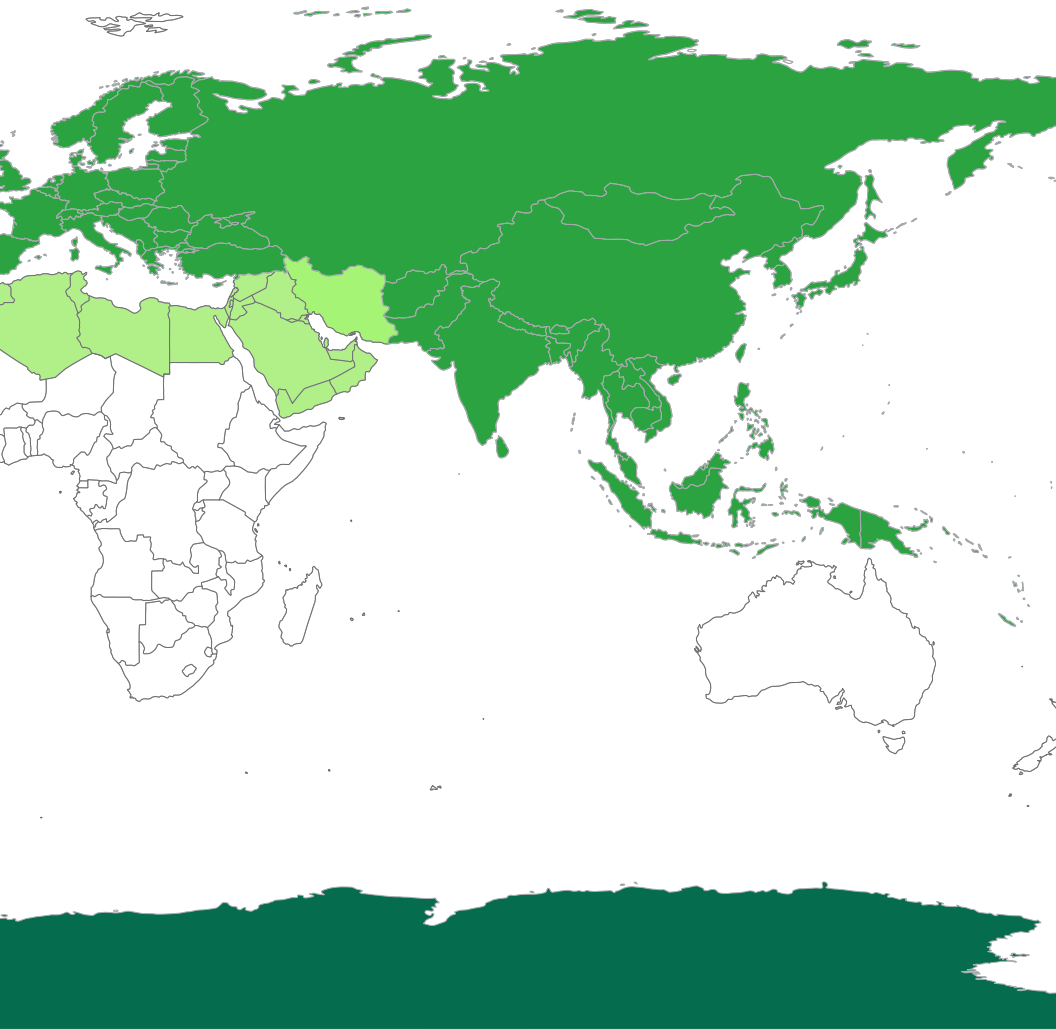


# SUSTAINABLE TRANSPORTATION

*AN INTERNATIONAL PERSPECTIVE*



**A NOTE OF THANKS** Editorship is an adventurous journey. I learned a lot and enjoyed it – and it could not have been possible without my mentors and supporters. First, I would like to thank Larry Vale, my faculty advisor, for his support, his guidance and practical advice throughout the process of bringing this *Projections* volume to life. I am also grateful to Ezra Glenn for pushing forward this volume and the journal's future.

I would like to thank the authors, who contributed through their knowledge to this volume, iterated patiently through several revisions, and showed tremendous passion for their fields of expertise. I also would like to thank the editors for giving advice that improved this *Projections* volume significantly.

The former managing editors of *Projections* were very open in sharing advice - thank you Anna Brand, Isabelle Anguelovski and Rachel Healy. I hope you will enjoy the layout of this volume, and would like to thank Marissa for designing and improving the graphic design with her ideas.

- EVA KASSENS, 2009

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# SUSTAINABLE TRANSPORTATION

## *AN INTERNATIONAL PERSPECTIVE*

**COVER IMAGE** Map courtesy of Eva Kassens; data courtesy of World Resources Institute, 2005. This map shows CO<sub>2</sub> emissions by transport as a percentage of emissions. The more grey the continent, the higher the CO<sub>2</sub> transport emissions in relation to total emission of that continent; the more green the continent, the lower the CO<sub>2</sub> transport emissions in relation to total emission of that continent.

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**EDITORIAL**

# **PLANNING FOR SUSTAINABLE TRANSPORTATION : AN INTERNATIONAL PERSPECTIVE**

The need to plan for sustainable transport is evident. Global warming poses significant challenges for cities. The transport sector alone, according to the World Resources Institute (2005), accounts for 24.1% of CO<sub>2</sub> emissions worldwide, yet its importance in local commuting, linking the global system of cities, and stimulating economic interactions is crucial. "The solution" for keeping up international, national, regional, and local interactions while fostering sustainable development has yet to be found; no strategy for sustainable transportation systems agreed to by all stakeholders across countries so far exists.

Sustainability and sustainable development have been the main theme of many international conferences, such the UN Rio de Janeiro 1992 Earth Summit, the 1995 European Conference of Ministers of Transport, and the 1997 Kyoto Convention on Climate Change. The origins of the concept of sustainability date back to the early seventies, but the most often cited definition of sustainable development was stated by the World Commission on Environment and Development in its so-called "Brundtland Report" (1987, p. 54). This report defines sustainable development as *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs."* Given that this sustainability definition was fairly broad, governments across the world sought to refine it in terms more applicable to their own situations, yet closely aligned with the Brundtland definition. Most such definitions had in common the three dimensions of sustainability: economic, social, and environmental. Sustainable solutions should be economically viable, socially equitable and ethically responsible, and consistent with the long-term ecological balance of the natural environment.

While the urgency of planning for sustainability has increased over the years, concrete solutions accepted internationally have been slow to emerge. Each country is constrained by its individual setting and hence faces unique hurdles in moving towards sustainability. Despite these hurdles and other international challenges, moves towards sustainable development are evident, as this Projections volume highlights. Across the globe researchers are seeking to develop, and cities are trying to implement, sustainable policies. Planning for sustainable transportation systems is a complex task that involves multiple options and uncertainties. Government seeks an optimal package of policies that is willingly accepted by all affected groups. An ideal implementation strategy would allow for easy transition from the way people formerly travelled to the new system. Finally, the actual impact of the policy package and travelers' responses need ongoing monitoring to insure that the policies' implementation is meeting desired goals.

This volume of *Projections* presents five articles focusing on metropolitan regions making efforts to implement sustainable policies in India, the U.K., the U.S.A., and Australia.

An "Urban Sustainability Framework" for the strategic planning of metropolitan regions is proposed by Doust and Black in their article "A holistic assessment framework for urban

development and transportation with innovative triple bottom line sustainability metrics.” As a holistic and integrated approach incorporating the three pillars of sustainability (environmental stewardship, social equity, economic efficiency), the Urban Sustainability Framework promises to measure and track sustainability changes over time. Using Sydney, Australia, as a case study, the authors apply the Urban Sustainability Framework to measure the interactions between urban housing markets, labor markets, and transportation linkages over a 20-year period. They highlight the importance of assessing sustainable performance as a complementary rather than a competing outcome.

The necessity of linking the sustainable transport concept with land-use planning is evident in Aditjandra, Mulley, and Nelson’s comparison of neighborhood design and its impact on travel behavior between the U.K. and the U.S.A. In their article titled “Neighborhood design impact on travel behavior: a comparison of US and UK experience”, the authors find that neighborhood design in both countries offers opportunities for sustainable mobility practices. Showing that travel accessibility is sensitive to changes in active and public transport use, the paper suggests that residents of British neighborhoods are not only more aware of but also more likely to use sustainable modes of transport than their US counterparts.

Highlighting the importance of integrating measures of job accessibility into sustainable transportation planning, Thakuriah’s article “Transportation and employment accessibility in a changing context of metropolitan growth: the case of New Delhi, India” examines the factors that have encouraged personal transportation in the Delhi metropolitan area. Transport policies significantly fostered the purchase and usage of the private motor vehicle while failing to protect the urban poor and non-motorized travelers. The result of these policies impact was severe traffic congestion. Emphasizing the different needs of local populations for access to jobs, she calls for comprehensive transport policies that foster sustainable metropolitan travel ensuring equitable access to economic opportunity for all.

Acknowledging the negative impacts of private car usage, Rouhani’s paper “Road privatization and sustainability” reflects on pricing strategies for road usage, maintenance, and construction. Recognizing the political and societal hindrances to implementation, levying fees on car users nonetheless appears to have great potential in solving congestion problems, in providing funds for the transportation sector, and in accounting for the negative externalities of road transport. Rouhani concludes that privatization of road transport seems capable of improving economic and environmental conditions, but points out that this solution falls significantly short on the equity dimension in sustainability.

Evidence of how sustainability influences public policy is presented in Locantore, Montagu, Rudy, and Sabina’s research brief “Scenario analysis helps identify sustainable land use and



transportation policies.” Their analysis, exploring land use, transportation development, and the environmental planning outcomes of the Denver metropolitan region, yielded six scenarios varying in transport funding allotted for highways vs. transit and compact design vs. sprawling development. The outcomes presented to the Denver Regional Council of Governments resulted in the Council’s shrinking the original urban growth boundary by 70 miles.

