest income households (22.6 miles). This could be indicative of wealthy far-flung suburbs in traditional rail cities.

Changes in transportation choices and employment associated with household income play a part in the time of day that people travel (see Table 12). Overall, peak period travel, from 6 to 9 a.m. and 4 to 7 p.m. on weekdays, is more common for higher income than lower income households. This pattern is least prominent for automobile travel, with all income classes traveling at peak times within a few percentage points of off-peak. Transit use, however, is more common at off-peak hours for households earning less than \$20,000 (45.7% off-peak versus 29.6% peak). Each income class over \$40,000 is more likely to use transit at peak times.

Low-income household are still the most common transit riders at peak hours, but this only manifests itself in the bus and light rail category; heavy rail and commuter rail are least likely to be used at peak hours by those earning less than \$20,000.

Housing and transportation are the largest expenses for Americans, together accounting for about half of a typical urban household's income (Lipman 2006). Choices and constraints for one of these expenses impact the other. Just as income played a role in mode choice, housing tenure and type influence travel behavior (see Table 13). Homeowners are more likely to drive than renters, making 86.1% of all trips by automobile, compared to 72.2%. Renters are also more likely to take automobile trips in a high occupancy vehicle (HOV). With decreased automobile use, renters use transit for 5.8% of all trips, and walk for 17.2%. Owners use transit for 1.1% of all trips and walk for 9.4%. Interestingly, renters and owners use a bicycle for nearly the same mode share, just over 1%.

Housing type shows many of the same

Mode of Transportation	Household Income					
	Less than \$20,000	\$20,000 to \$39,999	\$40,000 to \$74,999	\$75,000 to \$99,999	\$100,000 and over	All
<b>Total Auto</b>						
Peak	11.0	17.9	27.2	17.0	26.8	100.0
Off-Peak	13.1	19.8	27.1	15.7	24.3	100.0
<b>Total Transit</b>						
Peak	28.1	22.4	20.1	9.5	19.9	100.0
Off-peak	43.8	22.4	15.9	6.2	11.7	100.0
<b>Bus and light rail</b>						
Peak	37.8	23.2	17.7	7.5	13.8	100.0
Off-Peak	51.3	22.7	13.2	4.2	8.6	100.0
<b>Metro/subway/heavy rail</b>						
Peak	5.2	22.1	26.5	12.5	33.6	100.0
Off-Peak	13.0	21.8	26.9	14.3	24.0	100.0
<b>Commuter rail</b>						
Peak	12.5	16.7	22.5	17.0	31.3	100.0
Off-Peak	22.7	19.2	24.1	10.9	23.0	100.0
<b>Taxicab</b>						
Peak	36.5	17.1	7.4	6.3	32.5	100.0
Off-Peak	44.4	8.9	5.0	7.2	34.5	100.0
<b>All Modes</b>						
Peak	13.2	18.3	26.3	16.2	25.9	100.0
Off-Peak	15.2	19.8	26.2	15.0	23.9	100.0
All Modes & All Incomes						
Peak						31.8
Off-Peak						68.2

**Table 12: Peak vs. Off-Peak Travel by Income Class**

(percentage distribution of each mode's users by time of day and income)

Source: Calculated by the authors from the 2009 NHTS.

Notes: In order to isolate urban travel, the sample was limited to residents of urban areas and trips of 75 miles or less.

1. Peak period was defined as 6 to 9 am and 4 to 7 pm on weekdays; off-peak included all other times.
2. Light rail also includes conventional streetcars.
3. Metro/subway/heavy rail includes elevated rail and rail rapid transit.
4. Commuter rail includes suburban/regional rail systems and short-distance service provided by Amtrak.

Mode of Transportation	Housing Tenure		Housing Type							Total
	Own	Rent	Detached Single House	Duplex	Rowhouse or Townhouse	Apartment or Condo	Mobile Home or Trailer	Dorm, Fraternity, or Sorority	Other	
Percent of All Households	66.64	33.36	65.70	7.30	22.30	4.40	0.00	0.10	0.20	100.00
Percent of All Trips	70.05	29.95	70.36	8.32	19.25	1.96	0.01	0.00	0.11	100.00
<b>Total Auto</b>	86.1	72.2	86.1	78.7	67.9	83.8	76.5	71.3	75.9	81.9
SOV <sup>1</sup>	42.3	30.5	40.9	36.0	32.6	33.9	31.9	59.1	33.3	38.7
HOV <sup>2</sup>	43.8	41.6	45.2	42.7	35.4	49.9	44.7	12.2	42.7	43.2
<b>Total Transit</b>	1.1	5.8	0.9	3.2	8.3	1.1	3.4	0.0	0.9	2.5
Bus and light rail <sup>3</sup>	0.7	4.5	0.7	2.3	6.0	1.1	3.4	0.0	0.4	1.8
Metro/subway/heavy rail <sup>4</sup>	0.3	1.0	0.1	0.7	1.8	0.0	0.0	0.0	0.5	0.5
Commuter rail <sup>5</sup>	0.1	0.3	0.1	0.3	0.5	0.0	0.0	0.0	0.0	0.2
<b>Total Non-motorized</b>	10.5	18.3	10.5	15.2	20.8	10.5	19.0	28.7	22.8	12.9
Walk	9.4	17.2	9.3	14.4	19.7	9.4	9.2	28.7	22.7	11.7
Bicycle	1.1	1.2	1.2	0.8	1.0	1.1	9.9	0.0	0.0	1.1
School Bus	1.5	1.8	1.7	1.6	1.1	2.9	1.0	0.0	0.3	1.6
Taxicab	0.1	0.5	0.1	0.3	0.7	0.1	0.0	0.0	0.0	0.2
Other	0.7	1.4	0.8	1.0	1.3	1.5	0.0	0.0	0.1	0.9
All	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

**Table 13: Variation in Mode Share by Housing Tenure and Type** (percentage of trips by means of transportation)

Source: Calculated by the authors from the 2009 NHTS.

Notes: In order to isolate urban travel, the sample was limited to residents of urban areas and trips of 75 miles or less.

1. SOV (single occupancy vehicle) includes vehicles with driver and no passengers.
2. HOV (high occupancy vehicle) includes vehicles with two or more occupants.
3. Light rail also includes conventional streetcars. Special transit for people with disabilities is in this category.
4. Metro/subway/heavy rail includes elevated rail and rail rapid transit.
5. Commuter rail includes suburban/regional rail systems and short-distance service provided by Amtrak.

patterns as renters and owners. Single detached houses have the highest automobile share (86.1%), using transit for 0.9% of all trips and non-motorized modes for 10.5%. Apartments and condominiums also had high automobile use, 83.8% of all trips, despite being a common choice for rental property. Rowhouses and townhouses are the housing type with the lowest automobile share (67.9%), highest transit share (8.3%), and 19.7% of all trips made on foot. This housing type is almost exclusive to areas with high accessibility to destinations and transit service, while single detached homes may not have non-automobile modes as an option.

#### 5.4 Demographic Characteristics of Urban Travel

Like income, race and ethnicity are important characteristics to show variations in travel behavior (see Table 14). Blacks make 11.2% of all trips, but account for more transit trips than any other race. Bus and light rail is the most common transit mode for any race, but Blacks and Hispanics use it in much greater proportion in comparison to other transit modes. Asians have high mode shares for heavy rail at 1.4%.

Automobiles, as the predominant mode of transportation in the United States, exhibit a wide range of mode shares by race and ethnicity. Whites and Hispanics use an automobile over 85% of the time, Asians 80.0% of the time, and Blacks 77.1% of the time. Whites are the only race using SOVs and HOVs at similar percentages, with other races using HOVs more often.

While gender might have played a significant role in the mode share of Americans in the past, the results from the 2009 NHTS show only slight variations (see Table 15). Females are more likely to travel in a HOV, possibly due to childcare related trips, but overall the mode share for automobiles is almost identical between genders. Females have a slightly higher mode share for transit, entirely made up of bus and light rail trips. Males are slightly more likely to use a non-motorized mode of transportation, mainly due to a higher mode share for cycling.

Age has a significant impact on the mode choice of Americans, but sometimes in unexpected ways (see Table 16). The automobile mode share increases with each age range, with people over the age of 65

Mode of Transportation	Race/Ethnicity			
	Black	Asian	White	Hispanic <sup>6</sup>
<b>Total Auto</b>	77.1	80.0	85.8	85.2
SOV <sup>1</sup>	35.3	32.6	42.2	36.0
HOV <sup>2</sup>	41.8	47.4	43.6	49.2
<b>Total Transit</b>	6.1	4.5	1.1	3.2
Bus and light rail <sup>3</sup>	4.9	2.7	0.8	2.6
Metro/subway/heavy rail <sup>4</sup>	0.8	1.4	0.2	0.5
Commuter rail <sup>5</sup>	0.4	0.5	0.1	0.1
<b>Total Non-motorized</b>	13.0	13.8	10.5	10.6
Walk	11.9	12.9	9.4	9.8
Bicycle	1.0	0.9	1.1	0.7
School Bus	2.4	1.0	1.6	0.6
Taxicab	0.4	0.1	0.1	0.1
Other	0.9	0.5	0.7	0.2
<b>All</b>	100.0	100.0	100.0	100.0
<b>Overall Sample Distribution<sup>7</sup></b>				
Percent of Total Households	13.0	3.0	68.0	0.7
Percent of Total Trips	11.2	2.8	69.2	0.8

**Table 14: Variation in Mode Share by Race/Ethnicity**

(percentage of trips by mode of transportation)

Source: Calculated by the authors from the 2009 NHTS.

Notes: In order to isolate urban travel, the sample was limited to residents of urban areas and trips of 75 miles or less.

1. SOV (single occupancy vehicle) includes vehicles with driver and no passengers.

2. HOV (high occupancy vehicle) includes vehicles with two or more occupants.

3. Light rail also includes conventional streetcars.

4. Metro/subway/heavy rail includes elevated rail and rail rapid transit.

5. Commuter rail includes suburban/regional rail systems and short-distance service provided by Amtrak.

6. The Hispanic category was defined to be mutually exclusive of blacks and whites.

7. Rows do not add to 100% because some racial and ethnic categories are not shown.

Mode of Transportation	Sex		
	Male	Female	All
<b>Total Auto</b>	81.2	82.6	81.9
SOV <sup>1</sup>	40.8	36.9	38.7
HOV <sup>2</sup>	40.4	45.7	43.2
<b>Total Transit</b>	2.6	3.0	2.8
Bus and light rail <sup>3</sup>	1.9	2.3	2.1
Metro/subway/heavy rail <sup>4</sup>	0.5	0.5	0.5
Commuter rail <sup>5</sup>	0.2	0.2	0.2
<b>Total Non-motorized</b>	13.7	12.1	12.9
Walk	11.9	11.6	11.7
Bicycle	1.8	0.5	1.1
<b>School Bus</b>	1.7	1.4	1.6
<b>Taxicab</b>	0.2	0.3	0.2
<b>Other</b>	0.6	0.6	0.6
<b>All</b>	100.0	100.0	100.0

**Table 15: Variation in Mode Share by Sex**

(percentage of trips by mode of transportation)

Source: Calculated by the authors from the 2009 NHTS.

Notes: In order to isolate urban travel, the sample was limited to residents of urban areas and trips of 75 miles or less.

1. SOV (single occupancy vehicle) includes vehicles with driver and no passengers.
2. HOV (high occupancy vehicle) includes vehicles with two or more occupants.
3. Light rail also includes conventional streetcars.
4. Metro/subway/heavy rail includes elevated rail and rail rapid transit.
5. Commuter rail includes suburban/regional rail systems and short-distance service provided by Amtrak.

using an automobile 86.2% of the time. The two highest age ranges are more likely to use a SOV than a HOV, possibly because they are less likely to travel with kids in the car. The youngest age range, from 5 to 15, are typically not old enough to drive, yet still travel 69.0% by automobile as passengers.

Transit use is highest for young adults, age 16 to 24, at 3.9%. As age increases, transit use falls. Interestingly, people too

young to drive have the smallest mode share for transit, at 1.5%. Bus and light rail are used by young adults and elderly travelers, while heavy rail and commuter rail attract a more middle-aged ridership.

Non-motorized travel diminishes greatly after the youngest age group, corresponding with the increase in automobile use. People over the age of 65 have the smallest share of non-motorized travel. While bicycling is used for transportation by

Mode of Transportation	Age					All
	5 to 15	16 to 24	25 to 39	40 to 64	65 & over	
<b>Total Auto</b>	69.0	80.9	82.3	85.0	86.2	81.9
SOV <sup>1</sup>	0.0	37.7	39.7	49.1	46.2	38.7
HOV <sup>2</sup>	69.0	43.2	42.6	35.9	40.0	43.2
<b>Total Transit</b>	1.8	4.1	3.2	2.5	2.7	2.8
Bus and light rail <sup>3</sup>	1.6	3.1	2.2	1.8	2.5	2.1
Metro/subway/heavy rail <sup>4</sup>	0.2	0.8	0.7	0.5	0.2	0.5
Commuter rail <sup>5</sup>	0.1	0.2	0.3	0.2	0.1	0.2
<b>Total Non-motorized</b>	18.4	12.1	13.7	11.6	10.2	12.9
Walk	15.2	11.0	12.8	10.9	9.6	11.7
Bicycle	3.3	1.0	0.8	0.8	0.6	1.1
<b>School Bus</b>	9.9	1.7	0.0	0.0	0.1	1.6
<b>Taxicab</b>	0.1	0.2	0.3	0.2	0.3	0.2
<b>Other</b>	0.7	1.0	0.4	0.5	0.6	0.6
<b>All</b>	100.0	100.0	100.0	100.0	100.0	100.0

**Table 16: Impact of Age on Mode Share**

(percentage of trips by mode of transportation)

Source: Calculated by the authors from the 2009 NHTS.

Notes: In order to isolate urban travel, the sample was limited to residents of urban areas and trips of 75 miles or less.

1. SOV (single occupancy vehicle) includes vehicles with driver and no passengers.
2. HOV (high occupancy vehicle) includes vehicles with two or more occupants.
3. Light rail also includes conventional streetcars.
4. Metro/subway/heavy rail includes elevated rail and rail rapid transit.
5. Commuter rail includes suburban/regional rail systems and short-distance service provided by Amtrak.

3.3% of those aged 5 to 15, no other age group uses it for more than 1.0% of all trips. School buses account for 9.9% of all trips made by those aged 5 to 15.

## 6. Conclusions and Policy Implications

Findings related to the first two research questions (What are the patterns of mobility for urban travel in the United States? and How do these patterns vary by socio-economic characteristics?) demonstrate similar results to previous articles in this series – America is automobile dependent. Automobiles account for over 80% of all trips whereas walking and transit account for 10.5% and 2.0%, respectively. All other modes make up the difference.

The 2009 NHTS underscores the importance of transit and non-motorized modes for work and work related trips at 4.5% and 4.8%, respectively, despite that SOV trips continue to dominate at 73.9%. Work travel often occurs during predictable times and in predictable directions, leading to the concept of peak hours. The fact that this travel remains dominated by automobiles with one person inside helps explain the traffic and highway building decisions that are often made. But, since the travel patterns are predictable, transit would be able to offer better mobility with less space. While HOV trips only account for 15.6% of work and work related trips, they are more common than SOV trips for all other trip purposes. Non-motorized travel is relatively more important among social/recreational and school/church travel.

The lack of vehicle ownership is most prevalent among the lowest income households, with nearly one-quarter of those earning under \$20,000 lacking access to a car. While households without cars make only 25.2% of trips in an automobile, the relationship of automobile use and income is not as strong with 69.9% of the poorest income class making trips by car. This relationship extends to transit and non-motorized trips. Transit accounts for 23.6% of trips in households without cars but only 6.8% in households that earn less than \$20,000. Non-motorized trips account for 43.4% in households with zero vehicles but only 19.5% in the poorest households.

Blacks, followed by Asians, are the highest users of transit and non-motorized modes. Hispanics, a growing segment of our nation, drive at the same levels as Whites, and more than Asians. However, they make more trips in HOVs than any other race/ethnicity and more than twice as many transit trips as Whites. Table 14 shows how race has a significant correlation with mode share, but it is less clear what policy implications this has. Strategies to change mode share by focusing on one race ignore the more complex causes of transportation choice. However, transportation planners are required to prevent undue impacts and provide equal access to transportation.

Gender only accounted for small differences in mode shares, apart from a shift towards high-occupancy vehicles, likely relating to childcare-related transportation. However, though cycling represents a small percentage of trips, the male mode share was over three times that for females. Women face unique barriers to cycling, often relating to safety perceptions and infrastructure. Likewise, women are considered an indicator species for cycling; places with lots of female cyclists are considered the best for infrastructure and safety, and it manifests in a large overall mode share (Pucher and Buehler 2012). Variations in the average trip length does not appear to change much for drivers of different income groups from the mean of 7.2 miles whereas transit trip lengths increase by income group (see Table 11). Transit use and non-motorized travel varies significantly by region of the country. The four regions with the highest levels of transit use, New England, Middle Atlantic, East North Central and the Pacific, are also the same regions with the highest share of non-motorized trips. Car trips are often chosen for short journeys because of urban design and infrastructure. When walking or cycling is perceived as dangerous or impracticable for these trips, people have made automobile travel the default option for even the shortest distances.

Commuter rail was the one transit mode that showed a preference by high-income groups. This is likely a function of the places where commuter rail is available. In large metropolitan areas commuter rail

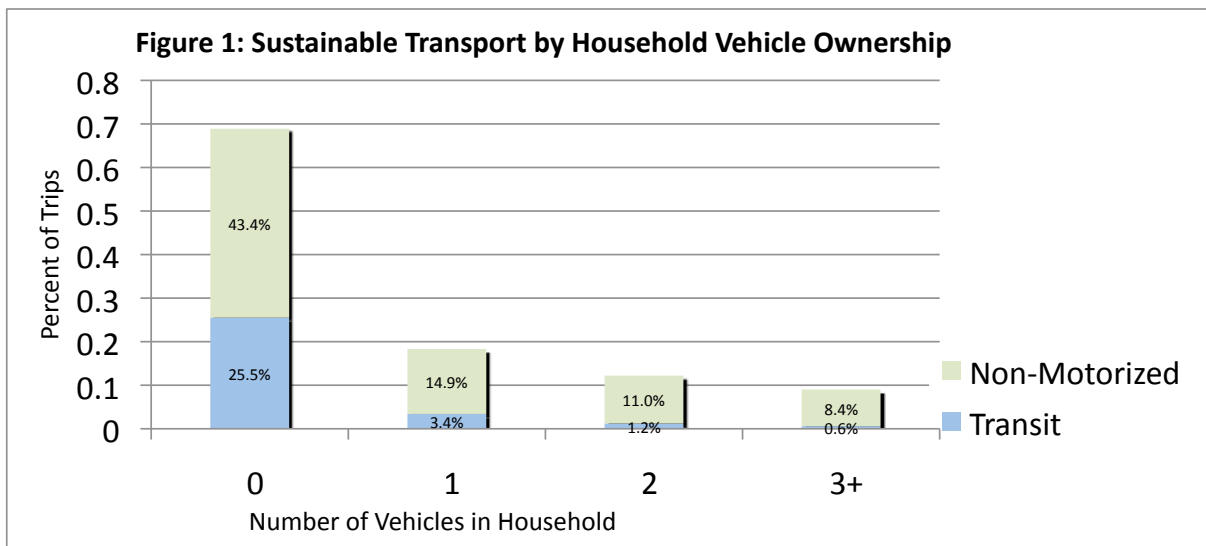
lines connect wealthier suburbs to the city center. Despite possible higher fares, commuter rail may offer a significant advantage over automobile commuting in these locations. It should be explored further how transit subsidies impact this phenomenon, and how resources are balanced between this mode and more widely used bus and metro transit modes. Moreover, property values around commuter rail stations also respond to direct downtown access. Studies show that there is pent-up demand for such transit-oriented neighborhoods (Renne 2013), thus higher income individuals are able to better compete in the market for these location efficient housing units.

This article expanded on the analysis compared to previous in this series and examined the relationship between housing tenure and travel behavior. This topic has received attention in recent years since the Center for Neighborhood Technology released the Housing + Transportation Index (H+T Index). We found that renters are more likely to take transit and walk as compared to homeowners. This is an important consideration as many communities are resistant to rental housing across

the United States, thus ensuring that this tenure option is available in close proximity to transit and walkable neighborhoods is important.

The findings above have implications for the third research question (What are the policy implications of current mobility patterns for creating a more sustainable society?).

Regions with the highest shares of transit and non-motorized modes, typically referred to in the literature as the sustainable modes (Newman and Kenworthy 1999; Banister, Pucher and Lee-Gosslin 2007), are the regions that have the most extensive infrastructure. Clearly, investment in non-automobile transportation infrastructure matters, but infrastructure alone might not be sufficient to encourage a more sustainable transport use. Policy is necessary to reduce automobile ownership, the most significant factor towards sustainable transport. As shown in Table 7 and Figure 1, households without automobiles make 67% of trips using a sustainable transport mode. This share drops to 18% in households with one vehicle, 12% in households with two automobiles and



**Figure 1: Sustainable Transport by Household Vehicle Ownership**

Source: Calculated by the authors from the 2009 NHTS.

Notes: In order to isolate urban travel, the sample was limited to residents of urban areas and trips of 75 miles or less.

1. SOV (single occupancy vehicle) includes vehicles with driver and no passengers.
2. HOV (high occupancy vehicle) includes vehicles with two or more occupants.
3. Light rail also includes conventional streetcars. Special transit for people with disabilities is in this category.
4. Metro/subway/heavy rail includes elevated rail and rail rapid transit.
5. Commuter rail includes suburban/regional rail systems and short-distance service provided by Amtrak.

9% in households with 3 or more cars. As discussed above, income is not as strong as a factor because in the poorest income class, under 30% of trips are made by a sustainable mode.

Travelers cannot give up automobile ownership without having viable transportation alternatives. As noted above, federal efforts to creating livable and sustainable communities is funding planning efforts and infrastructure towards the goal of creating mixed use and compact development that foster transit and non-motorized travel. Americans will remain automobile dependent unless land uses and transportation systems allow for alternatives.

Leinberger (2009) argues that although the supply of walkable urbanism is less than 5% of the current built environment, it is demanded at closer to 30% when Americans choose their housing. Younger generations who make up this demand, and who tend to be renters, will drive a new era of development towards walkable and transit-oriented communities. However, this is predicated on most local governments needing to update zoning codes to allow for this style of development. It is important to note, however, that zoning changes are not enough. Even if transit-oriented developments were built around all 4,500 rail stations across the country, the supply of housing would fail to serve much more than 5 to 10% of the overall population (Renne 2013).

Economists have identified the external costs of automobile travel as a reason why different modes struggle to compete for users. Road construction costs, parking requirements, air pollution, energy policy, and personal injury are all costs that are paid by society, and often from other sources of funding. Fuel taxes would need to be dramatically increased to address these issues, a change in the price of gas that could reverberate into a major change in mode choice.

However, if complementary policies are not adopted to encourage households to reduce or eliminate car ownership, land use and transportation improvements might not make a significant difference in overall travel behavior. Shoup (Shoup 2005) es-

timates that in 2002 the total subsidy of off-street parking cost was between \$127 and \$374 billion, a cost within the range of the cost of Medicare or national defense. These estimates do not include other external costs of driving on the environment or society. Pricing to better internalize the cost of owning, using, and parking automobiles is necessary for promoting more sustainable travel behavior.

Federal policy has been inconsistent in regards to the role of the automobile. The Partnership for Sustainable Communities was created at the same time as a bail-out of the automobile manufacturers and an expansion of roads and highways. The federal government fought over the importance of transit, walking and bicycling as compared to highways leading up to the recent MAP-21 bill in 2012. However, the fact that the USDOT has included sustainability and livability as two of their five strategic goals in the 2012-2016 Strategic Plan is an important signal that the United States is becoming more serious about creating a sustainable society. The rebuilding of America's transportation system and our communities could drive the economy to a new frontier that can result in a cleaner environment and more equitable society.

Many argue that electric cars or other automobile technology can solve our problems in the future. We believe that technological solutions are important to becoming a more sustainable society, but not the full solution. Until we choose to encourage a more balanced transport system, with more options for transit, walking and bicycling, the travel behavior of Americans will continue to be dominated by the automobile and not fully be able to achieve sustainable outcomes.

Cities in Western Europe and Asia can serve as inspiration of sustainable cities in the United States. In the census data for commuting to work on foot, over time, the US has seen a decline from 10.3% to 2.9%, while most European cities still show double-digit pedestrian mode shares. Dutch and Danish cities are well known for cycling being the most prevalent mode of transportation. Transit mode shares can approach European levels in Ameri-



can urban centers, but nationally and in most suburban, exurban and rural areas, the systems are often only rudimentary. It would take investment in infrastructure and land use development that makes these modes the most convenient choice for most trips. Many American cities have begun to make these investments, building new transit and bicycle networks, and incentivizing and requiring denser, walkable, mixed-use development. The market is pushing hard for these changes too, in a new post-recession era that brings much promise for sustainability across America.

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## Policy pathways towards achieving a zero carbon transport sector in the UK in 2050

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### 1. Introduction

Between 1990 and 2010, total greenhouse gas (GHG) emissions for the UK fell by 21 per cent whilst GHG emissions from UK transport increased by 11 per cent (to a total of 159.3 Mt CO<sub>2</sub>-eq) (DfT, 2012). Thus, as a proportion of total GHG emissions for the UK, transport emissions have risen from 18 per cent in 1990 to 26 per cent in 2010. Although road traffic accounted for the majority (69 per cent) of total transport emissions in 2010, most of the increase since 1990 has been due to international air travel, GHG emissions from this source having more than doubled since 1990 (DfT, 2012). For road transport, assuming no change in government policy beyond that already announced, the combined effect of fleet fuel efficiencies and increased travel demand is projected to result in a 15 per cent reduction in CO<sub>2</sub> emissions on 2010 levels by 2040 (DfT, 2013). Meanwhile, CO<sub>2</sub> emissions from UK aviation are set to continue rising, the DfT forecasting approximately 50 per cent increase on 2010 levels by 2040 (DfT, 2011).

The 2008 Climate Change Act committed the UK government to reducing GHG emissions by at least 80 per cent (in comparison to 1990 levels) by 2050 and it is recognised that effective decarbonisation<sup>1</sup> of the transport sector will play a large role in achieving this goal (DfT, 2009a). It should be noted that GHG emissions from international shipping and international aviation are specifically excluded from the UK's 80 per cent target although they are included within the analysis presented here. The Department of Transport (DfT) acknowledged that complete decarbonisation is unlikely to be possible for aviation and shipping due to the greater technical challenges although by 2050, these modes will have seen a transformative improvement in efficiency. Despite these envisaged difficulties, progress towards a desirable future of a zero carbon road transport system has enormous potential

to deliver GHG reductions and to embed the transport sector firmly within a wider process of societal change that delivers a decarbonised future. Indeed, it can be argued that without a clear and robust low carbon transport system in place reinforcing all other sectoral and lifestyle contributions to carbon reduction, the scale of CO<sub>2</sub> emission reductions required across the UK or the European Union (EU) may not be achieved (Pamlin and Szomolányi, 2006; Metz, 2008; Frondel et al., 2011).

Visioning desirable low carbon futures for particular sectors or countries has been carried out in a number of studies (Ackerman, 2005; Anderson et al., 2005; Raskin et al., 2002; OECD, 2002; Hickman and Banister, 2007; Stanely et al., 2011). A vision of a zero carbon transport system is one that has long-term social, environmental and economic benefits for society as a whole (Gilbert and Perl, 2008). In such a future, technical, financial, organisational and other obstacles that have impeded the move to a more sustainable transport future will be removed (Buchan, 2008). A cultural shift will occur with regard to how cities are designed, how people travel for work and leisure and how goods are produced and transported. The use of technology and economic incentives and penalties will be maximised and the use of fossil fuels in transport will be minimised. This transformed society, combined with increases in transport choice and improvement in safety and security will be fairer and will improve access for all (Appleyard, 1981; Solomon, 2003).

There has been enormous progress made in other EU countries and elsewhere to reshape the transport system so that it delivers societal objectives at a much lower carbon penalty than is currently the case in the UK (EEA, 2009). If it were possible to combine a small number of the elements from UK and EU best practice, and introduce them into the UK planning and transport system, good progress towards a zero carbon transport target could be made.

1 The word 'carbon' within commonly used terms such as 'decarbonisation', 'low-carbon' and 'zero-carbon' and 'reduced carbon' is short hand for, and synonymous with, 'carbon dioxide (CO<sub>2</sub>) emissions'.

This paper presents a vision of a desirable future for the UK transport sector and explores how it might be possible to deliver a zero carbon transport system for the UK by 2050. It quantifies and assesses the contributions that different CO<sub>2</sub> emission reduction measures can make in assisting the UK to move towards a zero carbon transport sector by 2050 according to two scenarios: a business-as-usual (BAU) scenario and a maximum impact (MI) scenario.

**2. Method**

In order to identify the different policy pathways towards a zero carbon transport in the UK by 2050, a range of behavioural, fiscal, spatial planning and technological CO<sub>2</sub> emission reduction measures were quantified and assessed. Existing published reports, academic papers and official statistical data were used to quantify CO<sub>2</sub> emissions from the UK transport sector for a baseline year and then to project emissions for 2050 according to two scenarios. These scenarios were a) a business-as-usual (BAU) scenario, with continuation of present trends and policies, and b) a maximum impact (MI) scenario in which all feasible interventions for achieving a 'zero carbon' UK transport sector are applied.

Much of the baseline and trend data were derived from other modelling initiatives such as the DfT's National Transport Model (NTM) (DfT, 2008b). Therefore, the BAU scenario estimates are constrained by these assumptions (e.g. the NTM's future fuel price increase assumptions). Transport-related CO<sub>2</sub> emissions are not restricted to vehicle exhaust emissions. Emissions of CO<sub>2</sub> are also produced by the energy consumed in the extraction, processing and distribution of fuels (i.e. 'well-to-wheel' emissions) as well as 'embodied energy' CO<sub>2</sub> emissions from the manufacture of vehicles, and construction of roads and other components of the transport infrastructure. However, it was beyond the scope of

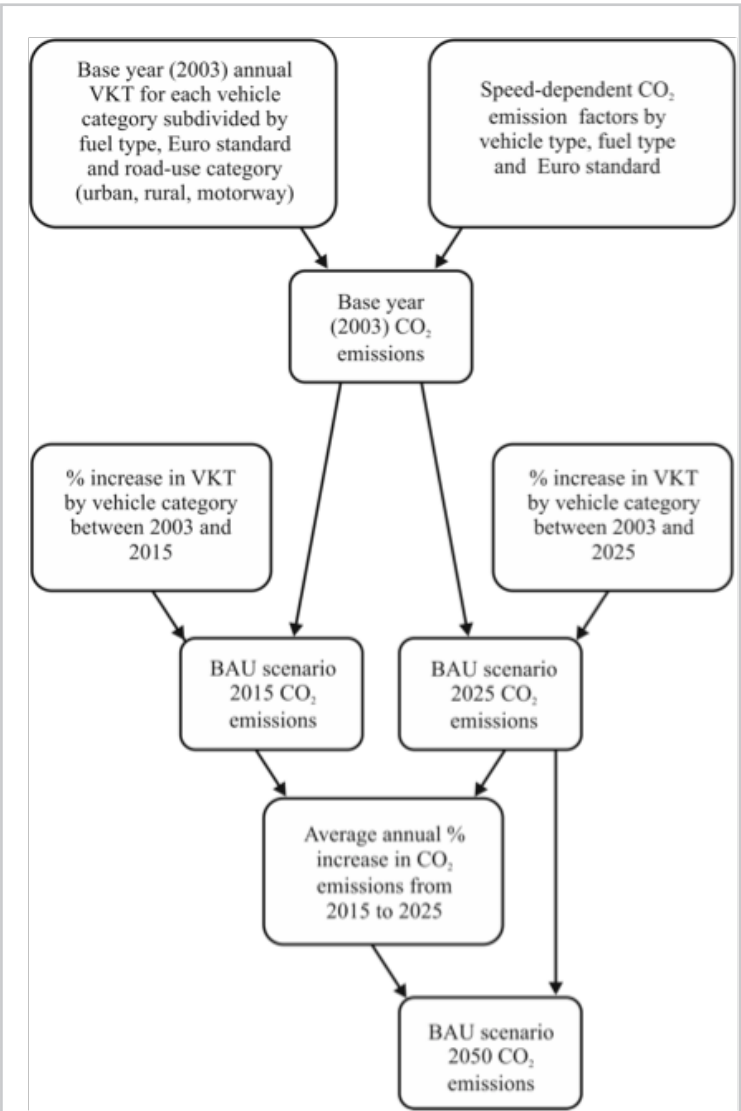
this assessment to include 'embodied energy' and 'well-to-wheel' GHG emissions. The focus was therefore solely on 'tailpipe' CO<sub>2</sub> emissions.

**2.1 Business-as-usual (BAU) Scenario**

The BAU Scenario estimates UK transport sector CO<sub>2</sub> emissions by 2050 based on the continuation of present trends and policies. Four transport modes were considered in each scenario: road, rail, air and shipping.

**2.1.1 Road transport**

Figure 1 summarises the methodology used to estimate the BAU Scenario CO<sub>2</sub> emissions for road transport. The CO<sub>2</sub> emissions were estimated by major vehicle category as used in the National Atmospheric Emissions Inventory NETCEN UK Fleet Composition Projections (NET-



**Figure 1. Flow chart of the methodology used to estimate CO<sub>2</sub> emissions from road transport in the Business-as-usual (BAU) Scenario. (VKT = vehicle kilometres travelled)**

CEN, 2003), but with the addition of motorcycles. The vehicle categories included in the analysis include petrol and diesel cars, petrol Light Duty Vehicle (LDVs), diesel LDV, rigid Heavy Duty Vehicles (HDVs), buses and motorcycles. These categories were further subdivided by Euro emission standard (e.g. for cars: Pre-Euro I, Euro I, Euro II, Euro III, Euro IV) and road type (urban, rural and motorway). Vehicle kilometres travelled (VKT) for the base year (2003) for the major vehicle categories (cars, LDVs, HGVs, buses and motorcycles) were taken from the DfT Traffic Statistics (DfT, 2008c; 2008b). Distances travelled were further subdivided by fuel type and Euro standard and road category (DfT, 2004). For motorcycles, CO<sub>2</sub> emissions were calculated from the total fuel consumption for 2003 (DfT, 2008c) multiplied by an emission factor of 3,180 g CO<sub>2</sub> kg<sup>-1</sup> fuel. For all other vehicle categories, speed dependent CO<sub>2</sub> (ultimate) emission factors (in g/km) for Euro standards up to Euro II (NETCEN, 2003) and post-Euro II (DfT, 2005) were calculated.