David Banister identifies the overlapping general issues across the five papers and draws conclusions for this Projections volume. Finally, he provides a look into the future of sustainable transportation by emphasizing similarities and differences of sustainable transport when seen in its international context.

Each of these essays highlights the unique approach a specific city took to implement sustainable transport solutions. Together they provide evidence that individual efforts to move towards sustainable transport can show significant results.

Eva Kassens  
Summer 2009

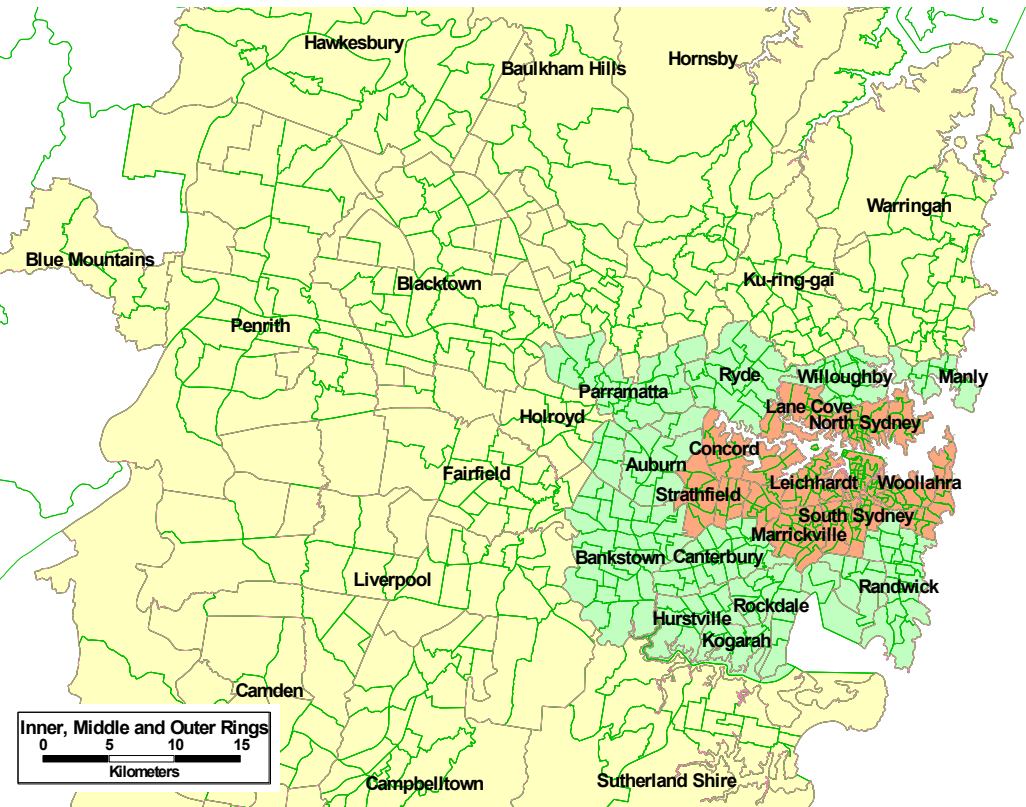
## REFERENCES

Bruntland, G. (Ed.). (1987). *Our common future: The World Commission on Environment and Development*. (Oxford: Oxford University Press).

World Resources Institute. (2005). World Resources 2005 - Data Tables. Retrieved April 9th 2009, from [http://pdf.wri.org/wrr05\\_dt\\_all.pdf](http://pdf.wri.org/wrr05_dt_all.pdf)

Dr. Ken Doust  
Professor John Black

# A HOLISTIC ASSESSMENT FRAMEWORK FOR URBAN DEVELOPMENT AND TRANSPORTATION WITH INNOVATIVE TRIPLE BOTTOM LINE SUSTAINABILITY METRICS



**ABSTRACT**

An urban sustainability framework is proposed for the strategic planning and assessment of the location of land-use activities and transportation facilities that incorporates the three pillars of sustainability: environmental stewardship, social equity and economic efficiency. Part of this framework is illustrated with the interactions amongst urban housing markets, labor markets and transportation linkages, in particular automobile travel and greenhouse gas emissions. The framework is applied to a case study of metropolitan Sydney using census data for a twenty-year period, and the results are used to assess the effectiveness of post-war strategic planning in metropolitan Sydney.

## INTRODUCTION

In Australia, when an Inter-Governmental (Federal, State and Local) Agreement was reached on ecologically sustainable development (ESD) in 1992, it was agreed that economic, social and environmental matters must be considered in any major development proposal. This includes assessment by the determining authority as part of the approval process. At the macro level, the periodic State of the Environment Reports provide quantitative evidence of the change of key indicators over time. In NSW, the latest is the *NSW State of the Environment Report, 2006*<sup>1</sup>. However, for transport infrastructure development and for metropolitan land-use and transport planning in Australia, there is still a need for quantitative indicators of sustainable development (Hutabarat, et al., 1998), as argued by Hidas and Black (2001) and Holliday (2008).

Building on previous methodologies, this paper reports on a holistic assessment methodology with practical outcomes:

- identify the system elements and interactions that determine the sustainability performance of the city (what to measure);
- formulate measures which are objective and traceable (how to measure);
- formulate methods of assessing mutual performance of the three pillars of sustainability in a manner that engages community and decision makers (how to assess).

The elements and interactions of importance for urban sustainability assessment are identified through a new framework - the "urban sustainability framework". The explanation of original metrics to quantify the three pillars of sustainability – economic, social and environmental – is the contribution of this paper.

The metrics are based on:

- accessibility to employment (social spatial equity)<sup>2</sup>;
- accessibility to labor markets (economic efficiency)<sup>3</sup>;
- greenhouse gas emissions from car trips (environmental load)<sup>4</sup>.

Authentic journey-to-work travel data and environmental data for the period of 1981 to 2001 (the latest data at the time of the research, although recently the 2006 data has been released) in the Sydney metropolitan region are used to demonstrate the practical utility of the metrics. Interpretation of the results offers evidence on whether or not successive, post-war planning policies have met their spatial equity and environmental improvement objectives.

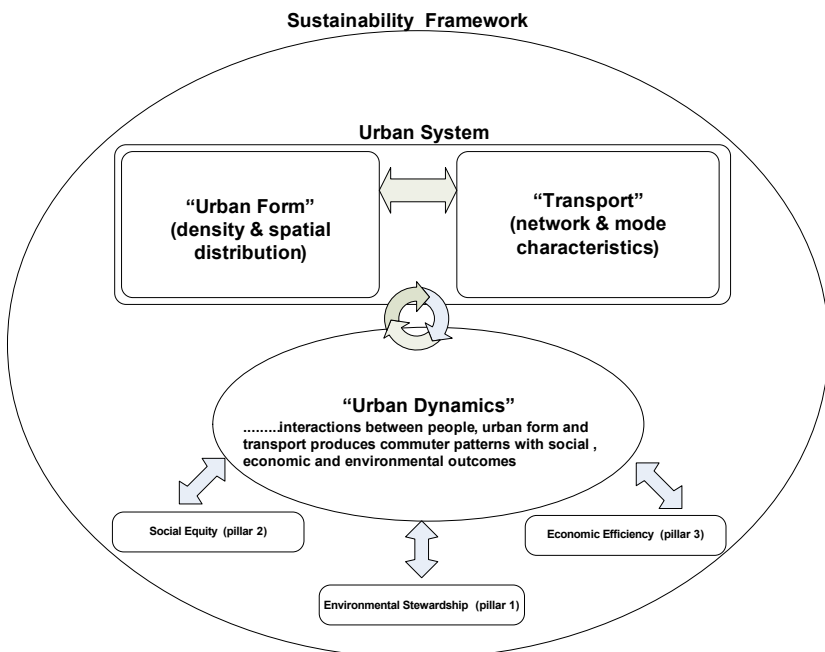
## URBAN SUSTAINABILITY FRAMEWORK

A key to urban sustainability is that the three pillars of sustainability - environmental stewardship, social equity and economic efficiency - are interdependent and need to be mutually reinforcing (United Nations, 2002). Good sustainability in this context requires all three pillars to have complementary rather than competing outcomes. Urban form, transportation and interactions with communities, are the central drivers of sustainability in cities. Understanding of interactions between urban form, transportation and community is essential to meaningful interpretation

of sustainability performance in terms of the three pillars of sustainability. A challenge for researchers is to develop methodologies that are not only objective but can also be easily understood, and meaningfully used by the community and governments.

An Urban Sustainability Framework is proposed in Figure 1 as a means of making visible the elements that drive the transport related urban sustainability outcomes. The “Urban System” is the physical aspect of the framework, consisting of the “Urban Form” and “Transport” elements which define the structural configuration of the city. Interaction between these two elements shows their interdependencies. “Urban Form” is characterised by density and spatial distribution of land-use. “Transport” on the other hand is characterised by the transport network spatial layout and the specific mode characteristics.

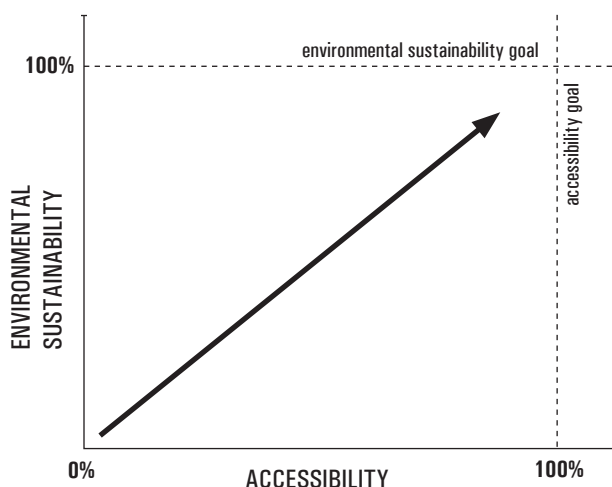
The system function is to provide for the needs of the community (including industry). Response of the community to the “Urban System” produces interactions that result in selection of location of residence and workplace, industry and trips and so on. These interactions are collectively known as “Urban Dynamics”. It is an iterative process as indicated by the circular arrow having feedback effect between each element. The resulting “Urban Dynamics” outcomes generate the sustainability performance in terms of the three pillars included as elements in Figure 1. Each pillar has a feedback to the “Urban Dynamics” and consequently the “Urban System”. This is indicated by the double headed arrows in the figure.