The traffic growth forecasts of the DfT's National Transport Model (NTM) were used for the BAU Scenario CO<sub>2</sub> emission projections to 2015 and 2025 (DfT, 2008d). Projected changes in distribution of VKT between road type were derived from the percentage changes given in the DfT's Road Transport Forecasts (DfT, 2008b). The BAU Scenario therefore incorporates the transport measures assumed for the NTM forecasts. These measures include graduated vehicle excise duty (VED), company car tax (CCT), fuel duty, the Renewable Transport Fuels Obligation (RTFO) and the voluntary agreements on new car fuel economy (VAs) (DfT, 2008b). The bulk of these (VED, CCT, fuel duty and the VAs) all work to reduce road transport CO<sub>2</sub> by encouraging improvements in fuel economy. The other measure aimed at cutting CO<sub>2</sub> emissions is the RTFO which places an obligation on fuel suppliers to ensure that a certain percentage of their aggregate sales are made up of biofuels. Continuation of the above assumptions up to 2050 is implicit in the BAU projections.

The key drivers of traffic growth in the NTM are changes in income, employment, population and falling travel costs as a re-

sult of fuel economy improvements. Detailed traffic growth forecasts (by vehicle and road type) are only provided for England and Wales and only up to 2025. It was therefore assumed that rates of change for England also apply to the UK as whole and that the annual percentage increases in traffic for each vehicle category between 2015 and 2025 continue unchanged to 2050. The NTM assumptions for motorcycles and Liquefied Petroleum Gas (LPG) fuelled vehicles are not stated and are therefore kept constant in the BAU Scenario.

### **2.1.2 Rail Transport**

For CO<sub>2</sub> emissions from rail transport, published data on diesel and electricity consumed by both passenger and freight rail transport (ATOC, 2007) were used for a 2006/07 baseline. Emissions were then estimated according to the percentage increases in CO<sub>2</sub> given by DfT's 'Business as planned scenario', minimum up-take projections, which take account of CO<sub>2</sub> saving initiatives that are either planned or expected to be introduced. Our BAU projections to 2050 assume a continuation of the average annual percentage increases in CO<sub>2</sub> emissions given in DfT (2009a) for the period 2020 to 2022 (i.e. 0.39, 0.65 and 0.85 per cent for diesel passenger, electric passenger and diesel freight respectively).

### **2.1.3 Aviation**

The DfT's passenger demand and CO<sub>2</sub> forecasts were used to develop the BAU Scenario for aviation (DfT, 2009b). In general, the DfT model forecasts the number of air transport movements (ATMs) at each airport depending on available capacity and combines these with projections of average flight distance and of type of flight (e.g. long-haul, short-haul, domestic etc.) to obtain seat-kilometre projections by airport. These are then combined with a projection of the fleet fuel efficiency taking into account different aircraft type and configurations.

Under their 'central case' scenario, the DfT assume that airport capacity is not constrained and forecast that air travel demand at UK airports will grow strongly from 241 million passengers per annum (mppa) in 2007 to 465 mppa in 2030 (within the range 415-500 mppa). This

will result in an increase in total UK aviation CO<sub>2</sub> emissions from 37.5 Mt CO<sub>2</sub> in 2005 to 58.4 (range 51.8 – 61.6) Mt CO<sub>2</sub> in 2030. After 2030, the growth in aviation emissions is projected to slow down due to market maturity, limits to improvements in aircraft efficiency, and capacity constraints slowing demand growth. By 2050, aviation emissions are projected to have stabilised at 59.9 (range 53.0 – 65.0) Mt CO<sub>2</sub>.

#### 2.1.4 Shipping

The International Maritime Organisation (IMO) estimates that international shipping account for 2.7 per cent of global emissions or 843 Mt CO<sub>2</sub> (MEPC, 2009). The IMO forecasts a rise in future global emissions which, by 2050, could be between 2,400 and 3,600 Mt CO<sub>2</sub> or 10 - 15 per cent of global CO<sub>2</sub> emissions (IMO, 2009)

Globally, emissions from shipping are greater than those from aviation and global growth rates are reflected in UK growth rates. UK port container traffic has increased from approximately 3.5 million twenty-foot equivalent units (TEU) in 1990 to nearly nine million TEU in 2007 (DfT, 2007). Entec (2005) projected a growth rate for shipping of 2.6 per cent per annum between 2000 and 2020 and in the BAU shipping scenario, this rate is assumed to continue up to 2050.

The allocation of global shipping emissions to the UK is problematic due to different methodologies being used to calculate emissions as well as the issues of ship ownership, operational differences and governance overseeing legislation and emission controls. The four main emission allocation options are those based on: bunker fuel sales/consumption<sup>2</sup>; freight tonne kilometres (FTK); country of departure/destination; and zone of emissions within radius of coastline (12 miles/200 miles). In this analysis, the FTK method of allocating emissions to the UK was used to avoid the problem of ships refuelling elsewhere or operating under different jurisdictions. FTK is also a measure of economic activity and so essentially this is an allocation of responsibility, i.e. who is benefiting from the economic returns from the transport of the cargo.

## 2.2 Maximum Impact (MI) Scenario

The MI Scenario envisions a radically different Britain by 2050, where the UK transport sector emits close to zero CO<sub>2</sub>. A wide range of measures known to reduce CO<sub>2</sub> emissions are grouped into four categories (spatial planning, fiscal, behavioural and technology) and the impacts of each assessed separately in order to allow their relative efficacy to be assessed.

The following methodology was used to avoid overestimating the combined effect of more than one measure applied to the same category. Clearly, two measures each reducing CO<sub>2</sub> emissions by 50 per cent when applied separately, would not give 100 per cent emissions reduction in combination. The 50 per cent reduction of the second measure would only apply to the 50 per cent remaining after the first measure, the total reduction being 75 per cent. The same logic applies to combining the effect of any number of measures. For example, if there are three measures to be combined and measure M1 alone reduces CO<sub>2</sub> emissions by x%, measure M2 alone reduces emissions by y% and measure M3 alone reduces emissions by z%, the combined percentage reduction due to all three (Mcomb) is calculated as:

$$M_{Comb} = 100 - (1-x/100) \times (1-y/100) \times (1-z/100) \times 100$$

(Equation 1)

It is acknowledged that there may also be interaction, either synergistic or antagonistic, between certain individual measures although no published data could be found quantifying such interaction terms. It was assumed therefore, for the purposes of the current analysis, that these interactions would be minimal and not materially affect the scale of emissions reductions achieved by each of the four main categories of measures.

A similar approach was used when applying a particular reduction measure annually over several years as we have done for air fare increases and the road fuel price escalator (FPE). If the annual decrease in

<sup>2</sup> Under the United Nations Framework Convention on Climate Change (UNFCCC), countries are not required to produce a GHG emissions inventory for shipping but they do provide an inventory for fuel bunker sales which is reported as a footnote.

emissions is  $x\%$  and the period of time over which it takes place is  $T$  years then the total percentage reduction  $R$  is calculated as:

$$R = 100 - (1 - x/100)^T \times 100$$

(Equation 2)

The assumptions used and CO<sub>2</sub> reduction achieved from different transport modes when a range of spatial planning, fiscal, behavioural and technology measures are applied are outlined below.

### 2.2.1 Road Transport

*Spatial planning.* There is clear evidence that high density cities that avoid urban sprawl, and have good quality accessibility policies to deliver services locally, produce significant reductions in VKT (e.g. Kenworthy and Laube, 1999). The development of compact cities could significantly reduce urban CO<sub>2</sub> emissions. MI Scenario assumptions for spatial planning are:

- Pedestrian-oriented design: urban car VKT reduced by 10 per cent (Dierkers et al., 2005).
- Road space reallocation: urban car CO<sub>2</sub> emissions reduced by 11 per cent (Cairns et al., 1998).
- High occupancy only vehicle (HOV) lanes: urban car VKT reduced by 1.4 per cent (Apogee, 1994).
- Compact development: for cities >100k population, all traffic VKT reduced by 30 per cent (Ewing et al., 2008).
- Regional co-operation model for HGVs: assume 50 per cent reduction in total VKT (Holzapfel, 1995).

*Fiscal measures* in the form of charges, tax increases and fare subsidies (for public transport) can have a powerful effect on people's transport choices from the type of car they purchase (if at all) through to choice of transport mode for each individual journey. The MI Scenario Fiscal assumptions are:

- Road user charges: three per cent reduction in all traffic (Kollamthodi, 2005).
- Workplace car parking charges: CO<sub>2</sub> emissions from commuting by car reduced by 12 per cent (Shoup, 2005). Thus, assuming 25 per cent of total car CO<sub>2</sub> emissions are due to commuting (DfT, 2008a; 2008b) this equates to a three per cent reduction in total passen-

ger car CO<sub>2</sub> emissions.

- Urban, non-commuting car parking charges: A 13 per cent reduction in urban car VKT assuming: (a) VKT elasticity factor of -0.07 (average quoted for predominantly urban areas by TRACE (1999)); (b) 75 per cent of car CO<sub>2</sub> emissions are for non-commuting purposes (DfT, 2008a; 2008b) assuming that this also applies to urban car use; and (c) average parking charges increase in real terms by 10 per cent per annum from 2010 to 2030, to give a 570 per cent final increase.
- Fuel price: A five per cent per annum fuel price escalator is introduced from 2010 onwards producing a 600 per cent fuel price increase by 2050 for all road vehicles. A short-term elasticity factor of -0.25 for fuel consumption (Goodwin et al., 2004) applied annually results in a 40 per cent reduction in CO<sub>2</sub> emissions for all fossil fuel powered road vehicles by 2050. The high rate of increase assumed for vehicle fuel costs is designed to gradually price the fossil fuel-powered vehicles off the road in favour of alternatives such as electric vehicles (powered by carbon neutral electricity), or to shift users of private transport over to (carbon neutral) public transport systems.
- VED circulation tax: Increased differentiation reduces VKT for all cars by 4.8 per cent (COWI, 2002).
- Car purchase tax and 'Feebate' systems based on fuel consumption: Reduces VKT for all cars by four per cent (Van den Brink and Van Wee, 2001).
- Public transport fares subsidy: a 30 per cent reduction in fares will reduce CO<sub>2</sub> emissions for all cars by two per cent (UKERC, 2009).

*Behavioural change.* Although fiscal measures and spatial planning will usually reduce transport related CO<sub>2</sub> emissions through their effect on peoples' behaviour, some measures can be regarded as 'purely' behavioural and these are included here. There is also a variety of mainly behavioural measures, termed 'Smarter choices' by Cairns et al. (2004), including workplace travel plans, home working and teleworking, travel awareness and education, public transport information and marketing, personal travel plans, local collection points, school travel plans,



home shopping and car clubs. Although these measures can make an important contribution to CO<sub>2</sub> emission reduction from road transport, there is considerable overlap with both spatial measures (e.g. compact development) and fiscal measures (e.g. parking charges) already dealt with above. Therefore, to avoid the danger of double-counting, these 'Smarter choices' have been omitted for the purposes of the current analysis. Thus estimates of the emissions reduction potential of the 'behavioural change' category used here can be considered to be conservative estimates. MI Scenario behavioural assumptions include:

- Ecological driving: eight per cent reduction in car CO<sub>2</sub> emissions (Defra, 2007; King 2007).
- Reducing motorway speed limit to 60 mph and enforcing it: 10 per cent reduction in motorway CO<sub>2</sub> emissions (Commission for Integrated Transport, 2005).
- Car share: reduction in car VKT for urban (8.3 per cent) and rural (3.6 per cent) driving (Apogee, 1994; TDM Resource Center, 1996)).
- Modal shift for road freight: 20 per cent reduction in CO<sub>2</sub> emissions from HGVs (Whitelegg, 1995).

*Technology.* The continued increases in internal combustion engine (ICE) efficiency, as assumed for the BAU Scenario, will deliver substantial CO<sub>2</sub> emission savings. However, in the likely absence of large-scale availability of sustainable biofuel substitutes for all fossil fuels currently used in transport, a radical shift to other technologies will be required in order to achieve a near zero carbon emission target for this sector by 2050. The New Automotive Innovation and Growth Team (NAIGT) has set out a roadmap, agreed by UK industry, that shows how automotive technology will need to develop to 2050 in order to tackle the CO<sub>2</sub> challenge (NAIGT, 2009). Although innovations in ICE vehicles and different types of electric hybrids will play a role in the intervening years, by 2050 road transport will have to be largely made up of some combination of PEVs and hydrogen fuel cell vehicles, depending on technology breakthroughs. Of course this technology shift would only deliver a low carbon future if the electricity required to charge the PEVs, or to produce the hydro-

gen for the fuel cells, comes from carbon-neutral sources such as renewables, fossil fuel combustion with carbon capture and storage (CCS), or nuclear energy. Thus, an implicit assumption here is that the vision contained in the UK Government's Carbon Plan (DECC, 2011) of an almost completely decarbonised electricity supply by 2050, will be realised. ICE passenger cars, vans and motorcycles would become obsolete in this low carbon future. Lighter HGVs up to 12 tonnes would also be fully electric (DfT, 2009a) although heavier HGVs would need to be powered by hydrogen fuel cells or sustainable biofuels (as described by Baker et al., 2009) in order to achieve carbon neutrality. MI Scenario assumptions for Technology:

- All passenger cars, LDVs, motorcycles and HGVs/buses less than 12 tonnes in weight to be PEV using 100 per cent renewable electricity or hydrogen fuel cell powered (using carbon neutral sourced hydrogen).
- Heavier HGVs and buses/coaches (>12 tonnes) to be powered by either hydrogen fuel cells (with carbon neutral sourced hydrogen) or sustainable biofuel.
- Liquefied petroleum gas (LPG) vehicles completely phased out.

The assumptions in the MI Technology package are different from the first three in that they comprise desired technology end-points rather than a set of policy interventions per se. These technology end-points could arise simply as a result of the spatial, fiscal and behavioural measures described earlier. In particular, the fiscal measures alone may render petrol/diesel powered vehicles prohibitively expensive compared with say, PEVs.

### **2.2.2 Rail Transport**

Electric trains emit 20 to 35 per cent less carbon per seat-kilometre than diesel equivalents on the basis of the current electricity generation mix (Rail Safety and Standards Board, 2007). This advantage will increase over time as our electricity generation mix becomes less carbon intensive. It is therefore assumed the railway network will be completely electrified by 2050 and that the electricity used will be carbon neutral. This is in line with the DfT (2009a) which envisages that by

2050, rail transport will be largely decarbonised and powered by clean electricity. The MI Scenario therefore assumes that CO<sub>2</sub> emissions from both passenger and freight rail will be zero by 2050.

### 2.2.3 Aviation

The aviation BAU Scenario already included changes expected over the next 40-50 years. The DfT (2009b) recognises that, even in the longer-term, the decarbonisation of aviation (and shipping) and the use of alternative fuel sources will be more challenging than for road and rail modes.

The International Air Transport Association (IATA) (2009) roadmap towards carbon neutral growth (no increase in emissions as demand continues to grow) includes setting emissions standards, use of biofuel and improvement in air traffic management. By 2020, a 1.5 per cent per annum improvement in fuel efficiency is expected. Within this timeframe, the industry is also expected to achieve carbon neutral growth. By 2050, emissions will have reduced by 50 per cent compared to 2005. The Sustainable Aviation Group (2008) presents a more optimistic future where demand increases threefold by 2050 but emissions from aircraft manage to return to 2000 levels. They suggest that this can be achieved through a combination of new technologies and operational efficiency gains and with ten per cent reduction by using biofuels.

The MI Scenario assumes there will be a reduction in flying activity and distance travelled due to people changing their lifestyles by taking fewer long-haul holidays, international business trips and overall travelling less by air. UK internal flights could be eradicated through substitution of transportation modes that are less GHG intensive than aircraft and by information technology playing a key role in reducing domestic and international air travel in the business sector.

*Fiscal measures:* In the MI Scenario there will be higher ticket prices due to a rise in the price of oil and with the introduction of some form of carbon tax. Reductions in flying, based on price elasticities (Brons, 2002; Njegovan, 2006) for leisure travellers will reduce emissions by 27 per cent.

*Behavioural:* Aviation growth will continue, albeit at an increasingly slower rate, and a general "greening" of attitudes and behaviour will gradually smooth out growth rates in the latter half of the projection. Improvements in other transport modes will see people substituting air with rail travel, for example, when travelling from the UK to continental Europe. Businesses will replace physical travel with virtual meetings due to improved telecommunication. High speed internet will see videoconferencing and tele-presence systems commonplace in offices. The MI foresees a cultural-change in organisations towards travel through de-incentivising foreign travel and a stronger sense of corporate social responsibility.

*Constraining capacity:* The BAU Scenario was based on DfT forecasts (the 's12s2' scenario) that included additional capacity at Stansted Airport and a third runway at Heathrow Airport. In the MI Scenario, we assume that the policy that sanctioned these additional runways would be reversed (as subsequently occurred under the 2010 Conservative-Liberal Democrat coalition government with respect to the third runway at Heathrow airport). However, growth at airports in terms of air traffic movements and passenger numbers will continue at expected rates using existing airport capacity. The impact of constrained capacity was modelled in the DfT CO<sub>2</sub> forecasts for 2050 in which CO<sub>2</sub> emissions reduce from 59.9 Mt CO<sub>2</sub> under their 's12s2' scenario to 54 Mt CO<sub>2</sub> under their 'maximum use' (s02) scenario. Therefore, as a consequence of this intervention measure to constrain demand, we assume a 10 per cent reduction in aviation emissions under the MI Scenario.

*Technology:* The MI Scenario does not foresee a radical shift in aircraft design or a major switch to alternative fuels. It is assumed aircraft manufacturers meet their Advisory Council for Aeronautical Research in Europe (ACARE, 2001) objectives to improve fuel efficiency in new aircraft by 2030. After this, additional improvements to the design of existing aircraft, making smaller improvements in efficiency, will be retrofitted in the current fleet. ACARE suggests that from 2021, 0.5 per cent per annum increase in efficiency is feasible with

further developments in new lightweight composite materials for turbines and compressors. Whilst the technology exists conceptually to produce more efficient aircraft, such as use of blended wing bodied aircraft, airlines are assumed to retain their existing aircraft fleets based on current designs. In the MI Scenario by 2050, the oldest and most fuel intensive aircraft will be scrapped or re-engineered. However, it is envisaged that more fuel efficient propfans, a hybrid between a turbofan and a turboprop engine, will be used for short-haul flights.

It is assumed that biofuels will only replace a small proportion of fossil fuel use in aviation due to limited production capacity constrained by the amount of land required to produce feedstock, issues relate to food security and the potential loss of biodiversity that could occur through land-use change. Hydrogen-based propulsion systems for aircraft are not yet technically feasible and would potentially pose a number of problems such as releasing water vapour (a GHG) into the atmosphere. Synthetic kerosene is another potential substitute fuel which could be used. However, its production process could lead to even more GHG emissions (CAEP, 2007). The use of these alternative fuels is not therefore, assumed for the MI Scenario.

As a result of the technological improvements, but not including radical new technology, CO<sub>2</sub> emissions from aviation in the MI Scenario are reduced by 14 per cent in 2050. This is consistent with the scale of reduction suggested by the Sustainable Aviation Group (2008).

Other improvements are feasible in areas such as airspace management (NATS, 2008) where there could be a coordinated approach to flight planning (Stollery, 2008) and sharing airspace with military operations (EC, 2009) who themselves will have lower levels of activity and with better communication due to technological developments in global positioning satellites and telematics (EUROCONTROL, 2008).

#### 2.2.4 Shipping

The MI scenario considers a number of operational, technological and design improvements in ships over the next forty years which could lead to a reduction in shipping emissions.

*Speed:* Ships travelling at slow speeds have been found to be far more fuel efficient and less polluting (Harrould-Kolieb, 2008). Slower speeds applied across the whole fleet could reduce emissions by 23 per cent (IMO, 2009).

*Voyage optimisation:* This is where ship operators take various measures to reduce fuel consumption and hence CO<sub>2</sub> and other emissions. These measures which include selection of optimal routes with respect to weather and currents; just-in-time arrival to take advantage of tides; and ballast optimisation to reduce unnecessary weight (AEAT, 2008).

*New Technology:* Kite sails are seen as a way of reducing fuel costs and carbon emissions due to their aerodynamic shape. Under optimal wind conditions, up to 1,000 feet above the sea surface where there are stronger winds, kite sails can reduce fuel consumption by up to 50 per cent. The main limiting factor is that weather conditions are usually variable. Fuel savings of 10-35 per cent are likely but only for the 30-50 per cent of the time the vessel is at sea, wind conditions permitting (Skysails, 2009). Improved weather-tracking using satellite and radar systems could enable the ships to alter their route to seek out stronger winds. The technology is already being used on cargo vessels and could be expanded to the whole fleet. In addition, reducing the frictional resistance of the ship's hull with the sea surface means that the less engine power is required which means lower fuel consumption and carbon emissions.

*Cleaner Fuels:* Switching to 'cleaner' marine diesel oil instead of using residual oil can reduce ship CO<sub>2</sub> emissions by 4-5 per cent. Residual (heavy) oil is much cheaper for shipping lines but requires more processing on board while cleaner fuels are processed at refineries. In the MI scenario a 4 per cent reduction in emissions is assumed for this measure. The use of

biofuels is not considered an option for the same reasons already outlined above for aircraft.

*Shore-side measures:* Other measures assumed for the MI scenario include shore-side measures such as cold-ironing. This is where ships, whilst docked in port, shut off their propulsion engines and use auxiliary engines to power lights, pumps, on-board refrigeration, and other equipment. An alternative, less polluting, measure to reduce emissions from the ships whilst docked is to connect to shore-side electricity generated from renewable sources. It is often possible to reduce energy consumption on board ships by using equipment more efficiently and using optimal settings for heating ventilation and air conditioning. The IMO states that up to a 2 per cent reduction in fuel consumption could be made from such shore-side measures and so this value is assumed for the MI scenario.

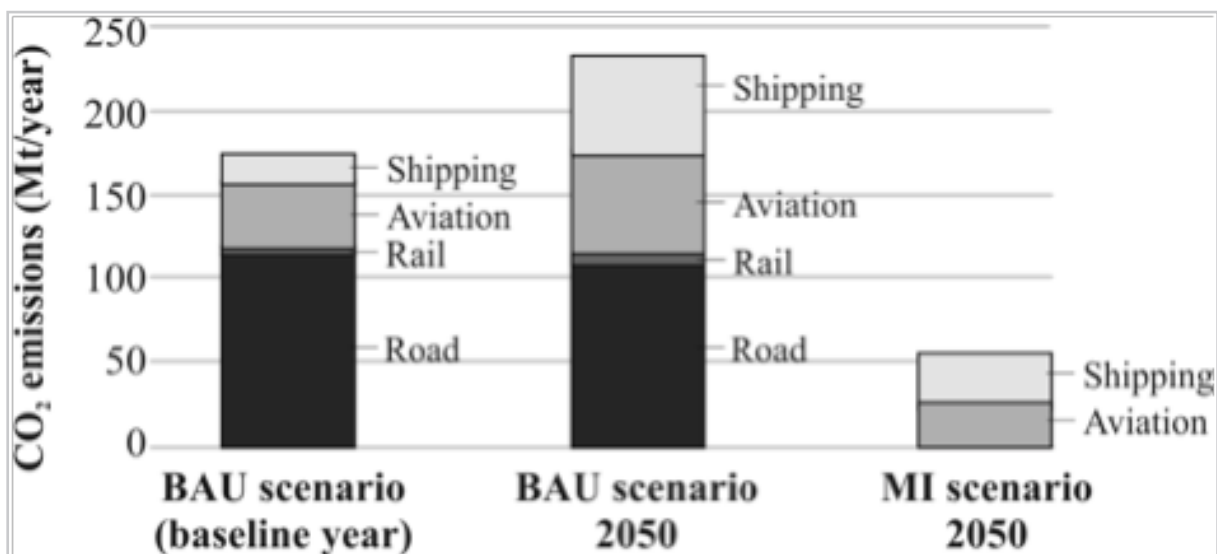
### 3. Results and Discussion

Table 1 presents the reductions in CO<sub>2</sub> emissions in 2050, compared to the BAU scenario, for all four modes of transport for the MI scenario using different spatial, fiscal and behavioural measures. A summary of the CO<sub>2</sub> emissions under each scenario is also depicted in Figure 2.

In the MI Scenario, road, rail passenger and rail freight transport CO<sub>2</sub> emissions

are reduced to zero by 2050 as a result of being powered by a fully decarbonised electricity supply. For road transport, technical measures include a whole-scale shift in technology to PEV and hydrogen fuel cell vehicles which will reduce emissions by 100 per cent. In contrast, the three non-technical packages of measures (spatial planning, fiscal and behavioural) combined would only reduce emissions by 75 per cent.

For road transport, it might appear that the technical measures alone would be sufficient to achieve zero carbon emissions. However, the success of the technical approach will also depend on the implementation of spatial planning, fiscal and behavioural measures in order to radically reduce the demand for using energy-inefficient private vehicles. This is because, in the absence of unabated private vehicle use by 2050, the whole-scale adoption of PEVs would be extremely challenging for the electricity power sector already coping with the adoption of carbon-neutral generation methods. Thus, it is more likely that simultaneous implementation of all four categories of measure would be required in order to achieve the ultimate aim of zero carbon emissions from road transport. Additional policy interventions would also be required to produce the decarbonised UK electricity power supply required in the MI Scenario for delivering zero carbon emissions for the road and rail transport sectors.



**Figure 2. Summary of UK transport CO<sub>2</sub> emissions for the baseline year (2003-2006/7 depending on sector), and in 2050 for the Business-as-usual (BAU) and the Maximum Impact (MI) scenarios.**

	Baseline year emissions (Mt CO <sub>2</sub> )	Scenario emissions (Mt CO <sub>2</sub> ) in 2050	Reduction in CO <sub>2</sub> emissions (Mt CO <sub>2</sub> ) relative to 2050 BAU	Percentage change in CO <sub>2</sub> emissions relative to 2050 BAU
<b>Road Transport</b>				
Baseline year (2003)	116.2			
BAU total		110.2		
MI measures:				
<i>Spatial planning</i>		83.0	27.2	-25%
<i>Fiscal</i>		44.3	65.9	-60%
<i>Behavioural</i>		91.1	19.1	-17%
Spatial planning, Fiscal and Behavioural measures combined		28.0	82.2	-75%
<i>Technical</i>		0.0	110.2	-100%
All four MI measures combined		0.0	110.2	100%
<b>Rail Transport</b>				
Baseline year (2006/7)	3.4			
BAU total		4.6		
MI Measures:				
<i>Electrification</i>		0	4.6	-100%
<b>Aviation (Domestic &amp; international)</b>				
Baseline year (2005)	37.5			
BAU total		59.9		
MI measures:				
<i>Constrained demand</i>		54.0	5.9	-10%
<i>Aircraft technology</i>		51.8	8.1	-14%
<i>Air traffic management</i>		52.1	7.8	-13%
<i>Fiscal measures</i>		43.5	16.4	-27%
<i>Railway substitution</i>		55.0	4.9	-8.2%
<i>Video substitution</i>		58.2	1.7	-2.8%
All six MI measures combined		26.3	33.6	-56%
<b>Shipping (Domestic &amp; international)</b>				
Baseline year (2005)	18.9			
BAU total		59.9		
MI measures:				
<i>New technology</i>		41.9	18.0	-30%
<i>Speed/voyage optimisation</i>		46.1	13.8	-23%
<i>Cleaner fuels</i>		57.5	2.2	-4%
<i>Shore-side measures</i>		58.7	1.2	-2%
All four MI measures combined		30.4	29.5	-49%

**Table 1. Reductions in transport CO<sub>2</sub> emissions in 2050 for the Maximum Impact (MI) Scenario compared with the Business-as-usual (BAU) Scenario**

Aviation emissions under the MI scenario are only reduced by 56 per cent when compared with the 2050 BAU emissions. Fiscal measures achieve a 27 per cent reduction in emissions while improvements in aircraft technology and management reduce emissions by 13-14 per cent.

Shipping emissions are only reduced by 49 per cent under the MI Scenario compared with the 2050 BAU emissions. New technology alone achieves emission reductions of 30 per cent while speed/voyage optimisation by itself achieves a 23 per cent re-

duction in emissions. However, emissions in the MI Scenario are still almost 60 per cent higher than those in the baseline year of 2005. This is due to the overall growth in shipping expected during the next forty years.

Although road and rail transport could both achieve the zero CO<sub>2</sub> emission target by 2050, emissions from aviation and shipping are more problematic with only a 49 per cent reduction achieved for shipping and a 56 per cent reduction for aviation compared with the 2050 BAU emissions.

Thus, under the 2050 MI Scenario, the net result for the UK transport sector as a whole is a 76 per cent reduction in CO<sub>2</sub> emissions (compared with the 2050 BAU scenario); well short of the zero carbon vision. To improve the CO<sub>2</sub> emissions reduction for UK transport as a whole, including those parts of international aviation and shipping for which the UK is responsible, would require much more radical interventions or technological innovations for these two sectors than envisaged here.

#### 4. Conclusion

Transport is an important source of CO<sub>2</sub> emissions in the UK showing relatively high growth rates that are inconsistent with the need to reduce UK's CO<sub>2</sub> emissions by 80 per cent by 2050. As an aid to the policy-making process, visioning and backcasting can together provide a useful means of characterising a preferred future and then exploring the impact of implementing a range of measures that might deliver that future. This process is a departure from traditional transport planning which has tended to focus on forecasting and modelling what might happen and then seeking to meet forecasts of increased demand for mobility with additional infrastructure e.g. airport terminals, lane widening on motorways, bypasses and high-speed rail.

In this paper, the vision and backcasting analysis shows that the potential to reduce transport CO<sub>2</sub> emissions is much larger than has hitherto been recognised. A largely decarbonised transport system can still deliver the transport needs of passengers and freight. It also shows that decarbonisation is highly dependent on the integrated and synergistic effects of adopting behavioural, spatial, fiscal and technological interventions simultaneously to support the changes to the transport system.

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## How Accessible Are The Public Transport Networks Of Berlin And London?

Christopher Paul Cook

Good public transport provision, which provides a convenient alternative to the private car aims to reduce traffic levels on the road and in turn carbon emissions, which both contribute to making the urban street a friendlier, quieter and safer environment for people to enjoy, whilst simultaneously striving to improve air quality and reduce climate change. Safe, clean streets should be an integral part of any residential urban space. It fosters better health, by encouraging people to walk or cycle more; sometimes just to their nearest public transport stopping point, but other times completing whole trips by these non-motorised modes and thereby substituting journeys, which were previously made by car. It also improves people's physical and emotional wellbeing, by allowing them the freedom to get out the house and exercise and to interact more with their neighbours and other members of society. "Local walking trips are the most environmentally sensitive, socially inclusive and economically efficient ways to ensure good access"<sup>1</sup>.

Whitelegg (2013)<sup>2</sup> highlights succinctly the fundamental roles, which an accessible, urban street should possess, to facilitate interaction between residents and passers-by and to encourage greater use of walking and cycling within a safe environment. He neatly encapsulates the major failings of current transport policy to nurture such urban spaces and concludes rather scathingly that too much emphasis is still being placed on the street as wholly the domain of the car. Efforts are focussed more on reducing congestion and accelerating overall journey time, which in turn is inhibiting pedestrians and cyclists from venturing out; perceiving the environment to be inherently dangerous.

*"Very clearly the street is a crucially important determinant of behaviour, sociability and interaction and hence has a direct impact on the amount of walking and cycling and use of that street. In turn this has a direct effect on the quality of life of children, the elderly, the mobility challenged and those with caring responsibilities for*

*the young or the old. (...) It is a remarkable legacy of 20th century and (so far) 21st century public policy that something so important and so central to so many quality of life and community attributes has been left to wither on the vine."*<sup>3</sup>

Much more still needs to be done, if most major European cities are to fulfil these fundamental, but yet basic social objectives. This article aims to explore some of the many challenges facing both UK and German governments in trying to meet the increasing levels of expectation placed upon them by those in society, who have a complex series of additional needs to be addressed, in order for them to have comparable levels of freedom and mobility to those able-bodied members of society. Anti-discrimination laws exist in both the UK and Germany and place a legal requirement on transport operators, to continue improving levels of access to their respective networks, but there's a distinct lack of tangible governmental transport policies, which aim to address the specific needs of people with a multitude of physical and sensory impairments.

It has also been cogently argued, that current UK government policies aimed at improving accessibility are failing in their fundamental objectives.

*"Transport related social exclusion is still widespread. Despite improving accessibility being the policy rationale for investing in transport, the current public funding of £20bn+ for transport each year may still be making more impact on growing travel demand than improving accessibility; perhaps also creating more exclusion than it solves; and compounding land use changes which continue to make some essential services less accessible."*<sup>4</sup>

The term "Accessibility" encompasses so many variables and can be defined in numerous different ways. It is thus often difficult to quantify exactly how many people have additional access requirements with regards to public transport, due to the highly complex nature of the term accessibility. The PTaccess Report compiled in 2009<sup>5</sup> estimated the numbers of regis-

tered disabled people in the 25 European countries featured in its extensive reports. The figure for disabled people quoted for Great Britain was 17% out of a population of 60.7 million which equals 10.32 million and the equivalent figure quoted for Germany was 8.25% out of a population of 82.3 million which equals 6.79 million; i.e. Germany has a larger population, but with a smaller number of disabled people. This was most likely caused by different definitions of disability used in Germany and Great Britain, further illustrating the complex nature of establishing a common definition used throughout Europe, which would in turn make comparing datasets much more straightforward and meaningful. The disabilities included in the PTaccess survey were defined as: motor impairment, visual impairment, hearing impairment, cognitive/ learning impairment and functional illiteracy<sup>6</sup>.