**FIGURE 1.** The Urban “Sustainability Framework.” *Source:* Doust, 2008, Figure 4.1, p. 136.

A top down logic is evident in tracing the driving influences on sustainability performance through this framework. However, it is also evident that community expectations and sustainability requirements flow from bottom to top in this framework when it comes to enabling new or changed urban systems or policies to provide an improved sustainability performance. Understanding the elements within this framework and their relationships requires application of the traditional Transportation Planning Models (TPM) and Integrated Land Use Transportation Models (ILUTM) and methodologies. These models and methodologies remain the strongest building blocks for a quantitative methodology for assessing the sustainability of cities, particularly when coupled with GIS visualization. In modeling the Urban System, accessibility to land-use activities (as operationalized by the Hansen model of potential accessibility – see Black, 1981, Chapter 1, Blunden and Black, 1984, Chapter 2), is an approach that brings the sustainability performance of the three pillars together. It provides a mechanism to visualize the complementary performance as well as the individual performance of the three pillars of sustainability.

An ideal planning goal is to have high accessibility with a low environmental footprint. A city's sustainability performance in relation to this goal can be analytically quantified and simply visualized in plots on what we define as the "environmental sustainability-accessibility space" (Figure 2). This figure refers to "Sustainability" as meaning environmental sustainability (stewardship) and "Accessibility" as meaning accessibility of workers to places of employment, shopping schools and so on, or, alternatively, accessibility of employment to workers – the spatial labor market.



**FIGURE 2.** Environmental Sustainability - Accessibility pace. *Source:* Doust, 2008, Figure 4.2, p. 138.

For either type of accessibility, the figure shows that the environmental sustainability performance on the ordinate can be plotted with the corresponding accessibility performance on the abscissa for any pair of land-use zones where interaction takes place. The concept enables both a quantifiable measure and a visual representation of the mutual performance. A goal or target for environmental sustainability and accessibility can be applied and visually represented in the same space. Note that the 100% goal position may vary depending on the relative weighting or priority of the two dimensions.

The two dimensional environmental sustainability-accessibility space has a parallel to the geographical information system (GIS) for geographic space. In geographic space, spatial disaggregation enables a visual appreciation, for example, of land-use distribution. In the environmental sustainability-accessibility space, the spatial disaggregation enables a visual appreciation of the sustainability performance distribution. One example is the sustainability distribution for land-use zone pairs in a city. The environmental sustainability measure adopted is the inverse urban CO<sub>2</sub>-e measure <sup>5</sup>,

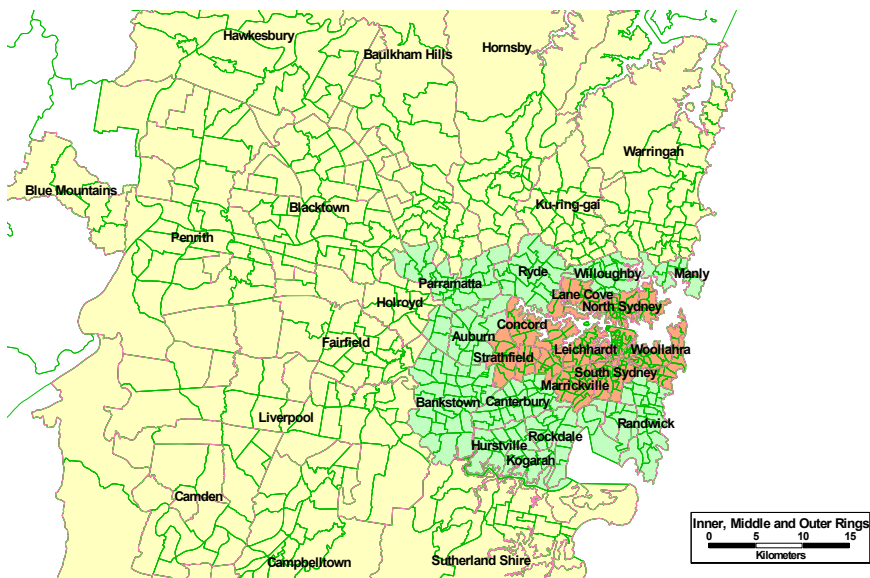
## METROPOLITAN SYDNEY CASE STUDY

Measures of the three triple bottom line sustainability pillars and tested metrics have been calculated using Sydney, Australia, as a case study of a metropolitan area.

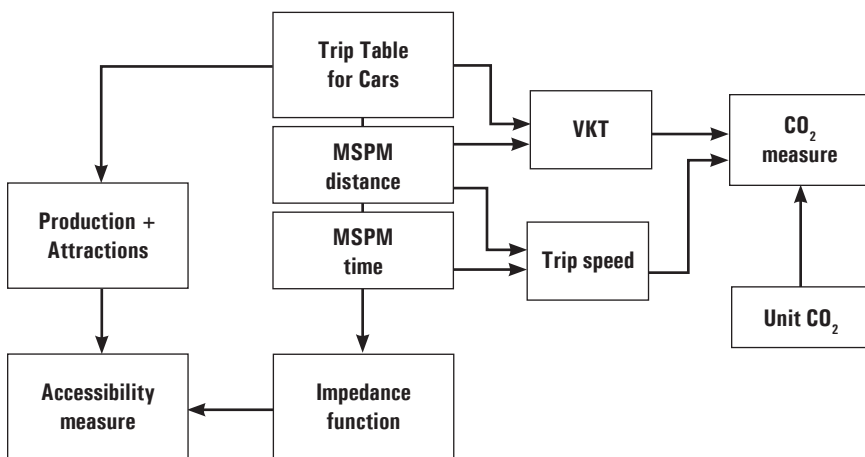
Sydney was selected because of its characteristic of being a low density, sprawling car-dependent city and its legacy of having transportation and population data over many years. Of particular value is the Census of Population and Housing with Journey to Work Trip (JTW) tabulations of trips to work for the whole Sydney population over a period from the 1961 to the present day. (The latest data available for analysis is 2001 with the 2006 Census expected for release soon.) The Sydney metropolitan region was partitioned into inner, middle and outer rings (see Figure 3) for convenience in presenting the aggregate results, but the software written for this analysis allows visualization of results for very fine geographical resolution (for each pair of zones in the urban system).

Existing building block methods for measuring accessibility <sup>6</sup> from residential original zones to places of employment and accessibility from places of employment to labor markets provided the foundation to ensure quantifiability and traceability in the metrics. 1) Accessibility to jobs is one measure of social equity. 2) Accessibility to the labor force for an industry is a measure of economic efficiency. 3) Environmental sustainability can be defined with many different measures, but to illustrate the general approach a CO<sub>2</sub> equivalent (CO<sub>2</sub>-e) was adopted that includes both energy embodied in transportation construction and maintenance, and in the energy consumed in making the journey by automobile.

The steps in developing the metrics through derived data are shown in Figure 4. Zonal land-use data and a highway network are the inputs for the analysis. The zone sets include destinations in up to 792 travel zones. TRANSCAD GIS-T was used to generate the multiple shortest path matrix (MSPM), transportation impedance tables and trip tables amongst these zones.



**FIGURE 3.** Sydney Case Study Ring Partitions. *Source:* Doust, 2008, Figure 5.1, p. 174.



**FIGURE 4.** Accessibility measures and environmental sustainability measures estimations. *Source:* Doust, 2008, Figure 4.7, p. 154.



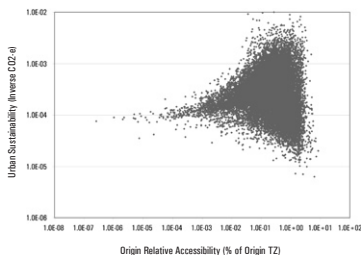
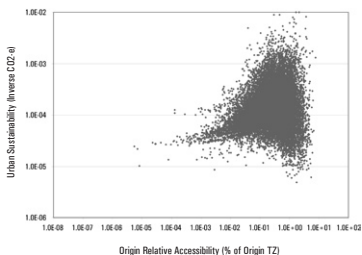
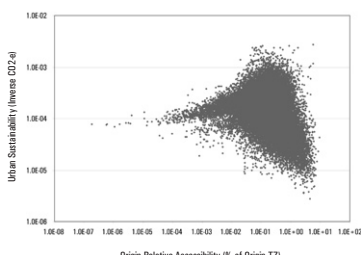
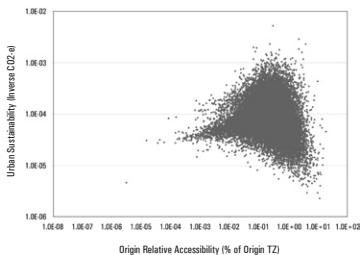
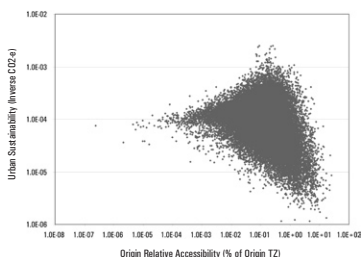
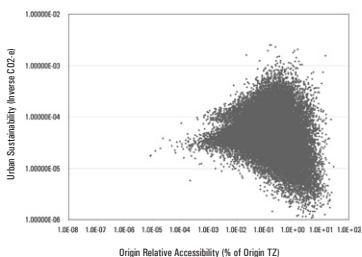
## 1981 Sustainability Accessibility Metric

## 2001 Sustainability Accessibility Metric

OUTER  
RING SETS

MIDDLE  
RING SETS

INNER  
RING SETS



**FIGURE 5.** Visualizations of residential sustainability: three rings of the Sydney Metropolitan Area. *Source:* Doust, 2008, Figure 6.17, p. 271.