It is not just people with physical or sensory impairments, who have additional access needs when using public transport services. Many people have so-called unseen disabilities, which present them with additional challenges when undertaking independent mobility on a regular basis. The average age of the population as a whole is increasing and will continue to do so over the coming decades. Age and a degree of mobility impairment have a direct correlation with each other; i.e. people over 65 years of age make fewer trips on average and of a shorter duration, both in terms of time taken and distance travelled than younger members of society. Their hearing and sight often begin to deteriorate too, which have major safety implications when having to cross busy roads safely.

*"Individuals aged 50 and over represent approximately 20 million people (33%). (...)By 2031 over 50s are expected to represent approximately 40% of the UK population (27.2 million). (...) "More pedestrians over 70 are killed on the roads than any other age group. Given that the proportion of the population aged 75+ is projected to increase from 7% to over 13% by 2018 to over 700,000 people...this has major implications on how we design and manage our streets"*<sup>7</sup>.

Whilst the above figures only refer to the UK, the broader picture within Europe and worldwide is fairly similar confirming that the aging society phenomenon is a global trend. Today almost 1 in 10 people in the world are over 60 years old and by 2050 the figure will be higher than 1 in 5, increasing from 673 million in 2005 to 2 billion. 64% of older people currently live in less developed regions and by 2050 this figure will rise to 80%. The number of people over 80 is growing at 4% per annum; as opposed to the population as a whole, which is growing at 1% per annum. 3.5 million people will be over 100 years old by 2050 and over half will live in Asia<sup>8</sup>.

It is necessary now to examine some of the various measures being implemented by transport operators, in order to facilitate access to their networks for all disabled travellers. The relative merits and shortcomings of such measures will be discussed, as well as outlining the difficulties of accurately and effectively evaluating their success in enhancing levels of access to the system. A brief overview of the main legislation and directives currently in law and their key objectives will be provided and mention will also be made as to where further research is required to help refine such evaluation methods. The cities of Berlin and London will serve as case studies, in order to compare and contrast the different definitions of accessibility in use, the policies implemented and approaches adopted in both the UK and Germany.

One of the main reasons for greatly improving access to public transport, as well as the challenges involved in achieving these goals is neatly stated by Whitelegg (1993)<sup>9</sup>. He outlines the enormity of the task, which still lies ahead to achieve this fundamental aim.

*"In many developed countries it is still normal to find buses with steps, railway stations with many changes of level and underground systems that are unfriendly particularly to the elderly and disabled. A sustainable transport system has to be equitable and accessible to all groups, if it is to play a full role in minimising the demand for motorised transport."*<sup>10</sup>.

The specific definition of accessibility with regards to disability used throughout this article is derived from a Transport for London (from now on TfL) accessibility document<sup>11</sup>.

*"When we use the word accessibility, we're referring to the ease with which people can use the Tube safely and independently, regardless of disability, age or encumbrance. (...) The Social Model of Disability, which accepts that: Disability is a social phenomenon. It is created by society's response to a person's impairments or learning difficulties. Discrimination against disabled people is just as oppressive as discrimination on the grounds of ethnicity, gender or sexual orientation."*<sup>12</sup>

The Social Accessibility Mapping Project (SAMP)<sup>13</sup> conducted by the Transport Studies Group at the university of Westminster described very succinctly how accessibility is a relatively new phenomenon in the transport industry.

*"Although 'accessibility' is a well-established concept in the disciplines of geography and urban economics, it is a fairly new concept for many transport practitioners."*<sup>14</sup>

Accessibility goes beyond physical access to the stops and vehicles and destinations served from a particular access point and extends into areas such as social exclusion. Seven different types of transport exclusion are cited in SAMP, which prevent people from getting out and about as easily as others. Two of the main ones are "Spatial": the location where people live with relation to the location of where they need to go, which might include longer walking distances to their nearest bus stop/railway station or the lack of through journey opportunities and the need to change en route; and "Financial": where the costs of making a journey are disproportionately high compared with their income. A typical indicator of social exclusion is low income<sup>15</sup>. This is a particular problem for many disabled people, due partly to their greater reliance on expensive modes of transport such as taxis and to the fact that they are more likely to be unemployed and thereby on a low income<sup>16</sup>.

*"In other words, accessibility problems are not just caused by poor transport planning and co-ordination of services, but are also related to the location and delivery of key activities and the ways that people reach them."*<sup>17</sup>

Geurs van Wee<sup>18</sup> cited four separate components of accessibility, which represent important practical measures of levels of accessibility to public transport and are similar in nature to the seven elements of transport exclusion highlighted in SAMP. They include the spatial distribution of jobs, shops and other facilities and the demand for these services at origin locations i.e. where people live and their ease of access to local services. The time required to make journeys on public transport including walking time to the stop, waiting time and in vehicle time, as opposed to how much time each individual has to make the journey to their chosen destination.

One of the major problems appears to be translating complex accessibility indicators and measures into tangible and easily comprehensible outputs for transport planners and policy makers to respond to and duly act upon. Geurs van Wee concluded that there is currently no easy transaction between theory and practice.

*"[...] There is no guaranteed or easy transition from accessibility research to the formulation of public policy and its implementation; public policy on accessibility will only be forthcoming if accessibility is a well-politicised issue."*<sup>19</sup>

This view was also shared by Handy and Niemeier<sup>20</sup> who concluded that

*"No one best approach to measuring accessibility exists; different situations and purposes demand different approaches. (...) As the complexity of such measures increases, however, the cost of calculation and the difficulty of interpretation increases as well."*<sup>21</sup>

The Equality Act (2010)<sup>22</sup> requires organisations including public transport operators in the UK, to make "reasonable adjustment", to ensure that their services are accessible to all. This applies to the

way vehicles are operated, e.g. staff helping mobility impaired passengers to board and alight from the vehicles safely, as well as on vehicle staff notifying visually impaired passengers when they have reached their chosen destination. Adequate and appropriate staff training is not however stipulated explicitly, but is implicit for the operator to be able to comply with these duties.

The equivalent German anti-discrimination legislation "Allgemeines Gleichbehandlungsgesetz" was introduced in 2006<sup>23</sup>. The law operates mainly at a federal state level in Germany, but there are also regional regulations which include general guidelines for the level of accessibility. Both the UK and German legislation unfortunately stop well short of defining a clear and robust set of measures for transport operators to implement and which can be easily reviewed and evaluated.

There is a major legal requirement under the United Nations Convention on the Rights of Persons with Disabilities (UNCRPD)<sup>24</sup> to which both the European Union and the UK are signatories, which necessitates the provision of training to be delivered in relation to passengers with disabilities and older travellers. Access to transport and personal mobility are among the fundamental principles set out in the Convention, which states explicitly that limited resources are not an excuse for failure to implement it.

One major and very noticeable difference between the transport networks of Berlin and London is the far greater number of staff at stations in London, who are on hand to offer assistance to the travelling public. All staff must receive some disability awareness training, but it would be true to say that standards do vary considerably between different train operating companies (TOCs) and the attitude of individual members of staff. The staff on the London Underground are often some of the best trained and most able to offer appropriate assistance to those who require it and without the need for prior booking, although their numbers have been considerably cut in recent times and they are due to be reduced further with the closure of all Underground ticket offices by the end

of 2015.

Training is essential, to give staff the skills and confidence they need, to be able to meet the many and various demands placed upon them by disabled passengers on the network. With an increasing number of elderly and disabled people wanting to get out and about, appropriate training of staff becomes even more essential. In these austere economic times however, training is often viewed as an expensive, additional extra by operators and is therefore more likely to be curtailed or kept to a bare minimum. Savings can prove to be rather costly though, as training is not just concerned with good practice, but is a vital prerequisite for ensuring the health and safety of staff and passengers.

An increased staff presence often gives disabled travellers the added confidence and reassurance to travel and thereby both enhances their physical well being and quality of life, as they are able to travel whenever and wherever they so choose. A lack of confidence is the biggest single barrier to independent public transport use among disabled and older people. With this in mind, some transport operators in both Berlin and London run taster days, where people with additional access needs can try out the vehicles away from the usual hustle and bustle of fellow passengers. These can take one of two forms; in Berlin, they typically involve a bus, tram or in some cases an underground train being parked up, where people can practice getting on and off them and familiarise themselves with the general layouts of the vehicles including positioning of seating, designated wheelchair spaces and grab rails, as well as lighting, customer information screens and communication points with the onboard staff. Representatives from the transport operators and from relevant local disabled organisations are also on hand to give further advice and support. During the safety days held in the Berlin underground (U-Bahn), as well as practicing boarding and alighting from the vehicles etc. additional safety features and equipment e.g. the emergency help buttons on the platforms are demonstrated, and people are also shown the safe places underneath the platforms, into which they can crawl and await help, if they've been

unfortunate enough to have fallen on the track.

In London, some train operating companies run so-called "try the train" days for disabled people. These usually involve making a short trip by train together with a visit to a local attraction and refreshments. The main aim of such days is to allay people's fears and build their confidence in independent travel and they are usually successful in fulfilling these aims.

Whilst staff presence on the network and assistance with travelling are undoubtedly beneficial in many ways for enhancing people's perceptions of access, independence, safety and security, an overreliance on this assistance always being available brings its own set of difficulties. An accessible transport network is usually considered to be one, which allows people with a wide range of sensory and physical impairments to use it freely and totally independently irrespective of relative staffing levels. Trained staff should certainly not be perceived as a panacea for all ills.

Two scenarios often occur, which are the subject of much debate amongst disabled travellers. Many people do not want to be restricted by having to request assistance for a journey a minimum of 24 hours in advance, and feel that the staff should be capable and flexible enough to respond to their needs on arrival at the station, as usually happens on the London Underground. The necessity to book in advance removes the spontaneity of last minute travel plans and is often perceived as being too restrictive and prescriptive. It is often the more experienced travellers who adopt this attitude, as they have sufficient experience and self-confidence to draw on, to seek alternative solutions, if staff assistance is not available for whatever reason. Lucas et al.<sup>25</sup> reported that some disabled passengers even refuse to give the stipulated 24 hours notice to use the trains, as they consider it illegal and immoral.

The opposite scenario can also occur and is equally as problematic. Travel assistance is duly booked in advance, but then is not provided at the time of travel for various reasons. This failure of the service is often a cause of intense dissatisfaction amongst

disabled travellers, who feel that they receive a substandard service compared with other customers and that transport providers should have the capacity to be flexible enough to deal with these situations when they arise, often citing the London Underground once again as providing an exemplary paradigm of this kind of "On Demand" service.

When people do go through the correct channels to book assistance for their train journey and the service has failed to be delivered, because their trains have been late or have been rerouted and they have arrived at a different destination and this information is not relayed to the relevant staff, they often become highly sceptical about booking in advance in case the same problems reoccur. They adopt the attitude of "Why Bother?" with regard to giving prior notice of their journey plans, if there's not going to be anyone to meet them anyway.

Whilst difficulties are bound to crop up from time to time caused by factors outside station staff's control, shortcomings in the service provided, which are directly attributable to failures in communication or insufficient staff being available should be avoided if at all possible. It only takes one poor experience during a journey, to knock the confidence severely of a relatively uninitiated traveller, to make them extremely hesitant about attempting the same or a similar journey on their own again in the future. These anxieties can escalate and can duly have a detrimental impact on the quality of life of the individual affected, as the boundaries of their mobility are shrunk.

*"The concept of a seamless intra and/or inter modal journey from door to door is very important for all people, but especially for disabled people, as they are less flexible and unable to find alternative solutions in case of a broken transport chain."*<sup>26</sup>

It is crucial for the transport operators to ensure that their investment in training is yielding tangible benefits and representing good value for money. One of the simplest and yet most effective ways of doing this is by asking disabled customers for con-

structive feedback after their journey on the network. For example: if the customer has pre-booked assistance, then contacting them by phone/email a few days later enables the transport operator to obtain useful information as to how smoothly (or not) everything went and what (if anything) could have gone better. The use of local disabled people as mystery shoppers can also provide the operators with useful feedback, as to how well things run when assistance has not been requested prior to travel. This is always the acid test of the system i.e. how well it can cope either during times of major disruption or how flexible it can be when responding to the demands of passengers, whose travel plans may have suddenly changed or who have not been able to request assistance in advance.

It is true to say that much of the Berlin suburban network including Underground (U-Bahn) and rapid transit railway (S-Bahn) are largely unstaffed; those they do have, are either located in travel centres/ticket offices or are performing dispatch duties on the platforms and are not able to offer the same levels of assistance as that provided by staff in London. A clear advantage though of this modus operandi is that the few physical staff on duty are located in fixed places and can therefore usually be located easily should the need arise. There are also help and information points located at the same place on every U-Bahn and S-Bahn platform.

Although this is not nearly as desirable as having a physical member of staff at the station to offer direct assistance, you are immediately connected to someone at the press of a button from the information points. They can offer all manner of support and advice on journey planning and can advise during times of unforeseen or planned service disruption. The information points are also fitted with cameras, so that the whole platform can be viewed if the person calling for assistance feels intimidated in any way by the behaviour of others in the near vicinity. If deemed appropriate by the staff at the help centre, a mobile station team can be quickly dispatched to the respective station, to deal with more urgent incidents firsthand. On one occasion this involved coming to the

aid of a visually impaired person, whose white cane had become trapped in train doors and had duly snapped. They then required a sighted person, to guide them safely back to their front door.

A further solution to the lack of visible staff on the Berlin transport networks was introduced by the umbrella transport body Verkehrsverbund Berlin-Brandenburg (VBB) in October 2008. This takes the form of a personal one-to-one escort service coordinated by VBB, which is funded currently by the Berlin S-Bahn compensation payments to the Senate and state of Berlin after several years of substandard performance. Requests for assistance have to be booked a minimum of 24 hours in advance either by phone or online, giving precise details of the journey planned, as well as the exact nature of the disability of the person wishing to travel.

The volunteer helpers are of all ages and social backgrounds, and have either recently become unemployed or have been out of work for a longer period of time. There are no restrictions on who is eligible to use the scheme, other than they must have some form of disability. This appears to be an extremely useful service to help overcome any barriers to mobility encountered by both Berliners and visitors to the city, especially as the escort service also covers all the airports in Berlin including the new and still as yet unopened Berlin Brandenburg International (BBI) airport. At its height, the scheme was staffed by 120 volunteers, but unfortunately this had to be reduced back down to the original number of 60 in 2011 due to funding constraints. The opening hours of the service were also reduced, so that it now only operates from 07.00 up until 20.00 Monday-Friday; journeys outside these regular opening hours and at weekends are possible, but only by prior booking.

There is also a "Meet and Assist" scheme operated by German National Railways "Deutsche Bahn" (DB), which operates in a similar way to the British one described in detail above. The PTaccess study states however that many German staff feel unable to deal with disabled travellers whenever the need arises and it is possible, that some of this may be attributable to inade-



quate staff awareness training. "(...) there is still a fear of contact between the people working at public transport operators and people with impairments. However, there is a clear improvement - particularly with younger people who seem to have fewer problems and are more motivated to help. But there is also a stronger self-confidence of people with impairments, which also helps for a better communication."<sup>27</sup>

So far only issues surrounding levels of staffing and assistance provided to disabled passengers in both Berlin and London have been discussed, but there are significant differences in the ease of carrying out such basic tasks as purchasing a ticket and travelling legitimately. It is a valid point that most disabled residents in London are in possession of a "Freedom Pass" entitling them to concessionary travel within the capital, whilst disabled Berliners usually have a "Schwerbehinderterausweis" (Severe Disablement Pass), which enables them to use all modes of public transport within any German town or city.

Any disabled UK residents or tourists arriving in London if not already in possession of a ticket or Oyster smart card can easily make their purchases from one of the staffed ticket offices at railway stations and at most underground stations, or can seek staff assistance to use one of the many vending machines. Once bought, the ticket is immediately valid for travel. The same is however not true for foreign visitors to Berlin.

Disabled visitors to Berlin are required to purchase tickets just like any other travellers. These are available from automated machines at bus and tram stops, on S-Bahn or U-Bahn station platforms, or from fully staffed ticket offices at larger stations and from all BVG bus drivers. A new generation of ticket machines has been introduced at every S-Bahn station and these include such accessibility features as Braille markings on some of the keys, a bigger, brighter, backlit screen with adjustable colour contrast and font size for people who are partially sighted and induction loops for the hearing impaired, which can be used when communicating with someone in the help centre at the press of a button. They also have multi-

lingual functionality and are reported to have synthetic speech output as well, to assist the totally blind in using them.