### *Spatial Equity*

Figure 5 provides a series of visualizations of the environmental sustainability and accessibility to jobs for the residential travel zones in an outer, middle and inner ring partitioning of the Sydney Metropolitan Area for the census years of 1981 and 2001. The ring partitions represent three different urban expansion periods of Sydney during the 20<sup>th</sup> Century, with the inner ring being the metropolitan limit until the 1950s. The outer ring is the most recent, occurring from the 1970's and characterized by lower residential density and less access to public transportation.

The visualizations are for car-based trips across the whole Sydney Metropolitan Area to employment travel zones with journey to work trip ends. Each travel zone pair is represented by a metric point. The census year data sets for 1981 and 2001 are plotted in these figures, to allow interpretation of the spread and distribution in environmental sustainability – accessibility space and the changes across a twenty-year timeframe. The plot scale is logarithmic for both the

environmental sustainability and the relative accessibility measures.

Each scatter plot visualization represents the relative accessibility measure plotted with an urban environmental sustainability measure (1/CO<sub>2</sub>-e) for each travel zone pair. Over the twenty-year time frame from 1981 to 2001, a reduction in environmental sustainability for each ring is evident. A larger reduction is noticeable for the outer ring in comparison to the other rings. This is consistent with a larger increase in vehicle kilometers for the journey to work travelled in the outer areas of Sydney over the same time frame (Suthanaya and Black, 2001). Over the same time frame, the spatial equity as measured by the spread in relative accessibility has not deteriorated for any of the rings. However, the inner ring has the least spread and the outer ring the greatest spread.

### ***Economic Efficiency***

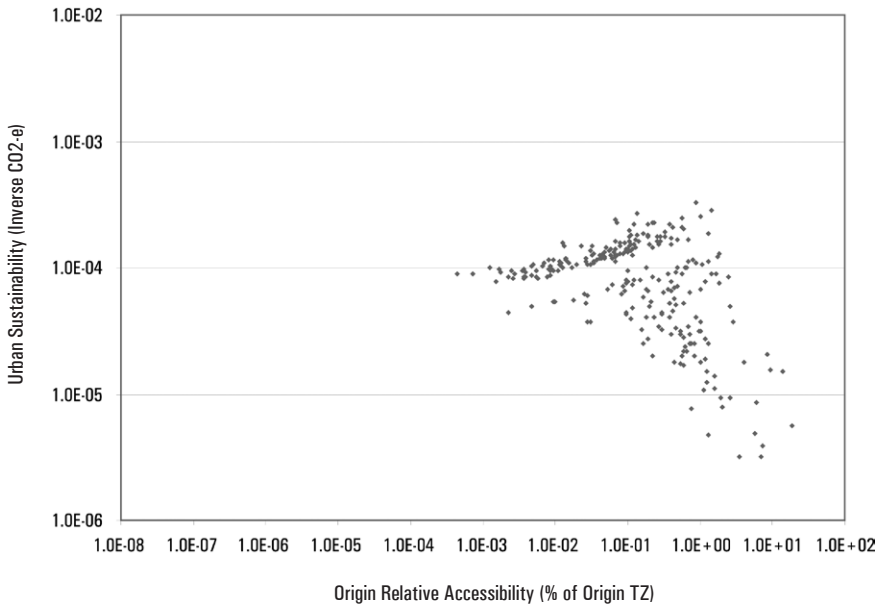
Figure 6 provides a series of visualizations of the environmental sustainability and accessibility to the workforce for the employment travel zones in the outer suburban Penrith 'River City' precinct, some 45 km from the Sydney CBD. Figure 7 provides the same visualizations of the Sydney CBD 'global city' for comparison. The visualizations are for car-based trips to all travel zones with worker residences, right across the Sydney Metropolitan Area. Each travel zone pair is represented by a metric point. The census year data sets for 1981 and 2001 are plotted in these figures, to allow interpretation of the spread and distribution in environmental sustainability – accessibility space and the changes across a twenty-year timeframe. The plot scale is logarithmic for both the environmental sustainability and the relative accessibility measures.

Each scatter plot visualization in Figures 6 and 7 represents the relative accessibility measure plotted with an urban environmental sustainability measure (1/CO<sub>2</sub>-e) for each travel zone pair. Over the twenty-year time frame from 1981 to 2001, a reduction in environmental sustainability is noticeable for both centres. However, there is a greater reduction in the Penrith environmental sustainability. This is consistent with a larger increase in vehicle kilometres for the journey to work travelled in the outer areas of Sydney over the same time frame (Suthanaya and Black, 2001). In comparison to the Sydney CBD employment zones, the Penrith scatter plot displays a similar degree of spread (left to right) in relative accessibility, at least four orders of magnitude.

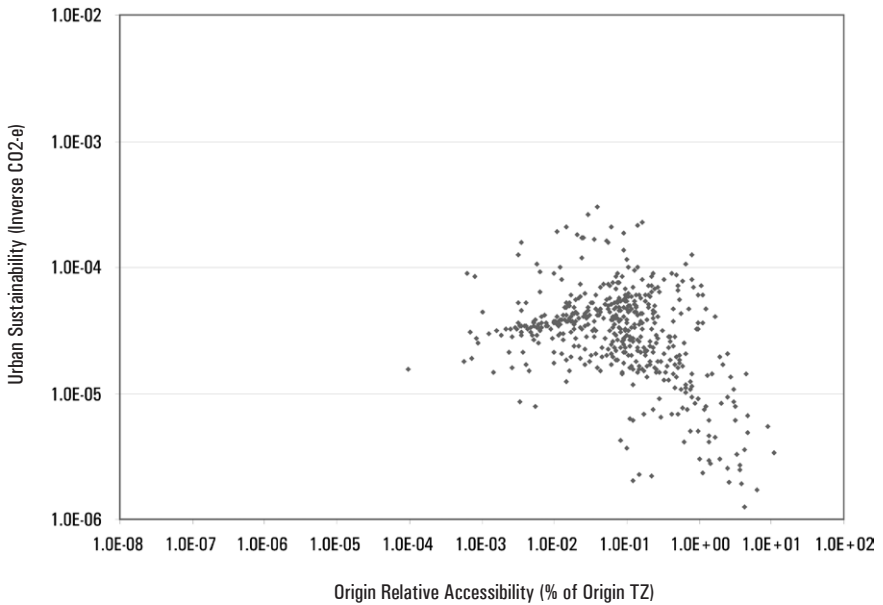
### **COMMENTARY**

The practical application of the assessment framework is demonstrated using metropolitan Sydney as a case study. Each of these elements of the sustainability framework work together and can connect the planning instruments (especially, Winston, 1957; New South Wales Government., 1968, 2005) through to the outcomes that drive the sustainability performance. The visualizations of the sustainability metrics provide the measure of performance in terms of the three pillars of sustainability (environmental sustainability, social equity and economic

### 1981 Sustainability Accessibility Metric

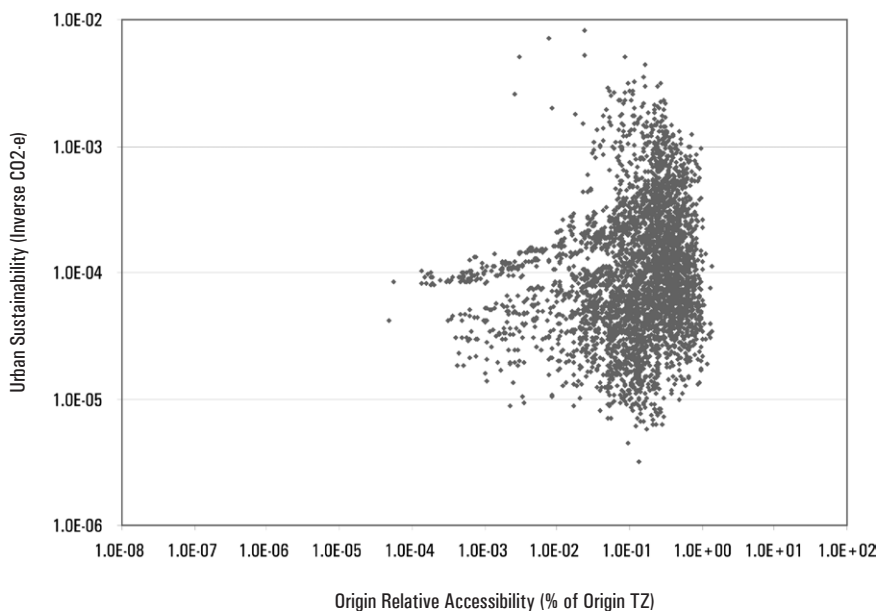


### 2001 Sustainability Accessibility Metric

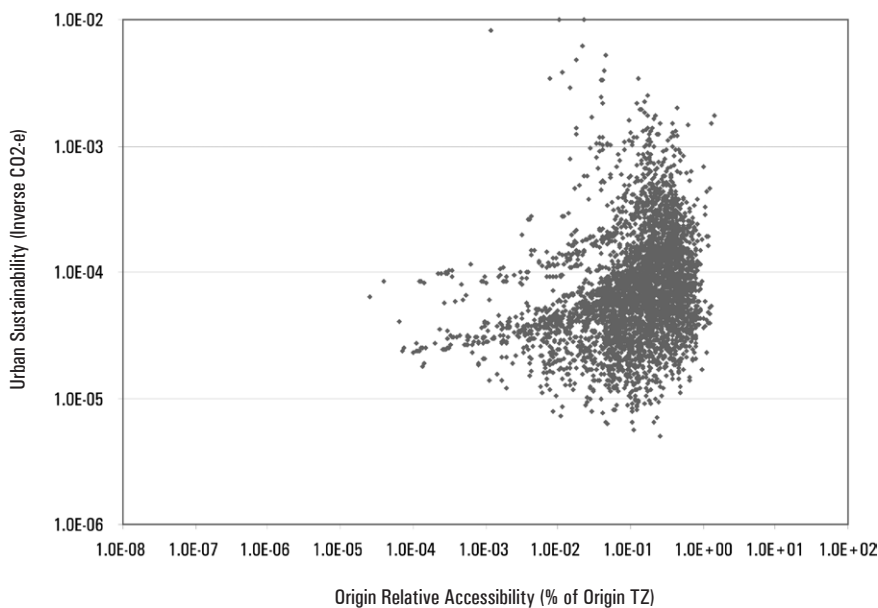


**FIGURE 6.** Visualizations of Employment Centre Sustainability: Scatter Plots for Penrith. *Source:* Doust, 2008, Figure 6.17, p. 271.

### 1981 Sustainability Accessibility Metric



### 2001 Sustainability Accessibility Metric



**FIGURE 7.** Visualizations of Employment Centre Sustainability: Scatter Plots for Sydney CBD. *Source:* Doust, 2008, Figure 6.17, p. 271.

efficiency). Although the interpretations that follow are supported by the data for Sydney, we would expect to find similar findings in other low-density, sprawling cities where data are available for comparative analyses.

**Pillar 1** is that of environmental sustainability, or environmental stewardship. The measure trialed through the Sydney case study was the inverse CO<sub>2</sub>-e measure based on greenhouse gas emissions. This is a measure of residential zones' environmental sustainability in terms of trips to all places of work in the case study area. It is also a measure of the major employment centre's environmental sustainability in terms of the workforce trips back home from that centre (economic efficiency of labor markets).

Observations made include:

- The metrics showed differences in sustainability performance of the three large datasets of Sydney differentiated as the Inner, Middle and Outer Ring sets from 1981 to 2001. The trends in environmental sustainability have shown that the Outer Ring, where the planning instruments have been focusing on residential growth, is worse than for the Inner and Middle Ring zones. Furthermore, this trend has deteriorated over the period 1981 to 2001.
- The trend for all major employment centres from 1981 to 2001 is one of deterioration in environmental sustainability. In the major employment centres the largest deteriorations were in Penrith, the Sydney CBD, followed by Parramatta, Liverpool and North Sydney. This indicates an opposite trend to that required to halt the growth in total VKT by private transportation by 2021, which is a policy of the New South Wales Government in *Action for Transport* (1998). Planning instruments do not appear to have succeeded in working towards this goal.
- The visualizations for 2001 show that the Sydney CBD and North Sydney remain the better performing centres, with Parramatta, Liverpool and Penrith the least environmentally sustainable. While the planning instruments have produced urban dynamics outcomes whereby local trips are a greater proportion of the Penrith and Liverpool centre's workforce trip patterns, this has not translated into higher environmental sustainability, principally due to the high mode share of the trips by automobile. The corollary is that the planning instruments that have led to the high public transportation share of the Sydney CBD centre work trips are shown to be effective even with a much larger spatial distribution of the workforce away from the centre.

**Pillar 2** is that of spatial social equity. The measures proposed in the Sydney case study were the relative accessibility and "raw" accessibility measures in terms of workers accessibility to jobs in the whole case study area, from their place of residence.

Observations made include:

- The *Sydney Region Outline Plan* (NSW Government, 1968) planning instrument has been focusing on establishing a balance of employment to match the residential growth. The trends in raw accessibility have shown that the equity (measured by accessibility to employment) was lower in the Outer Ring in comparison to the Inner Ring and Middle Ring for the whole period from 1981 to 2001.
- The “mean” Outer Ring performance has improved in comparison to the Inner and Middle Rings over the period 1981 to 2001, although the relative improvement in spread is less conclusive. On balance, the planning instruments appear to have improved the Outer Ring accessibility over the period but this is not sufficient to match the higher spatial equity experienced by workers and therefore their families in the Inner and Middle Rings.
- Comparison of the overall case study raw accessibility shows that the spatial equity for the whole area has improved steadily from 1981 to 2001.

**Pillar 3** is that of economic efficiency. A measure proposed in the Sydney case study was the raw accessibility measure in terms of employment centre accessibility to workers in the whole case study area, from the travel zones that make up each centre.

Observations made include:

- The raw accessibility-based measures indicated that Liverpool centre is the most economically efficient centre based on accessibility to the workforce, with the Penrith Centre the least accessible to the workforce.
- Liverpool and Penrith have both improved in economic efficiency, as indicated by the “mean” raw accessibility changes from 1981 to 2001. The policy instruments of the study period were aimed at increasing the job opportunities at these outer suburban area centres. Evidence of this was found through urban dynamics metrics, which showed that the workforce was much more localized than in the Sydney CBD, North Sydney or Parramatta (Doust and Black, 2008). The improvement in economic efficiency result shown by this improvement in raw accessibility measure over the study period suggests that the policy instruments have achieved positive Pillar 3 outcomes for the outer suburban Penrith and Liverpool centres. The increase in raw accessibility for the Liverpool centre indicates a much improved pattern of access to the workforce from 1981 to 2001.

*Overall Sustainability Performance of the Outer Ring* is a summary of the combined assessment of the three sustainability pillars. The summary is from the perspective only of the workers resident in the Outer Ring and the centres of Parramatta, Penrith and Liverpool located in the Outer Ring.

Observations made include:

- Based on the “environmental sustainability-accessibility space” visualization, the sustainability for resident workers is lower than for workers resident in the Inner and Middle Ring zones. The impact of planning instruments has been a neutral change in sustainability in relation to the target trend. However, it has enabled a better performance than the Inner Ring trend.
- Based on the “environmental sustainability-accessibility space” visualization, the sustainability for the Parramatta, Liverpool and Penrith centres is lower than for centres in the Inner Ring zone. The impact of planning instruments has been a neutral change in sustainability in relation to the target trend for the Penrith centre, a drop for the Parramatta centre and a significant improvement for the Liverpool centre. Performance improvements in comparison to the Inner Ring centres of North Sydney and the Sydney CBD are similar, although Liverpool showed a greater improvement. However, the accessibility spread metrics show better performance by the Inner Ring centres.

Overall the strategic instruments, and other planning instruments, shaping a linear extension of residential, commercial and industrial development in new cities along western and south-western transportation corridors, and a new north-western corridor, have not delivered an improvement in sustainability to the level of current community expectations of the early 21<sup>st</sup> century. However, the outcomes over the twenty-year period for the Outer Ring have generally been an improvement in comparison to the trend in the Inner Ring.

From a sustainability perspective, the New South Wales Government’s “Centres Policy” over the 20 year period 1981 to 2001 shows a mixed result. The first decade showed evidence of decentralization and formation of polycentric centres. These have continued to develop but at a slower pace in the second decade compared with the Sydney CBD and North Sydney – the new “global cities”. These have maintained an overall sustainability advantage over the decentralized centres of Parramatta, Liverpool and Penrith even though there have been some gains by the Liverpool centre over the study period.

## CONCLUSIONS

A key to urban sustainability in cities is that environmental sustainability (stewardship), social equity and economic efficiency work together. In the assessment of sustainable performance all three pillars need to achieve complementary outcomes rather than competing outcomes. Urban form, transportation and interactions with communities are central to the question of the long-term sustainability of cities. A holistic, integrated approach to the assessment of the three pillars of sustainability (environmental stewardship, social equity and economic efficiency), and changes over time has been proposed, called the Urban Sustainability Framework (Figure 1).

A particular strength of using the Urban Sustainability Framework and the metrics demonstrated in this paper with particular reference to metropolitan Sydney, Australia, is that they are derived from data sets that have been commonly used by planners for many years. The sustainability framework enables the holistic picture of sustainability to be maintained during the assessment process.

However, a most important aspect of this methodology is that it is analytically based and all visualizations have traceability back through the algorithms to the three source inputs discussed in the paper. This is a particular strength when checking results, making scenario changes, applying different planning instruments and communicating the results to stakeholders and the general community.

Collectively, the Urban Sustainability Framework, sustainability metrics, companion urban dynamics metrics and urban system measures are a practical methodology in assessing urban sustainability performance.



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## ENDNOTES

1. [http://www.environment.nsw.gov.au/soe/soe2006/chapter2/chp\\_2.4.html#2.4.24](http://www.environment.nsw.gov.au/soe/soe2006/chapter2/chp_2.4.html#2.4.24). (accessed 10 Dec 2008)
2. Accessibility to employment (social spatial equity) is a metric of accessibility to employment for workers from their place of residence. This is a measure of social equity for workers in terms of the spatial location. It excludes any measure of the differences in social equity associated with personal characteristics of workers at each place of residence.
3. Accessibility to workforce (economic efficiency) is a metric of accessibility to workers for businesses. This is a measure of economic efficiency for each business in terms of the spatial advantage they have in attracting its workforce. Businesses with high accessibility to workforce are considered to have the greater choice in selection of staff and more opportunity to negotiate wages and salaries, increasing the efficiency of the business.
4. This includes the embedded CO<sub>2</sub>-e from car and road construction & maintenance over that route allocated to each vehicle kilometer travelled
5. Where units are (grams of CO<sub>2</sub>)<sup>-1</sup>
6. Hansen measures of potential accessibility

## REFERENCES

- Black, J. (1981) *Urban Transport Planning: Theory and Practice*, Baltimore: John Hopkins University Press.
- Black, J., and Doust, K. (2008). "Metrics of Environmental Sustainability, Social Equity and Economic Efficiency for Employment Location and Commuting." In Tony Gilmour and Edward J. Blakely with Rafael E. Pizarro (eds) *Dialogues in Planning, Towards Sustainable Regions*, Sydney University Press, Chapter 2.
- Blunden, W. R. and J. A. Black. (1984) *The Land-use/Transport System*, 2<sup>nd</sup> ed., Pergamon Press, Sydney.
- Doust, K. (2008) *Metrics of Environmental Sustainability, Social Equity, and Economic Efficiency in Cities*. Unpublished PhD thesis, University of New South Wales, School of Civil and Environmental Engineering, December.
- Hidas, P. and J. Black. (2001) "SMART Targets for Sustainable Transport – A Review of International and Local (NSW) Practice", *Transport Engineering in Australia*, Vol.7, Nos. 1 & 2, pp.77 - 92.
- Holliday, S. (2008) "Planning for National Growth and Urban Development – Outlining Best Practice Models from around the Nation," 3rd Annual Metropolitan Planning & Design Summit, 26th & 27th May, 2008 - The Radisson Plaza, Sydney (CD-ROM).
- Hutabarat, R., Harris, D. and Black, J. (1998) "Transport and Sustainable Development: Considerations for Australia and Approaches in the USA and UK", 22nd ATRF, Sydney, 30 September to 2 October, Papers of the Australasian Transport Research Forum, Vol. 22, Part 1, pp. 99 - 115.
- Newman, P. and J. Kenworthy. (1999) *Sustainability and Cities: Overcoming Automobile Dependence*, Washington, D. C., Island Press.