On closer examination of at least three separate examples of these new vending machines during a research visit to Berlin in October 2010, none of them appeared to have any form of audible output; subsequent visits in the two following years have yielded similar results. Ideally this function should be switched on by default, as otherwise it would be very difficult for a blind person to be able to select the appropriate option to activate speech before then being able to use the machine. Even when the chosen ticket has been purchased, it still needs to be correctly stamped in another machine to be valid for travel; failure to validate it correctly may well result in a fine being received for unauthorised travel. Even if you purchase a ticket from a staffed ticket window, they are unable to stamp it for you there and so you are still often reliant on trusting total strangers to do this for you at one of the "Entwerter" machines on the platform. This modus operandi has two additional risks; firstly the stranger assisting you could steal the ticket from you or may inadvertently incorrectly stamp the ticket thus invalidating it. Both these scenarios would result in the disabled traveller losing their money. The only way which you can currently guarantee that your ticket is correctly validated is to purchase it from the driver of a BVG bus. Their ticket machines automatically stamp and validate the ticket before it's issued.

The above difficulties highlighted mainly affect people with a visual impairment, but there may be other groups of disabled travellers also disadvantaged by the current practices adopted in Berlin. The situation is all the more frustrating when potential solutions such as having ticket validators in staffed travel centres or at ticket windows, or having ticket machines which automatically validate the ticket before issuing it such as on BVG buses would be relatively low cost in the grand scheme of things. This would then alleviate totally the need to trust and rely upon complete strangers to do this for you. BVG propose introducing an online web shop, where tickets can be purchased in advance and

sent to you prior to your arrival in Berlin. They have also announced the gradual replacement of all their ticket machines with a new more accessible generation similar to those recently introduced on the S-Bahn network, but neither of these measures really tackle the precise problem of being able to correctly stamp your ticket once purchased. After suggesting the possible solutions to the key employees responsible for disabled and elderly travellers at BVG and the Berlin S-Bahn, they both replied that these problems affect a very low number of people per annum and also that few visually impaired tourists usually travel without a sighted companion. They did agree to look into the issues, but stressed that any changes would have to be ratified by the overarching organisation Verkehrsverbund Berlin-Brandenburg (VBB) and as yet no changes have been implemented.

### **Measuring Accessibility**

A key theme which requires further research is the development of a set of measures, which give a precise indication of the overall accessibility of a city's transport system. There is good data on the proportion of the vehicles, which are compliant with the relevant accessibility legislation, but it could be argued that an accessible, low floor vehicle is only as accessible as the infrastructure on which it runs and the staff onboard it. Good quality data on the state of the infrastructure and the training of staff and their individual attitudes is much less available and is also difficult to transpose onto the aforementioned data on the vehicles themselves. These sorts of measures do not shed any light on the impact on people's actual mobility. A reliable measure of outcomes needs to be established, in order to ascertain fully whether the accessibility legislation is really working; e.g. how many more people can travel now as a result of the changes brought about by legislation.

Berlin and London have vastly different histories, which have duly affected the shape and structure of their transport networks. The current population of London (7.75 million) is more than twice that of Berlin (3.44 million). There are also considerable differences in the two cities ur-

ban form, economic structure and public transport funding, transport policy and social attitudes. They all affect the market share of public transport and the travel patterns in each city and its suburbs and they highlight such factors as service frequency, the distribution of stops within a catchment area and the access/egress time from particular stops to places of employment or interest. They tell us very little however about the physical accessibility of the stops, and the ease of boarding and alighting from the vehicles for various groups of mobility impaired passengers. This includes not only people with a physical disability or sensory impairment, but also parents with children in prams/buggies or with large amounts of luggage or shopping trolleys etc.

In spite of its quintessential role as the start and finishing point of most journeys, together with the numerous, known difficulties which disabled people often report when walking on foot, the exact role of the pedestrian environment in all of this is rather a grey area. The Department for Transport (DfT)'s own guidance on recommended walking distances to bus stops/railway stations for different categories of disabled people states that the distances disabled people are typically able to walk are considerably less than the values usually adopted by urban planners. Failure to combine the features of the pedestrian environment with those of the public transport system, as current legislation appears to do, merely results in detracting from its overall degree of accessibility.

A summary of key figures concerning accessibility to the public transport networks of Berlin and London can be seen in Table 1 below.

The Public Transport Accessibility Level (PTAL) and Public Transport Accessibility Index (PTAI) are useful indicators, which take account of the most important issues when analysing access to public transport at the network level. The distance to the nearest stop or station is ideally not more than around 400 metres from the place of work or home. This represents around a 5 minute walk for most people, assuming an average walking speed of 80 metres per minute. Reliability and frequency of

Percentage of Bus Fleet with Low Floor Entry	Berlin 100%	London 100%
Percentage of Light Rail Fleet with Low Floor Entry	Berlin 40%	London (Including DLR) 100%
Number of Step Free Stations	Berlin S-Bahn 149/168 (89%)	Surface Rail (within Greater 103/333 (31%)
Number of Step Free Stations	Berlin U-Bahn 100/173 (58%)	London Underground 65/270 (24%)

**Table 1: Vehicle And Station Accessibility In Berlin And London**

Sources:

Figures for Berlin S-Bahn obtained from: <http://www.s-bahn-berlin.de>

Figures for Berlin U-Bahn/Tram/Bus obtained from <http://www.bvg.de/barrierefrei>

Figures for all London modes taken from TfL(2011A).

service have a major bearing on how attractive the public transport mode is for its customers to use, and whether the routes which serve their nearest stop or station offer them direct connections to places of importance or interest.

Berlin has a similar measure of accessibility with regard to the number of people who live within a certain distance of their nearest public transport stop. There are two main bands for accessibility. The first is that 80% of the population live within 300 metres of their nearest public transport stop or station, and the second is that 96% of the population live no more than 400 metres from their nearest public transport service<sup>28</sup>.

Investment in new low floor vehicles and rolling stock is essential, to enhance levels of accessibility to the transport network, by making it much easier for people with physical impairments to board and alight from the vehicles independently and safely. BVG placed a large order for a new generation of low floor Bombardier 'Flexity Berlin' trams in spring 2008. Deliveries commenced in summer 2011 and the last Tatra cars are destined to be replaced by 2017, at which time Berlin will have a 100% low floor light rail fleet bringing it into line with that of London Tramlink, which has been wholly low floor since its inception in the year 2000.

Berlin has had a 100% low floor bus fleet

since 2008, only three years after London achieved this goal. All of the new vehicles have a ramp for the mobility impaired, which can be lowered at any bus stop. The ramps used to be deployed at every stop en route, but in the autumn of 2011, BVG announced that they wished to phase out this practice, as it was allegedly causing the ramps to fail more regularly and was having a negative effect on overall dwell times. In future passengers will need to request the use of the ramp from the driver by pressing a button on the vehicle or by talking to him directly if waiting at a stop, which is broadly comparable to the practice currently adopted on buses in London. Concern has been expressed by a campaign group of wheelchair users in Berlin, that many bus drivers may be inclined to state falsely that the ramp on their vehicle is defective, to avoid having to deploy it to facilitate the mobility impaired passenger to board the vehicle. It is as yet too early to deduce whether their fears are in any way founded.

The SAMP project concluded that equipment such as wheelchair ramps on buses in London was quite often not working, or the bus driver refused to operate it, especially if he was running late or if the bus was particularly busy. This issue was often further compounded by there being no clear guidance as to how many people with buggies/shopping trolleys/wheelchairs were able to fit on the bus. Some drivers would allow three buggies on,

provided that one was folded up, whereas other drivers would only allow one on. These inconsistencies in customer service often left many people either waiting at the stop for the next bus or seeking alternative methods of making their journeys. It was strongly felt by many of the participants in the research that more thorough staff training in disability awareness and access issues, together with clearer guidelines for the carriage of buggies/wheelchairs, would all help to standardise the treatment and overall journey experience of these groups of passengers. It should be pointed out that there have doubtless been some significant improvements in all of these areas, e.g. in driver training in London since the study took place in 2005.

Similar heavy investment in new rail vehicles has taken place in Berlin and London in the past decade and both cities now contain fleets with a substantial number of low floor vehicles in them. Gough (2006)<sup>29</sup> documented the complex planning process for the restructuring and revitalisation of Berlin's railways and the building of the new Hauptbahnhof; the largest cruciform station in Europe. Hauptbahnhof had major accessibility features such as multiple spacious lifts between all levels and tactile strips along all platform edges incorporated into its design from the outset.

It can be concluded that different groups of mobility impaired passengers have different needs with regards to accessibility at stations and on the vehicles themselves. Wheelchair users need level access to the vehicles and a large, wide, clear space near the doors, to enable them to board and alight independently and without unnecessarily inconveniencing fellow able-bodied passengers. Visually impaired passengers on the other hand often find it useful to have grab rails located near to the doorways of vehicles, as it gives them something tangible to hold onto and orientate themselves with when finding a seat. These are just two of several, separate examples of accessibility issues, which have to be addressed when trying to provide a network which is truly accessible to all its potential customers.

The PT access project stated that one of the major issues it faced with undertak-

ing such an EU-wide study was obtaining comparable, statistical data on disability as has been mentioned above, because there are so many definitions of the term disability within the countries of the EU, and no one definition was universally applicable. There were also many discrepancies concerning people's perception of the safety aspect of public transport within the EU countries, some of which (although not Germany or Great Britain, focussed on here) considered public transport to be dangerous and would actively discourage disabled passengers from using it alone. One thing that was common across the sample of countries was that public transport stops and stations were generally much more accessible in urban areas, as opposed to suburban and rural areas. The report then went on to say that "In most countries accessibility issues are only taken into account, when stops and stations are newly constructed and when existing stops are refurbished. The results showed that the existing stops and stations are not sufficiently accessible for people with disabilities"<sup>30</sup>.

Cost Benefit Analysis (CBA) which has until now been the main tool used to evaluate the success of accessibility improvement schemes, fails to take any account of the "(...) gains in the objective and subjective quality of life for the affected people by an increased quality and quantity of accessible destinations being available."<sup>31</sup> This has particular relevance when analysing services such as dial-a-ride, which provides severely disabled people, who are otherwise unable to use scheduled public transport, with the opportunity to go out and integrate in society, even though the trip cost per capita of the service in London is extremely high (estimated to be around £20-£25 per journey). Other benefits arising from enhanced accessibility may also include increased independence, greater self esteem, alleviation of perceptions of loneliness and social isolation<sup>32</sup>. One of the main problems of using cost benefit analysis to evaluate such schemes is that it deals with changes in purely financial terms and thereby fails to take any account of welfare impacts and improvements to quality of life. These improvements may well be priceless in enriching the lives of many individuals, who often

experience difficulties in getting out and about.

One main reason is that measures to improve accessibility are often only undertaken in response to changes or strict enforcement of anti-discrimination or equal rights laws such as the Equality Act (2010) in the UK. This often means that public transport operators are awarded a pre-determined level of funding for meeting a core level of basic standards or targets in their transport provision. This might cover the purchase or lease of new vehicles or rolling stock, or for making stops/stations step free during a planned programme of refurbishment.

Another reason is that many of the projects to enhance accessibility are either pilot ones, or they make use of earmarked funds for that sole purpose. There is therefore no need to evaluate the relative merits of different measures to be implemented, because the level of funding is directly linked to the individual measure rather than to its perceived user benefits.

The third reason is that municipal authorities and transport operators understand the onus placed upon them to provide accessible and affordable public transport. They thus define their own standards based upon this obligation, many of which can prove to be rather ambitious. Once a course of action has been agreed, then no other potential solutions are considered, even if they may turn out to be more effective at delivering the desired end results, and represent better value for money than the original scheme.

The report attributes the second main course of evaluation deficits to the fact that the costs of the project cannot easily be assigned to one improvement measure for public transport access for disabled people. There are also many reasons for this, but they include the fact that the measures are financed by different sources of funding as parts of larger projects, and it is thus very difficult to separate off the costs for one particular measure, e.g. contracts for purchasing new vehicles are negotiated as a package, including the specification of onboard equipment and order quantity. Another example is the

repainting of train doors to improve their colour contrast and make them more easily identifiable for visually impaired people, which is usually completed as part of a general train refurbishment programme.

A further difficulty is that different parts of the infrastructure are owned by different people, e.g. the station platforms are owned by one company, for example Network Rail in Great Britain, and the shops on the concourse by another. Each of the individual stakeholders will have to contribute and collaborate to make the different parts of the station barrier free and it is very difficult to disaggregate the separate effects from each other afterwards.

There are other problems which may well hinder critical and meaningful evaluation of schemes. There is often a lengthy lead time between implementing improved accessibility measures at stations and their increased usage. There also has to be a sufficient number of stations made barrier free for people to use, so that they have a good number of potential destinations to choose from when planning their journey. Disabled people have to be made aware and kept up-to-date about increased accessibility on the network.

The impacts of the improvements are usually long term, and are once again difficult to attribute to one particular measure. Even if the improvements for disabled people are clearly tangible, such improvements often benefit many other groups of travellers such as parents with young children, and these additional benefits are far harder to quantify.

This lack of efficient evaluation of accessibility measures means that there is no clear way of establishing whether limited funds have been usefully allocated and have represented good value for money in achieving the intended aims of the transport operator.

*"Decisions in the transport sector are complex, and often expensive, and there are always different alternatives that make it necessary to weigh the costs and benefits. Assessment methods enable transparent decisions. Public institutions in particular often must*

*bring the proof of the efficient use of public money. Evaluation additionally provides the opportunity for benchmarking, to share experiences gained and to increase the knowledge base for future projects.*"<sup>33</sup>

The evaluation of measures aimed at improving access to a public transport network would seem to be even more essential, as they are often extremely expensive e.g. the installation of lifts in underground stations is usually complex, time consuming and costly. The group of obvious users and beneficiaries of such schemes is often small, representing at most 40% of the population depending on how the statistics are calculated. It must not be overlooked though, that many other groups of users also profit from such improvements at stations, including parents with young children in pushchairs and passengers with heavy luggage. It may also attract new people to start using public transport, thereby switching from making their journeys by private car or taxi. This will benefit the transport operator by giving them an increase in their passenger numbers and subsequent revenue, and will also benefit the environment by reducing the number of cars on the road, as less special transport provision and/or taxis/minicabs will be used to complete journeys.

One of the most difficult challenges facing the transport operators in Berlin, London and many other cities worldwide is the fact that no one accessibility improvement measure suits everyone. There is always a need for a package of flexible measures, in order to benefit customers who have a diverse range of physical and sensory impairments. One size certainly does not fit all as far as accessibility improvements to the network are concerned. Advances in mobile phones and other portable electronic navigation devices have already made considerable inroads into giving disabled people independence and future technological advances will doubtless continue to further this aim.

Hi-tech solutions do not suit everyone however and there is still a constant need for transport operators to continue to develop and adapt their networks to cater for the diverse needs of a wide range

of people. This is often best done with a team of well trained staff deployed on the network, to offer direct assistance to passengers whenever it's required. TfL have recently announced the closure of all ticket offices on the London Underground by 2015 and has attempted to allay passenger concerns by stating that the closures will free up many former ticket office staff, who can duly be redeployed in the station to carry out various other duties e.g. helping customers purchase tickets and assisting disabled travellers directly to their trains. TfL's upbeat statement has as yet fail to neutralise the announcement of another round of redundancies, thereby cutting the overall number of staff at stations available to offer information and assistance to all passengers. This is rather concerning given previous swathes of station staff cuts and especially after all the glitz and glamour of the London 2012 Olympic and Paralympic Games had died down.

As has been demonstrated by examining the far lower staffing levels in Berlin, once TfL has closed all its ticket offices, then the remaining staff will need to be based in clearly visible, designated areas, where they can be easily found by any traveller in need. In other words; having a greater number of staff in numerical terms, merely wandering around the station concourse and platform areas rather than based in a ticket office, may in real terms represent a drop in staffing levels for disabled passengers; especially those with a visual impairment, who may find it much harder to seek and locate someone, should they require any assistance when travelling.

## **Conclusion**

Whilst it is often difficult to compare levels of access provision between different countries even within Europe, due to a variety of factors such as differences in definition, every effort has been made in this article to compare like with like.

*"The idea of comparing European cities on quality of life and built environment attributes is fraught with difficulty and is unlikely to pass a rigorous test of research design, data collection and inference. It is, nevertheless, an important part of the policy improve-*

*ment cycle and the absence of a serious policy-oriented discussion on such comparisons has undoubtedly contributed to the lack of learning, the lack of discussion of innovation and the existence of cities in the UK that show little sign of benchmarking, learning and innovation in key policy areas”<sup>34</sup>*

Neither Berlin, nor London featured in this case study has exemplary levels of all round accessibility to their public transport networks, but both wish to preserve what they already have and they would hope to strengthen provision in the future, depending on levels of funding available. A key area, which appears to be lacking from both UK and German urban planning is the uniformity of design of such things as tactile paving to designate traffic crossings, or along platform edges at railway stations. On the London Underground, almost all stations have now been so equipped and the tactile strips are not just useful for people with a visual impairment, to prevent them from inadvertently stepping off the platform edge, but they also serve as a useful reminder to other passengers, who are paying more attention to the screens of their mobile phones rather than looking where they are going.