New South Wales Government. (1968) *Sydney Region Outline Plan*, Sydney, The State Planning Authority of New South Wales.

New South Wales Government, (2005) *NSW Government's Metropolitan Strategy - City of Cities: A Plan for Sydney's Future* (CD-ROM).

Parliament of Australia, House Standing Committee on Environment and Heritage (2005) *Sustainable Cities, Canberra: Commonwealth of Australia*. (<http://www.aph.gov.au/house/committee/enviro/cities/prelims.htm>.)

Suthanaya, P. and Black, J. (2001) "Urban form and journey to work travel behaviour using Census data for 1961 – 1996." *Journal of the East Asia Society for Transportation Studies: Environment and Safety*, 4(5), pp.27-42.

United Nations. (2002) *Report of the World Summit on Sustainable Development*, 26 August - 4 September 2002. Johannesburg, South Africa.

Winston, D. (1957) *Sydney's Great Experiment: The Progress of the County of Cumberland Plan*, Angus and Robertson, Sydney.

World Commission on Environment and Development. (1987) *Brundtland Report - Our Common Future*, Oxford University Press, Oxford.

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# NEIGHBOURHOOD DESIGN IMPACT ON TRAVEL BEHAVIOR : A COMPARISON OF US AND UK EXPERIENCE



## ABSTRACT

This paper presents evidence from the UK in respect of the impact of neighbourhood design on travel behaviour using a neighbourhood, micro scale, case-study approach. Whilst there is an extensive American literature on this subject, this is limited in applicability to European or British practice since the urban form variables, such as street layout and levels of car use in all areas, have a different scale.

Neighbourhood design and travel attitude characteristics were modelled using factor analysis and the causation relationship was established using reported vehicle miles driven (VMD) as the dependent variable in a subsequent regression analysis. Despite modest differences in VMD between UK and US, there are significant differences in its explanation. The most important predictors for the UK study are the socio-economic variables, followed by travel attitudes, neighbourhood characteristics preferences and land-use type in contrast to the US experience which identifies travel attitude as the biggest predictor of VMD.

Many studies in this field suffer from the criticism that respondents select their area of residence because of specific neighbourhood characteristics and this gives rise to a 'self-selection' issue. This study addresses this by the collection and analysis of quasi-longitudinal data from respondents who moved home in the previous eight years. This analysis shows that travel accessibility is sensitive to changes in walking and public transport use, suggesting that residents of British neighbourhoods are more aware of public transport than their US counterparts and more likely to use sustainable, low carbon means of travel.

## INTRODUCTION

Whilst individuals appear increasingly wedded to their cars, there are new trends emerging from the developments of neighbourhoods arising out of the 'New Urbanism' movement in the US and 'Compact City' movement in Europe. These movements promote a state of sustainable travel identified as a low carbon based travel. Governments have been quite sensitive in their response to this idea with 'Smart Growth' in the US, the 'ABC' policy in the Netherlands and PPG13 in the UK being the confirmation of governmental support of such movements. These trends also confirm the increasing research findings that support a less car dependent environment and promote alternatives travel through land-use planning. Although it has long been thought that urban form, land-use and design can influence travel demand (Cervero & Kockelman, 1997), recent research findings have revealed that land-use characteristics impacts on travel behaviour through quite complex relationships (Boarnet & Crane, 2001). Socio-economic variables, attitudes and preferences towards travel and neighbourhood characteristics, and residential self-selection, are some of the contributing characteristics which also bring about change in travel behaviour (Handy et al, 2005).

Most studies looking at the impact of the built environment on travel behaviour identify that the provision of higher density, mixed land-use, public transport service accessibility and pedestrian friendly built environment can contribute to a less car dependent environment. At the macro scale (i.e. density and mixture of land-use) there is considerable evidence identifying advantages and improving understanding towards sustainable travel development (see for example: Newman & Kenworthy, 1989; Badoe & Miller, 2000; Ewing & Cervero, 2001) although the implementation of this in the planning policy at all levels (despite Governmental support) has never been a straightforward issue (Curtis, 2007). At the micro scale (i.e. neighbourhood design characteristics and personal travel behaviour) more recent studies are emerging showing that neighbourhood characteristics can influence people's travel pattern towards sustainable travel (see for example: Handy et al., 2005, Bhat & Guo, 2007). The planning practice to implement development to promote sustainable travel pattern at this micro level has (again) not been easy (CABE, 2004), particularly as it is against a growth in car ownership and increases in car travel. However, the trend of looking at the micro scale of land-use and travel behaviour relationships identifies a need to understand design at a human scale. The message is quite clear that urban form should be built for the human not car if sustainable travel is to be achieved.

There is a considerable American literature on land-use and travel behaviour and in the UK, the most extensive work has been undertaken by Stead (2001) who concluded that socio-economic factors explained more than 50% of the variation in the amount of travel by census wards (which are slightly larger than the US census tract). Recently there have been two publicly funded projects to address this issue. 'City Form', started in 2001, has been looking at the macro scale

to answer the extent the ways urban form contributes to sustainability. Its main finding is that density is the largest explanatory variable of sustainability. The second, 'SOLUTIONS', started in 2004, is also working at the macro scale to identify how far, and by what means, towns and cities can be planned so they are socially inclusive, economically efficient and environmentally sustainable. The study reported in this paper is conceived at the micro scale of neighbourhoods with the objective of understanding the links between neighbourhood design characteristics and travel behaviour that contribute towards sustainable travel patterns.

Although there have been many studies, these have concentrated on looking at the association between neighbourhood design characteristics and travel behaviour. In the US, an important step forward has been the investigation of causal relationships between neighbourhood design characteristics and travel behaviour (Handy et al., 2005). Perhaps even more importantly, work in this area has shown that changes in neighbourhood design lead to changes in travel behaviour (Cao et al., 2007). This paper will report British evidence of the impact of neighbourhood design characteristics on travel behaviour. The study approach uses a case study and a quasi-longitudinal questionnaire methodology to investigate the relationships between travel behaviour and neighbourhood design characteristics as well as to capture changes in travel behaviour before and after people relocate.

In the cross-sectional analysis, the study found that there is a similarity between the US and the UK evidence where the built environment characteristics impacts on travel behaviour although in UK the impact is relatively bigger. In contrast, whilst the US evidence found that travel attitude explained the vehicle miles driven (VMD) better than the socio-economic variables, the reverse is true in the UK with socio-economic variables being more influential in the explanation of VMD suggesting that travel behaviour in the UK and US are different.

In the quasi-longitudinal analysis, undertaken to look at the issue of residential self-selection, the study found that travel accessibility perception in the UK is sensitive to changes in walking and public transport use. This suggests that residents of British neighbourhoods are more aware of public transport than their US counterparts and more likely to use sustainable, low carbon means of travel. However, this is influenced by the transport and land-use patterns and in the UK these are different from the US. Many of the suburban residential neighbourhoods of the UK are not as isolated as the suburban neighbourhoods of the US. In the US evidence, residents who live in the suburban neighbourhoods and who claim to prefer not to use private car have no alternative. In contrast UK residents who live in suburban neighbourhoods still have access to public transport service and local facilities, especially when living in a metropolitan conurbation area such as Tyne and Wear which has an extensive public transport system. This means that residential self-selection may not be as big an issue in the UK, as compared to the US, because alternatives are more available for those who have preferences – both pro-public transport and pro-car.

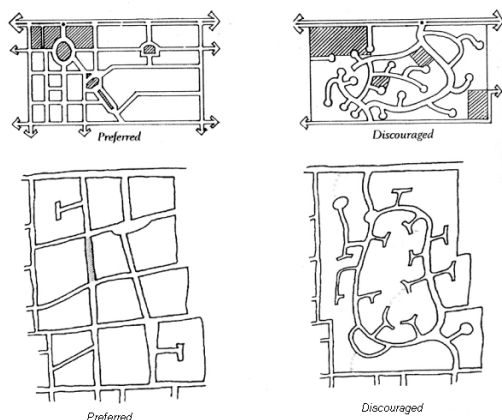
## LITERATURE REVIEW

The literature reported here is looking at the trend of analysis over time in the search for evidence of land-use planning contributing to sustainable travel. In the US the idea that land-use and design polices could be used to influence travel behaviour started in the late 1970s whereas in the UK this was not happening until the late 1980s when the issue began to attract research interest (Headicar, 2003). The work of Newman and Kenworthy (1989) looked at a sample of international cities and established that density could have a strong relationship with travel behaviour. Their campaign to overcome car dependence in favour of more environmentally sustainable travel patterns has led to many subsequent questions as to the cause and effect between urban form and travel behaviour. Since the early 1990s there have been many studies (especially in the US) which have put effort into testing the hypothesis that polices that shape the built environment can be used to reduce car travel where the built environment is defined as consisting of three components: land-use patterns, transportation system and design (Handy, 2005).

In broad terms, research on the influence of built environment on travel behaviour can be classified into three different approaches: hypothetical studies, descriptive studies and multivariate statistical studies (Boarnet and Crane, 2001). In hypothetical studies, the general idea is to construct situations, in a strategically and controlled environment, where different land-use patterns and other urban features can be linked to travel. Traditional transportation models are used to predict differences in total travel between typical suburban neighbourhoods and hypothetical neo-traditional neighbourhoods (Handy, 1996). These studies are not intended to explain behaviour; rather they make certain assumptions regarding behaviour and then apply those to alternative situations to see what happens. This approach has usually tended to focus on the overall structure of a city or metropolitan area, in terms of the distribution of employment and residential activities and/or the structure of the transportation network (Handy, 1996). Figure 1 describes the illustration of the differences of street pattern that may lead to differences of travel pattern with the 'preferred' layout being associated with more sustainable travel.

Descriptive studies provide an account of travel experiences, individually or on average. These studies provide a picture of observed behaviour and may contain important data and revealing insights regarding travel patterns in different settings. However, these studies can not explain travel behaviour and only report what is observed. Multivariate statistical studies examine observed rather than hypothetical behaviour. These studies attempt to explain rather than merely describe what is going on. The studies in this category vary from descriptive studies in several significant ways. First, they ask different questions of their data. Second, their data captures different features of the built environment and of travellers and at different levels of detail. Third, they investigate their data by (usually) statistical means (Boarnet & Crane, 2001). For example,





**FIGURE 1.** Examples of 'Preferred' + 'Discouraged' neighborhood street layouts. *Source:* Marshall, 2005.

Ewing and Cervero (2001) in their meta analysis of built environment impact on travel behaviour came to the conclusion that the built environment has a greater impact on trip length than trip frequencies and that mode choice depends on socio-economic as much as the built environment characteristics. Cervero and Kockelman (1997) in their study of mode choice impact on built environment concluded that compact, mixed land-use and pedestrian friendly urban development can significantly reduce car travel.

A questionnaire that simply asks for information on the current residential neighbourhood is open to the criticism of ignoring the issue of residential self-selection. For this reason, recent studies have involved a longitudinal design to capture the effect of time order. Thus, the issue of causality of the neighbourhood design impact on travel behaviour is the main focus in recent US studies (e.g. Handy et al., 2005 and Krizek, 2003). The studies involving time order factors have revealed causal relationships between neighbourhood design and travel behaviour (Meurs & Haaijer, 2001, Krizek, 2003, Handy et al., 2005). An extensive residential self-selection study by Schwanen and Mokhtarian (2005) found that neighbourhood type does impact on travel behaviour.

Table 1 brings together the results from some influential studies in urban form and travel behaviour relationships. This extensive American literature gives mixed results. There appears always to be a positive result (in terms of built environment can impact on travel behaviour to reduce car travel) when a hypothetical or descriptive approach is taken but this same effect is not shown in multivariate analysis which has given rise to both negative and positive results. Thus it is clear that the explanation as to why people have certain travel patterns depends on many factors. More evidence is needed to strengthen the understanding of various land-use impacts on travel. Where land-use characteristics are used to measure car use (e.g. Vehicle Miles Driven as known VMD), density, mixed land-use, pedestrian pavements and public transport provision play a role

in reducing car travel (Cervero & Kockelman, 1997, Meurs & Haaijer, 2001, and Krizek, 2003) but this is not always clear cut as there are some studies confirming negative results of land-use characteristics in explaining VMD (Boarnet & Crane, 2001, Handy et al., 2005).

When socio-economic and travel attitudes are accounted for, the results suggest land-use characteristics play less of a role in explaining car travel (Kitamura et al., 1997, Stead, 2001, Dieleman et al., 2002, Boarnet & Crane, 2001, Naess and Jensen, 2004 and Handy et al., 2005), although a recent study by Bhat and Guo (2007) without travel attitude consideration, confirms that built environment characteristics affect residential choice decisions as well as car ownership decisions. However, the studies that have looked at longitudinal data to capture what happens when people move residence and the way their travel changes according to the available built environment characteristics has revealed causal relationships in terms of land-use transport issues (Meurs & Haaijer, 2001, Krizek, 2003, Handy et al., 2005). Furthermore, European studies such as Naess and Jensen (2004) and Meurs and Haaijer (2001) show that neighbourhood design characteristics clearly influences travel behaviour.

More recent US studies are now focussing on residential self-selection. The argument is that if people choose to live in a neighbourhood which favours their preferences, then it is their preferences what make them travel the way they do, not the neighbourhood design characteristics (Handy et al., 2005). (Cao et al., 2009 - forthcoming) undertakes a thorough review of methods used to investigate the residential self-selection issue and concludes that the methodology employed by Handy et al. approach is the most powerful. For this reason, this study has developed the approach of Handy et al. (2005) to include travel attitude characteristics and to look at the impact of residential self-selection.

In the UK, the issue of how neighbourhood design impacts on travel behaviour together with the issue of residential self-selection has been less well researched. As land-use patterns in the UK are different from the US, this paper addresses whether the impact of neighbourhood design and residential self-selection might also be different. Many of the suburban residential neighbourhoods of the UK are not as isolated as the suburban residential neighbourhoods of the US (Schwanen and Mokhtarian, 2005). In the US evidence, residents who live in the suburban neighbourhoods and who claim to prefer not to use private car have no alternative. In contrast UK residents who live in suburban neighbourhoods still have access to public transport service and local facilities. This means that residential self-selection may not be as big an issue in the UK, as compared to the US. For this reason, looking at the neighbourhood design impact on travel behaviour in the UK will give insight to the extent to which neighbourhood characteristics or residential self-selection play a role in explaining travel behaviour.

The UK based study by Stead (2001) looked at the three dimensional relationships of land-use,

travel patterns and socio-economic variables but did not consider travel attitudes and preferences. The evidence presented in this paper provides evidence for this gap using disaggregated data to focus on the British evidence on the impact of neighbourhood design and residential self-selection on travel behaviour.

## METHODOLOGY

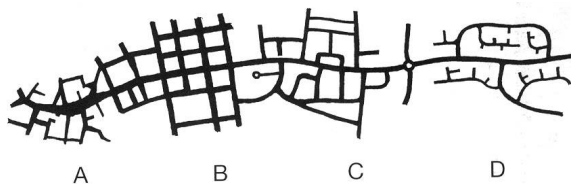
The objectives of the study presented here are to explore the relationship between neighbourhood design and travel behaviour with a deliberate focus on a British case study at the micro level. As such it provides evidence to assess whether the US literature in this field has a direct applicability to British cities where the urban form variables, such as street layout and levels of car use in all areas, have a different scale. In addition to scale differences, of the association and causation between different neighbourhood design characteristics and travel behaviour, the travel attitudes and preferences in the UK could differ from the US experience because of underlying cultural differences. Thus the underlying hypothesis to this study is

*“Neighbourhood design characteristics and travel behaviour association in the UK may be different to those exposed for the US in the existing American literature because of differences in the nature of urban form and underlying differences in travel attitudes and preferences”*

A questionnaire methodology was used to capture four aspects of neighbourhood design characteristics (through respondents’ perception and preferences and also for their previous residence if they had moved in the past 8 years): travel attitudes, socio-economic variables and travel patterns (including information on Vehicle Miles Driven known as VMD). These are important for this study as the intention is to model the impact of the built environment characteristics and travel attitudes, in addition to the normal travel demand characteristics, on travel behaviour.

### Selection of case study neighbourhoods

Since the objective of the study is to examine British case, the selection of neighbourhood hotspots to depict the typical British residential neighbourhoods was important. Ten neighbourhoods were selected to represent five Districts of Tyne and Wear metropolitan area in the North East of England. The neighbourhoods were selected to vary systematically on neighbourhood type, the Districts of the metropolitan conurbation and size of neighbourhoods. The neighbourhood types were characterised by various street pattern layouts based on typo-morphology classification advocated by Marshall (2005) (See Figure 2). However this typology does not easily create comparison with the existing American literature, and for the purpose of this paper, traditional and suburban neighbourhood comparison is used to make a descriptive comparison. Traditional neighbourhoods were built mostly before World War II and suburban neighbourhoods were built



**FIGURE 2.** ABCD typology as transect. *Source:* Marshall, 2005.

**TABLE 2.** Case-Study areas classified by ABCD typology, Census 2001 percentage of sustainable travel to work and neighbourhood types

| ABCD typology sorting  | % Sustainable travel to work (walk, cycle, metro and bus) |                                    |
|------------------------|---|------------------------------------|
|                        | High  | Low                                |
| B or B prone to C type | South Shields, South Tyneside (T)                         |                                    |
|                        | Low Fell, Gateshead (T)                                   |                                    |
| C type                 | Lemington, Newcastle (T)                                  | Cleadon Park, South Tyneside (S)   |
|                        | Fulwell, Sunderland (T)                                   | Tynemouth, North Tyneside (T)      |
| D type                 | Pelaw - Wardley, Gateshead (S)                            | Chapel Park, Newcastle (S)         |
|                        |   | Preston Grange, North Tyneside (S) |
|                        |   | Washington, Sunderland (S)         |

(T) = traditional neighbourhood

(S) = suburban neighbourhood

post-1960s. Thus to compare the results of this study with the American based literature, the suburban typology has been classified as D type neighbourhoods and the traditional neighbourhood as C type or B type although the scale of street design in the UK is lower than in the US.

The neighbourhood unit was captured by reference to the lowest administration area used in the latest British Census (2001), the Lower Layer Super Output Area (LSOA). Tyne and Wear metropolitan area contains 719 different LSOA in total and on average, a LSOA consist of 1500 household with 7500 individual persons. The potential neighbourhoods for survey were screened District by District to ensure that income and other characteristics were above average for the area using Index of Multiple Deprivation 2004<sup>1</sup> to control for these characteristics. The purpose of this screening was to find neighbourhoods where people would choose to live rather than areas where housing might be allocated on the basis of need as it is preferences in the choice in the built environment that is being considered.

To combine the census screening and neighbourhood design screening, Google Earth™ was then used to capture the aerial view of a shortlist of potential neighbourhood ‘hotspots’ as well as to identify the homogeneity of street lay out within the LSOA. A total of 190 LSOAs from the

38 highest IMD of each district were image captured and analysed in this way. After filtering the potential 'hotspots' through controlling for income (high IMD) and the sustainability of travel exhibited (percentage of high and low of car travel to work as well as the percentage of walking, cycling and public transport use), the most representative residential neighbourhood according to traditional and suburban layout were selected as the areas for the case-study approach.