Unfortunately similar platform edge tactile strips have only been installed at a handful of National Rail stations in Great Britain and Network Rail, who’s primarily responsible for such installations during station upgrade work has as yet failed to appreciate the significance of such relatively low cost measures in enhancing greatly the safety of disabled and able-bodied travellers alike.

Similar tactile strips known as “Blindenleitsystem” can be found at most U-Bahn (underground) stations in Berlin and at most S-Bahn (rapid transit) stations too, but due to the continual refinement of the type of markings used etc. the situation has thus arisen that some stations have an earlier version of the guidance system fitted, whilst others have a more modern version. Sometimes stations have different variants on different platforms. The later variants of the system are easier to distinguish using a long cane, as the metal bobbles or grills are more pronounced. It

will take some considerable time for all stations to be fitted with a standard design, but this is definitely a target for the Berlin transport providers to aim for in years to come. A future aspiration for all European cities would be to have a common design of tactile markings fitted along all platform edges and at pedestrian crossings, so that the strips would be easily recognisable by citizens, visitors and tourists alike, regardless of where they come from.

Another area where greater standardisation is required is in the quality and availability of on platform and on vehicle announcements. Most modes of public transport in Berlin and London now have good audible and visual information displays within the vehicles themselves, but such basic, useful information is still lacking from many underground stations and bus stops. This means that you’re still reliant on asking fellow passengers where the next train/bus is heading for or in the latter case, which number is due next.

Smart phone aps and other hi-tech solutions are slowly levelling this playing field for the visually impaired, but as previously stated, the hi-tech approach, whilst often cited by transport operators as the main way forward, doesn’t suit everyone. Some elderly travellers often have a distinct fear of modern-day technology. An overreliance on such systems is also flawed, if for any reason the network suddenly fails or in the case of the London Underground, where there is little or no signal coverage in the stations or on the trains, both of which render any such way finding software completely redundant.

There is a stark need to expand such access provisions out into networks serving smaller cities and more rural areas. Whilst most buses in Germany have audible and visual announcements, which are either automated or made by the driver, this is certainly not the case in even larger towns in the UK. There are some small pockets of good practice emerging in the UK, but the number of new buses being fitted with such audio-visual equipment is pitifully low. Attempts are ongoing by leading UK disability charities e.g. The Guide Dogs for the Blind Association, to lobby the government to change current legislation, which

would then compel operators to fit all new vehicles with such equipment. The government response has up until now been lukewarm at best, but regrettably mostly unreceptive to what constitutes a basic change in the law and at relatively low cost to the transport operators themselves.

Buses usually represent the main mode of public transport for many disabled people, to be able to leave their homes and travel. The fact that many of them don't provide passengers with visual or aural impairments with the most basic route information is quite shameful. This is a similar scenario to the tactile strips outlined above; i.e. good quality audible/visual announcements onboard all buses in the UK and Germany would not only benefit those with sensory impairments and who are otherwise familiar with the area, but also visitors to the area and tourists to the country. In other words, any accessibility improvements would be basic in nature and would benefit far more than the niche groups of people they purport to serve.

It would be highly advantageous to involve disabled people at the planning and design stage of our future 21st century urban environments and public transport systems, so that their individual needs can be considered and duly integrated into designs from the outset. This would help ensure their quality and reduce the need for expensive retrofitting of station platforms or vehicles in the two particular examples cited above. There is often a reluctance by operators to make such automated equipment like ticket machines fully accessible, as most local disabled people have a concessionary pass, but as previously mentioned, visitors to a city such as Berlin don't have this luxury, but still require a ticket to travel legitimately on the network.

As has been previously discussed, many solutions to current problems would not cost much in financial terms, but would make a tremendous difference in enabling disabled passengers to use the public transport networks of Berlin and London far more independently than has previously been possible. An exemplary paradigm of this would be the positioning of "Entwerter" (stamping machines) at staffed

ticket offices in Berlin, which would then allow staff selling you a ticket to validate it immediately and remove your reliance on a total stranger to do this for you. TfL are desperately attempting to soften the blow of closing all London Underground ticket offices by 2015 with the reassurance, that many former ticket office staff will be visible in stations, to assist passengers with purchasing tickets from machines and to escort disabled passengers to their trains, but staff randomly circulating in a station is not nearly as effective as having them strategically stationed at designated points in the concourse.

An ideal scenario of fully accessible public transport in Berlin and London would offer users a seamless journey experience and could operate along the following lines. All public transport rail and road vehicles are low floor and draw up at stations/stops, where their arrival is preceded by clear audible and visual announcements, ramps deploy to offer level access to and from the vehicles and people can board and alight with ease. Tactile markings delineating platform edges are of a standard design and all traffic crossings have clear, audible beepers or some other form of tactile signal i.e. the revolving cones, which are becoming popular in the UK or the vibrating panels favoured in Germany. There would also be clear information readily available in a variety of formats, to be able to report any failures of these safety mechanisms immediately and without fuss. All rail and underground stations would be equipped with wide lifts, to allow passengers to change levels easily.

Things are gradually improving, but the rate of change needs to greatly accelerate and also to spread out through other cities, smaller towns and more rural areas of Germany and the UK, with the rest of the EU and Europe then following the lead and duly implementing similar packages of measures in their own towns and cities. If we are truly serious about making significant headway in providing equal levels of accessible public transport provision to everyone everywhere, then it is surely the role of powerful, influential, European capital cities like Berlin and London to lead the way and establish and implement best practice frameworks in the fields of



urban planning and design, as well as in accessible public transport systems. These could then be adopted by other countries throughout the EU and latterly worldwide and subsequently adapted to suit their own individual needs.

London seems destined to become more like Berlin in its greater automation and with fewer staff on the system, but it is absolutely crucial that both cities preserve a core staff presence at major stations or via designated help points, so that passengers feel safe and secure using public transport and can seek and acquire additional assistance at any time if need be. If all the above detailed measures were successfully implemented in Berlin and London, all passengers including those with physical and sensory impairments would have an unparalleled degree of choice hitherto almost unheard of in any world city.

The choice is not just to stay at home or risk going out, but they would be able to select the mode of transport best suited to their own needs and individual journey purpose. They would also be safe in the knowledge, that they could use their chosen modes of public transport safely and completely independently, but could summon help at any time if required. This freedom of choice and ability to get around independently and at will is highly valued by everyone regardless of physical or sensory impairment and is inextricably linked to the fundamental, basic human right of civil liberty.

A key message from this article is that making an environment more accessible to one group of passengers with a physical or sensory impairment, if done correctly and to exacting standards certainly does not make it more inaccessible for other groups of people with differing needs. E.g. the example above concerning the tactile platform edge strips or alternatively a newly installed lift at an underground station provides easier access to and from the platforms, for those with heavy luggage, parents with children in pushchairs, as well as the primary group of wheelchair users, for whom the station would otherwise be inaccessible.

With a clearly focussed plan of continued network investment, Berlin and London can build on what they already have and can lead the world in sustainable and accessible public transport provision. With an aging population, it is imperative to act now, in order to safeguard and expand standards and levels of mobility currently enjoyed by millions throughout Europe and the world. These are all tangible, achievable aims, which just require sufficient funding and the backing of future governments and urban planners, in order to turn them into a future reality; let's hope that with a concerted effort from all concerned, that such a time is just around the corner.

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## Changing Do-nothing Baselines for Transport Investments

*Sudhir Gota, Lee Schipper Scholar*

### 1. Introduction

*"Government cannot experiment on the BRT project which is estimated to cost P10 billion<sup>1</sup>"*

- President Aquino, President, Philippines

Transport agencies are required to justify the economic viability and cost effectiveness of a project alternative before the implementation of a project. All the benefits of the projects and its alternatives are generally compared with 'no build' / 'without project' / 'doing nothing' scenario. This comparison of 'With project' and 'Without project or 'doing nothing' forms the foundation of transport projects' economic and environmental assessments from past many decades. For example, World Bank (2005), Inter American Development Bank (2010) and Asian Development Bank (1997) all recommend realistic "do nothing" scenario against the which the proposed project impact is assessed.

However, people often confuse "do nothing" as no additional significant investment in the baseline. No city has managed to sustain "doing nothing" as the cornerstone of its policy making. We can examine the "do nothing" concept in simple terms: if the total ridership of a proposed Bus Rapid Transit project (BRT) is 10 million over 20 years, the baseline would be the same amount of trips (neglecting induced traffic) traveling in different modes without the project. However, the 'same passenger trips' in both with and without scenarios actually signify additional investment in expanding roadways. It is illogical to assume that the same amount of existing roads would accommodate such a drastic increase in traffic volume without subsequent expansion or addition of a suitable alternative. Thus, in practice the "do nothing scenario" actually implies "doing something" – increasing supply to sustain the projected traffic movement. Historically, we have been expanding roads to accommodate increasing traffic.

This paper tries to argue in favor of incorporating the measurement of additional

infrastructure required in without project scenario during assessment of sustainable transport options. Incorporating this "supply increase" concept in the baseline has the potential to radically alter the project evaluation approach of sustainable urban transport options. Incorporating such a component in cost and benefits stream will automatically make many of public transport improvement projects feasible and their implementation faster. This aspect has been highlighted in the paper with examples from BRT system.

### 2. Transport Baseline in Projects

Constructing the transport baseline is probably the most critical task in the appraisal process as all project cost and benefits are compared with this baseline. In general, there exists three types of possible baseline counterfactuals.

1. 'Do Nothing': This scenario does not consider any improvement and investment in absence of proposed project which often results in a pro-bias towards projects as the baseline describes a deteriorating scenario where facility is unable to meet demand.
2. 'Do Minimum': This scenario considers minimum investment to keep the existing capacity operational for full length of analysis. This scenario does not envisage high comparable investments in absence of proposed project.
3. 'Do something else': This scenario envisages an alternative project in absence of proposed project.

Generally, all transport economic and environmental assessment guidelines propose comparison with 'do nothing' or 'do minimum'. It is hard to determine when exactly 'without project' was first used as a reference for project evaluation, but it is being used from early 1960's in transport sector when cost-benefit analysis gained prominence. 'Without project' was essentially used since there was a need for a standard datum against which project benefits can be compared with.

<sup>1</sup> Sunstar Cebu, 2012, "BRT hits roadblocks" - <http://www.sunstar.com.ph/cebu/opinion/2012/12/04/barrita-brt-hits-roadblock-256684>, accessed on 2-November-2013.

This paper tries to argue in favour of incorporating the measurement of 'most likely' step in the baseline for evaluation of sustainable transport projects for a start.

Based on traditional investment patterns in developing cities, 'most likely' step would be infrastructure expansion and considering this additional infrastructure requirement in without project scenario could change the project evaluation dynamics. The cost of additional infrastructure prevented by the project is a benefit to sustainable transport investment. In the context of the challenges described, baseline aspect has been scoped in detail in this paper with many examples from BRT systems. BRT systems are considered as many methodologies and toolkits exist to determine economic and environmental feasibility of the projects. In this paper, BRT is considered as an example to illustrate that good public transport and non motorized transport projects would yield high benefits in terms of its impact on motorization and prevention of investments on additional road construction.

### 3. BRT System Benefits

Globally, more than 160 cities have adopted Bus Rapid Transit systems with over 300 bus corridors<sup>2</sup> and 2,000 BRT lane kilometres are already in operation. Increased demand for BRT in cities around the world is mainly due to high benefits generated by the system.

BRT benefits quantified can be generally categorized in three tiers -

1. Tier 1 - "generally quantified" such as Travel time savings and Fuel savings;
2. Tier 2- "sometimes quantified" such as emission reductions and road safety improvements and
3. Tier 3 - "acknowledged but often not quantified" such as noise reduction, land use impacts, health benefits, improvement in quality of life, improved economic opportunities, increased jobs, increased revenue, fuel security, etc.

In project implementation cycle, Tier 1 benefits (often called as direct benefits) are always quantified and compared against project costs during economic fea-

sibility stage of the project. In case the project is being financed partly by development banks or through carbon finance mechanisms, quantification of CO2 savings becomes critical (tier 2). Methodologies in Tier 1 and Tier 2 for calculating fuel consumption and carbon emissions are not actually very different from each other as once fuel savings from a project are estimated, calculating CO2 emissions is a simple multiplication of carbon content of fuel. However, this aspect has been neglected with institutions and researchers struggling over the assumptions and boundary establishment in CO2 quantifications in projects thus making it complicated and difficult.

Benefits of the BRT projects are often due to mode shift and improved BRT buses in terms of occupancy and speed. By shifting the projected vehicular trips to more efficient buses and comparing it without any BRT project case, savings such as travel time, fuel and emissions are established. Due to the BRT system, many people change their origin or/and destination to use this better mode of transport and thus density (housing and employment) increases in the areas influenced by the project, thereby increasing land values, increasing employment opportunities, reducing emissions and generating health benefits.

However, in spite of many cities building or planning for BRT, doubts still persist on BRT and its cost effectiveness which often delays the implementation. For example,

1. Cebu BRT in Philippines was delayed by more than a year because the President of Philippines was not convinced of the high costs associated with the BRT.
2. New Delhi is struggling to implement an ambitious BRT system due to uncertainties on its advantages. By 2010, Delhi had only built 5.8 km out of planned 115 KM to be finished by 2010. Leading political parties have promised to scrap BRTS in local election manifestos and future of BRTS implementation in New Delhi is not clear.

<sup>2</sup> Zottis Luísa (2013), "Over 300 BRT's and Busways around the world", TheCity Fix, <http://thecityfix.com/blog/over-300-brts-around-the-world-bus-rapid-transit-number-luisa-zottis/>, accessed on 2- November-2013

Clearly, BRT benefits were not adequately established when compared with investments required for expanding roadways in without project scenario.

#### 4. Reduced Motorized Travel due to BRT

Let us consider four BRT projects in Asia - Ahmedabad & Pimpri in India, Cebu in Philippines and Guangzhou in China and quantify the magnitude of "without project" road expansion activities in respective cities. Of the four BRTS considered, two systems are already in operation ( Ahmedabad in 2009 and Guangzhou 2010) and two under implementation ( Pimpri under construction and Cebu has just been approved). Both Ahmedabad

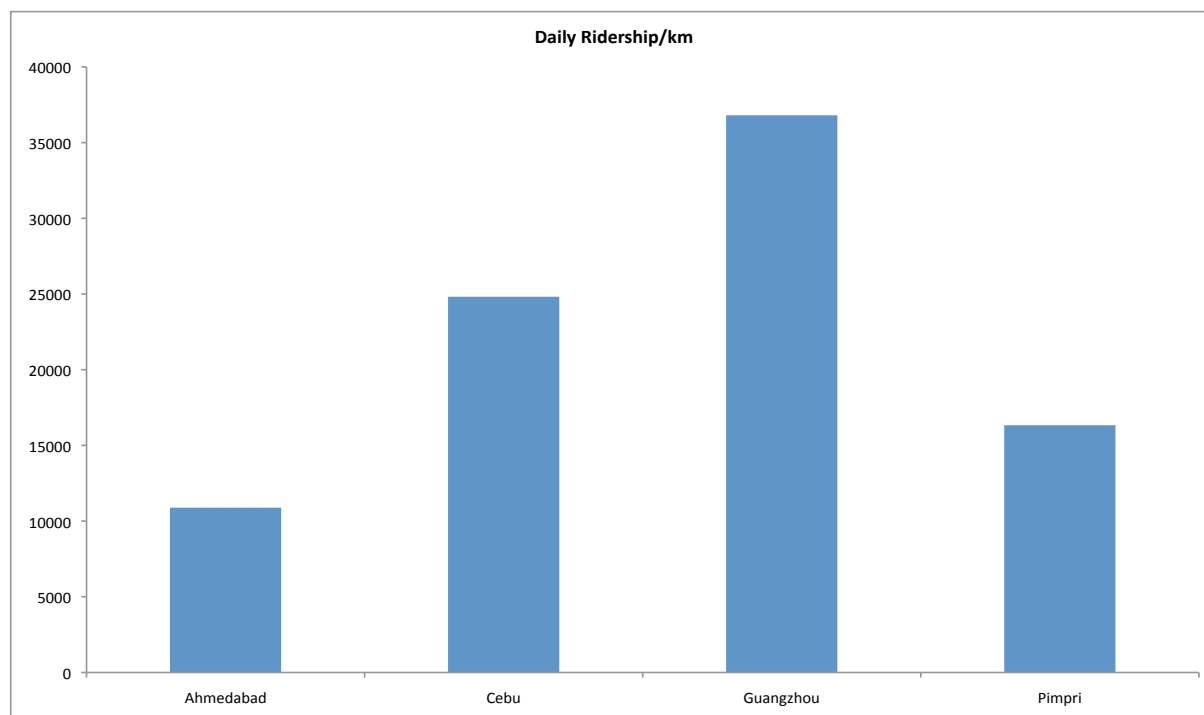
and Guangzhou systems are considered as Best Practice case studies for rest of Asian developing cities.

Construction and maintenance cost of the systems vary from 1 to 5 million USD/km. The average daily ridership per kilometer of the projects vary from 10000 to 37000 and thus providing adequate range for estimating benefits of the BRT system.

In case the BRT would not have been constructed (no project scenario), BRT riders would have been forced to use the existing modes throughout the twenty years of project lifecycle. Since the shift is from low occupancy vehicles to improved BRT buses with higher occupancy and travelling at higher speeds, the savings generated in time and fuel costs are primarily quanti-

BRT	Country	BRT (KM)	Financed	Cost Million USD
Ahmedabad	India	59.0	Indian Government	106
Cebu	Philippines	16.0	Co-funded by Climate Technology Fund	152
Guangzhou	China	23.0	Chinese Government	146
Pimpri	India	19.2	Co-funded by Global Environment Facility	147

**Table 1 : BRT Length and Costs**



**Figure 1 : BRT Daily Ridership/kilometer**

	BRT Starting Year											
	Ahmedabad			Cebu			Pimpri			Guangzhou		
	Mode Shift	Trip Length	Occupancy	Mode Shift	Trip Length	Occupancy	Mode Shift	Trip Length	Occupancy	Mode Shift	Trip Length	Occupancy
Cars	2%	11	1.1	14%	6	2	2%	6.4	1.42	20%	20	2
2-Wheeler	12%	5.6	1	18%	6	1	12%	6.4	1.09			
3-Wheeler	38%	5.3	3				38%	6.4	1.9			
Taxi				5%		2				7%	10	3
Normal bus	47%	12	28				47%	6.4	35	72%	12	45
Minibus				63%	6	16						
Cycling	1%						1%	6.4		2%	7	
BRT		8	45		6	40		6.4	45		12	54

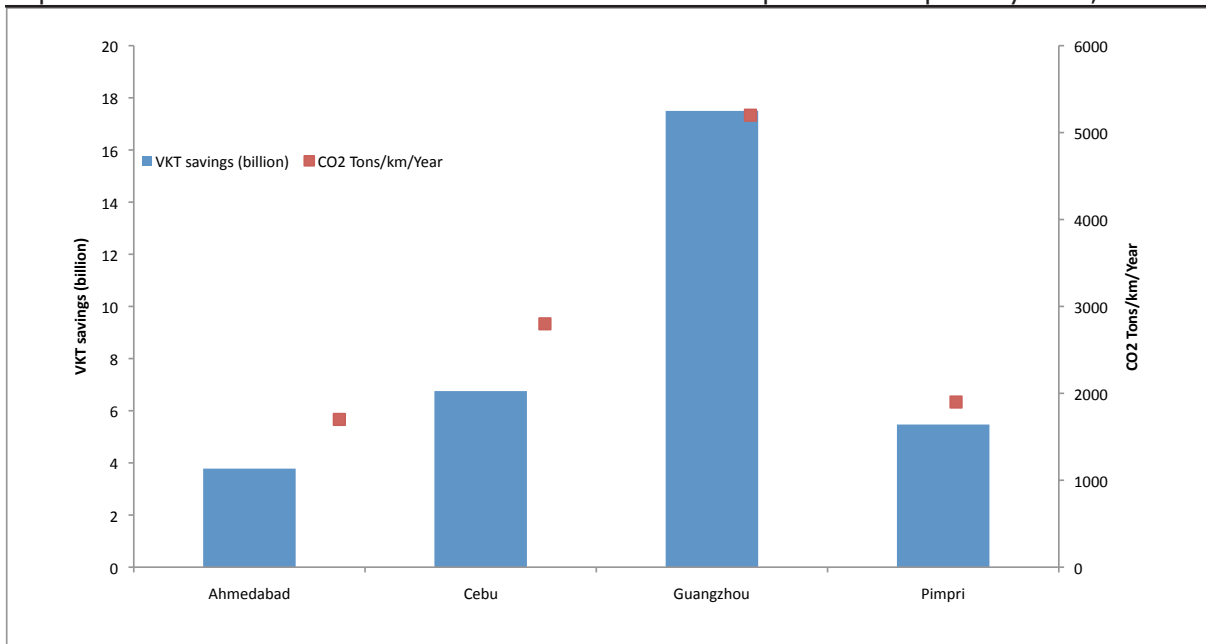
**Table 2 : BRT Modeshift, Trip length and Occupancy details at Starting Year**

fied. These projects have been analyzed using TEEMP methodologies by Clean Air Asia with partners for ADB (Guangzhou), World Bank ( Ahmedabad, Pimpri) and French Development Agency (Cebu)<sup>3</sup>.

The modal shift data provided above is for the first year and it does not consider the impact of future motorization in absence

ducting surveys to capture ex-post trip behaviour.

Avoided motorized vehicle travel due to these projects range from 4 to 17 billion vehicle kilometer travel for twenty years of project analysis . In the without project case i.e. city without effective and prioritized public transport system, this in-



**Figure 2: BRT Vehicle Kilometer Travel and CO2 Emissions Savings**

of the project. Mode shift data is based on transport modelling and ex-ante surveys in respective cities. It is interesting to note minor shift from non motorized transport to BRT systems. More accurate insights can be drawn in future by con-

3 for more details on individual projects and TEEMP suite of models, please refer to - Clean Air Asia, Transport Emissions Evaluation Model for Projects at <http://cleanairinitiative.org/portal/projects/TEEMP>. In this paper, methodology and actual project application is not explained in detail.

crease in traffic would lead to slowing of traffic speeds, congestion and this would subsequently force cities to widen roads to cater for increased traffic growth. In order to make most conservative calculation of this infrastructure requirement, Singapore has been considered as an example.

**5. Road Expansion in Singapore**

Singapore does not follow the traditional approach of increasing road space with increasing congestion. From 1991 to 2012, vehicles have increased by 2.7% annually while vehicle kilometer travel has increased by 2.2% and road supply (lane kilometers) have only increased by 1% as per the statistics of Land Transport Authority-Singapore<sup>4</sup>. Singapore has limited land supply, so road widening is only carried out when all other options fail. The major emphasis is on curbing travel demand by road pricing, controlling ownership, better and effective public transport facilities. In comparison for example in India from 2000 to 2010, vehicle travel has increased at 3.2% (WBCSD, 2004) while road kilometers have increased at 3.3%. Within a decade, India has expanded lane kilometers by 1 million km. IEA has docu-

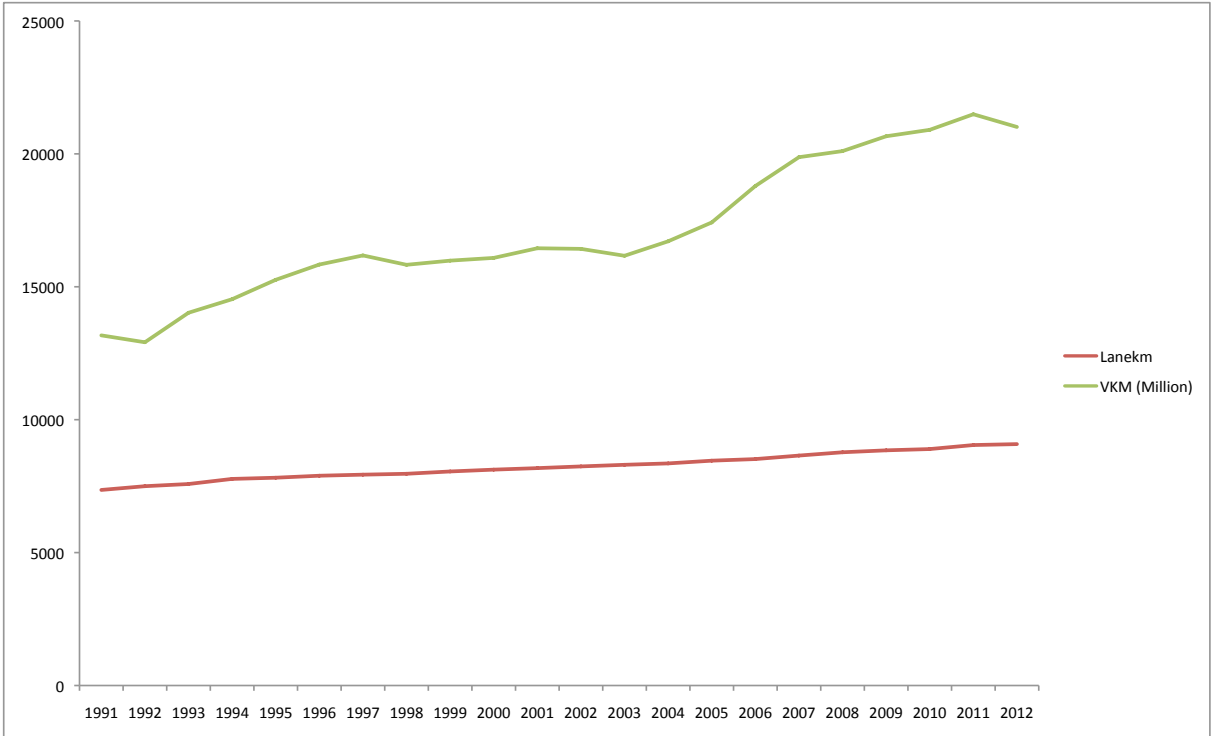
mented that now countries like China, India and ASEAN are expanding roads(lane-km) at an annual speed of 350000,98000 and 54000 km every year (Dulac, 2013). Majority of developing cities in Asia are yet to adopt sustainable urban transport policies in letter and spirit. The current vision is more oriented towards improving speeds and not founded on avoid-shift-improve approach.

To give an example, Philippines development plan-2011-2016 (NEDA, 2011) quotes speed improvement as a primary indicator in measuring success of Metro Manila’s transport strategy. It quotes -

- 1. Decreased travel time from 2.17 min/km to 1.57 min/km in 2016
- 2. Increase in travel speed from 27.79Km/hour to 38.2 km/hour by 2016
- 3. Increased occupancy due to reduction of city buses - air-conditioned from 40 to 65, non-air-conditioned from 37 to 45.

In contrast, Singapore’s Master plan 2013 targets -

- 1. 8 in 10 households living within a 10 min walk from the MRT station



**Figure3: Singapore Infrastructure Expansion with Growing Traffic Movement**

<sup>4</sup> Singapore Land Transport: Statistics In Brief, <http://www.lta.gov.sg/content/ltaweb/en/publications-and-research.html>, Accessed 6-10-2013.

2. 85% of public transport journeys less than 20km completed within one hour
3. 75% of all journeys during peak hour undertaken on public transport

Thus, Singapore explains a conservative example of road expansion within a city. By considering Singapore's experience with road supply increase and translating this ratio on projected vehicle travel in project baseline for BRT/Metro would allow conservative computation of infrastructure increase in absence of BRT/Metro project.

### 6. Avoided Road Infrastructure due to BRT Projects

In Singapore, each lane kilometer accommodates around 5600 VKT/day/Lane. This ratio is translated to above projects and the results show very high impact. For the entire BRT corridor length, each project helps prevent construction of 6 lane, 16 lane, 10 lane and 23 lanes for the twenty years of travel demand in Ahmedabad, Cebu, Pimpri and Guangzhou. On an average, avoided road space for a BRT is 2 square meters per rider.

In terms of costs, all the BRT's turn out to be cost effective as the alternate cost of road expansion in the without project scenario exceeds BRT construction cost with

an assumption of 2 million USD/Lanekm for urban roads without even considering inflation. This cost can be considered as conservative as urban land is scarce and expensive and hence the roads which would be built would be either underground or elevated which may require 10 times more investment. Thus, considering only the costs (neglecting all the other benefits), BRT's are economically feasible when compared to building more roads. For example in Cebu study (Clean Air Asia, 2012) the costs of avoided infrastructure (500 M\$) exceeded not only other benefits such as fuel savings (445 M\$), Health Impact (100 M\$), travel time savings (81 M\$) and avoiding traffic fatalities (37 M\$) but also the costs (150 M\$).

### Co-Benefits

In without project scenario due to road expansion, additional motor traffic is induced as public transport deteriorates and new roads with extra capacity attract more use of vehicles. This leads to a vicious cycle of motorization. Avoiding this vicious cycle of induced motorized travel by high penetration of BRT network would have exponential impacts on the quantification of co-benefits and these should not be missed out.

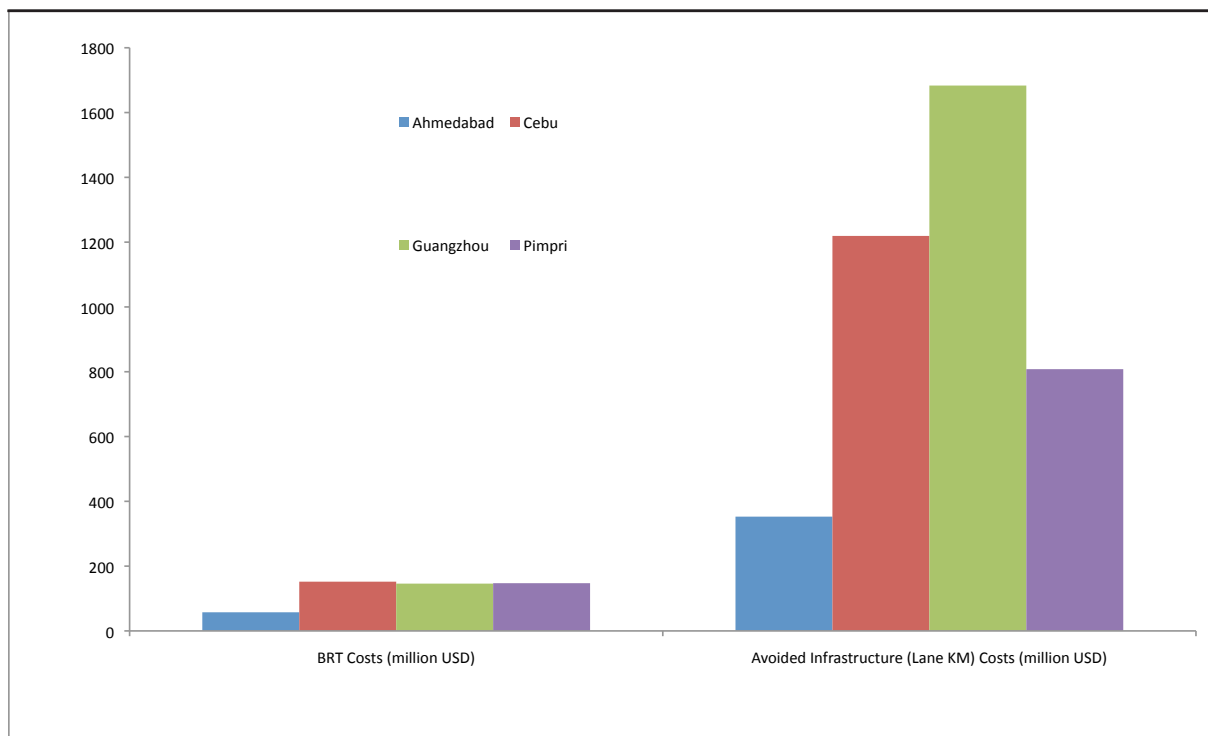


Figure4: BRTS and Avoided Infrastructure Costs



In terms of carbon emissions reductions in above projects, BRT projects save 1700 to 5200 tons/km/year. Recent report by ADB (Independent Evaluation Department, 2010) has estimated that in general, expressway projects increase CO2 emissions by one-fifth to one-half or more over their 20-year lifetime compared with business as usual because of effects on induced travel that overwhelm the short-term benefits of curbing low-efficiency congested traffic. Clearly, the carbon benefits of the BRT projects would multiply considering induced motorized travel increase in without BRT project scenario.

BRT also has significant impact on air quality. Based on the health assessment study in Cebu BRT it was found that Health benefits from the BRT due to pollution reduction could range from US\$94 to US\$137 million (Clean Air Asia, 2012). In case the BRT is not constructed but roadways are expanded, then increased air pollution would magnify health related problems. Health Effects institute (Health Effects Institute, 2010) has suggested a boundary of 300 to 500 meters from a highway or a major road is most highly affected by traffic emissions. Considering the high density of roads in urban areas and considering that outdoor air pollution is now considered carcinogenic, health impacts due to BRT construction would also multiply as it breaks vicious cycle of induced motorized traffic.

Wide roads promoting vehicle travel would make non motorized commute difficult in without project scenario and thereby leading to severe loss of mobility and accessibility. Further, loss of livability is directly connected with urban sprawl and this will lead to further motorization.

However, this hypothesis of reduced vehicle travel can be questioned from the perspective of induced motorized traffic generated by BRT systems in the "with project scenario". Considering that many people "shift" to BRT systems, the existing road space per motor vehicle may increase due to shift of few passengers and this may induce additional motorized traffic. Further, there can be a case that people may have more access to vehicles as their family members shift to BRT especially in house-

holds with single vehicle ownership. However, the impact of such "induced travel" in 'with BRT' scenario is negligible as shift is from private modes considered vary from 14% to 30%. Further, in many cases, the road space for private modes gets restricted due to construction of BRT systems and travel times often increase due to priority provided to public transport. Thus additional motor traffic induced by BRT is minimum.

## Conclusion

*"Without project" scenario should be ideally considered as to what would "most likely" happen if this project is not executed.* Including a measurement of avoided road infrastructure in decision making has a potential to radically alter our perception of worthwhile urban transport projects. With growing requirements of transport financing, inclusion of this parameter would give a greater push to cost effective solutions. Currently no transport project assessments factor this component in economic and environmental assessment.

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