Table 2 shows how the chosen areas are classified according to the ABCD typology, as well as the characteristics of high vs low percentages of sustainable travel to work attributes derived from the British Census 2001 data which includes the modes of walk, cycle, metro and bus. It is noticeable that the A type is missing as it was not possible to find this within Tyne and Wear. Aerial views of Tyne and Wear with the geographical position of these 10 selected neighbourhoods is shown in Figure 3.

### Survey and sampling

The survey was undertaken in late spring 2007 in the form of a self-administered 8 page questionnaire booklet. The survey was delivered to personally addressed households in each of the ten neighbourhoods identified in the previous section. A sample of approximately 220 households in each neighbourhood was selected in proportion to the total size of the LSOA. Names and addresses were obtained from the electoral register of voters. A prepaid self-addressed envelope was enclosed inside each questionnaire which was hand delivered. One week later, a reminder postcard with individually addressed was delivered.

In total 2157 questionnaire were delivered. The number of returned questionnaires totalled 716 giving a response rate of 33% of which 32% provided valid data for the analysis. A comparison of sample characteristics (based on British Census 2001) shows that overall the socio-economic variables of the sample characteristics are quite similar to the population characteristics with the exception of age and the number of households with dependent children. The number of people aged above 45 is higher than displayed in the Census and the number of household with dependent children is less than recorded in the Census. However, the average number of years lived at the current address is extremely high for respondents (over 20 years in the traditional neighbourhood and over 15 years in the suburban neighbourhood) and thus a proportion of households which would have dependent children in 2001 would have not had dependent children at the time of this survey, six years later. Given the growth in car ownership nationally it is also not surprising that the respondents from the survey showed more cars per household than at the time of the Census. Despite these differences of the sample against the Census, the focus of this study is on explaining the relationships of other variables to travel behaviour rather than on describing travel behaviour on its own and these differences are not expected to affect the results (Babbie, 2004).



1. Chapel Park, Newcastle



4. Pelaw-Wardley, Gateshead



7. Cleadon Park, South Tyneside



8. South Shields, South Tyneside



2. Lemington, Newcastle



5. Washington, Sunderland



9. Tynemouth, North Tyneside



3. Low Fell, Gateshead



6. Fulwell, Sunderland



10. Preston Grange, N. Tyneside



**FIGURE 3.** Google Earth aerial view captured for ten selected neighbourhoods in the Tyne and Wear metropolitan district. *Source:* Aditjandra, 2008.



## EMPIRICAL RESULTS

This section considers the results of this survey. In the first, neighbourhood design characteristics and travel attitude characteristics are analysed. The characteristics were measured through statements used in the questionnaire which derived from Handy et al. (2005) work. Initially this replication of work will allow result of neighbourhood characteristics and travel attitude to be compared between the US and the UK. Factor analysis has been used to disentangle the many statements used in the questionnaire into fewer factors that construct the neighbourhood and travel attitude characteristics. The travel pattern variable is described in the second section and this is followed in the third section by a descriptive analysis of differences between the urban forms identified in this study using ANOVA. The fourth section shows the results of modelling the relationship between the factors obtained in the earlier sections, socio-economic variables and travel patterns using ordinary least square regression. The final section considers the results of quasi longitudinal analysis of travel behaviour.

### Neighbourhood design characteristics and travel attitudes

Respondents were given 27 statements about neighbourhood characteristics and asked to rate how true these were for where they lived on a four-point scale from 'not at all true' until 'entirely true'. If respondents had moved to their current address within the last 8 years, they were asked to do the same for their previous address. These neighbourhood characteristics, as perceived by survey respondents, reflect the fundamental differences in neighbourhood design. The importance of these characteristics to respondents when they were looking for their 'ideal' place to live was also measured with a four-point scale from 'not at all important' to 'extremely important'. Handy et al. (2005) has highlighted that the comparison of individuals' perceived neighbourhood characteristics for their current residence and their preferences for neighbourhood characteristics indicates how well their current neighbourhoods meet their preferences. Since many of these characteristics measure similar dimensions, factor analysis is used to reduce the data so as to identify the main factors of perceived and preferred neighbourhood characteristics respectively.

Factor analysis was conducted to identify the underlying constructs of perceived and preferences for neighbourhood characteristics since many statements of neighbourhood design characteristics used in the questionnaire measure similar dimensions. Through this analysis perceived and preferred neighbourhood design characteristics were extracted into 7 factors which include safety, travel accessibility, residential spaciousness, social factors, shopping/facilities accessibility, outdoor space accessibility and neighbourhood attractiveness as shown in Table 3.

Travel attitudes were measured by asking the respondents of their level of agreement on a series

of 28 statements on a five-point scale from 'strongly disagree' to 'strongly agree'. For the same reason as the above neighbourhood characteristics perceptions and preferences, factor analysis was carried out again to reduce the many statements into fewer factors and these are shown on the right side of Table 3. The 28 statements were reduced to 8 factors including pro-public transport use, travel minimising awareness, pro-cycling, travel time sensitivity, safety of car, pro-walking, pro-travel and car dependent.

There are a number of differences between these British results and the US results reported by Handy et al. (2005). First, the analysis has identified more factors for perceptions and preferences of neighbourhood characteristics and travel attitudes. In particular, this study has found three factors of accessibility of neighbourhood: travel accessibility (which has a high association with public transport service), shopping/facilities accessibility (which has a high association with access to a shopping centre) and outdoor space accessibility (which has a high association with parks and open space). Whilst 'outdoor space accessibility' is a similar factor to the 'physical activity options' factor found in the US study, the US 'accessibility' is only correspond to the 'shopping/facilities accessibility' in this study. The separation of 'travel accessibility' and 'shopping/facilities accessibility' in this study suggest that for British neighbourhoods, public transport service use is recognised as a useable option which in turn suggests that public transport can be made to be a reasonable alternative to a car.

In travel attitudes, the respondents in this study differentiate between travel attitude factors for walking and cycling. This finding contrasts with the result from the US study which found that walking and cycling were identified as a single factor, suggesting that US respondents perceive walking and cycling as similar. It is also suggests that cycling and walking are thought of as different in British neighbourhoods: this could be because cycling is often thought of as a recreational activity whereas walking within the neighbourhood can be part of a daily commuting or shopping pattern as well as a recreational activity.

### Travel pattern

Travel patterns of the respondents were measured in the questionnaire by asking respondents to report the vehicle miles driven (VMD), chosen as the dependent variable because of its importance in the planning process. The questionnaire asked for information on the commute trip separately from other travel. In capturing VMD, the respondents were asked to give this information day by day for the previous week's travel by car and to identify if this reported mileage was typical. If the mileage was not typical, respondents were asked to identify their typical VMD and to report this separately. Respondents were also asked to give information of their household VMD by leaving space for other member of the household to report their VMD. The total reported typical VMD per week is used as the dependent variable in cross-sectional model.



Weekly VMD per household by the suburban neighbourhood group is 54% higher than the traditional neighbourhood group (Table 4). This pattern contrasts with the US evidence that shows that their traditional neighbourhoods had higher VMD but that their suburban neighbourhood had lower average VMD than this study. This finding suggests that British neighbourhoods show a


**TABLE 4. Vehicle miles driven (VMD) and explanatory variables by neighbourhood type**

|  | Average<br>for<br>traditional | Average<br>for<br>suburban | p-value <sup>b</sup><br>traditional<br>only | p-value <sup>b</sup><br>suburban<br>only | p-value <sup>b</sup><br>traditional/<br>suburban pooled |
|--|-------------------------------|----------------------------|---|--|---|
| Weekly VMD by household                              | 123                           | 190                        | 0.00  | 0.00                                     | 0.00  |
| Perceived neighbourhood characteristics <sup>a</sup> |                               |                            |   |  |   |
| Safety   | -0.08                         | 0.07                       | .00   | .45                                      | .00   |
| Travel accessibility                                 | 0.14                          | -0.12                      | .00   | .00                                      | .00   |
| Residential spaciousness                             | -0.38                         | 0.21                       | .00   | .00                                      | .00   |
| Social factors                                       | 0.20                          | -0.15                      | .01   | .01                                      | .00   |
| Shopping/facilities<br>accessibility                 | 0.23                          | -0.20                      | .00   | .00                                      | .00   |
| Outdoor space accessibility                          | -0.16                         | 0.25                       | .00   | .00                                      | .00   |
| Neighbourhood attractiveness                         | 0.14                          | -0.12                      | .00   | .05                                      | .00   |
| Preferred neighbourhood characteristics <sup>a</sup> |                               |                            |   |  |   |
| Safety   | 0.05                          | -0.03                      | .42   | .59                                      | .38   |
| Travel accessibility                                 | 0.08                          | -0.07                      | .30   | .00                                      | .01   |
| Residential spaciousness                             | -0.17                         | 0.11                       | .00   | .40                                      | .00   |
| Social factors                                       | 0.10                          | -0.10                      | .06   | .14                                      | .04   |
| Shopping/facilities<br>accessibility                 | 0.03                          | -0.01                      | .13   | .28                                      | .95   |
| Outdoor space accessibility                          | -0.03                         | 0.06                       | .43   | .46                                      | .19   |
| Neighbourhood attractiveness                         | 0.12                          | -0.08                      | .25   | .32                                      | .01   |
| Travel attitudes <sup>a</sup>                        |                               |                            |   |  |   |
| Pro-public transport use                             | 0.09                          | -0.07                      | .34   | .00                                      | .01   |
| Travel minimising awareness                          | 0.01                          | -0.05                      | .19   | .48                                      | .35   |
| Pro-cycling  | 0.04                          | -0.09                      | .09   | .19                                      | .06   |
| Travel time sensitivity                              | -0.02                         | 0.00                       | .37   | .46                                      | .81   |
| Safety of car  | 0.00                          | 0.02                       | .04   | .37                                      | .45   |
| Pro-walking  | 0.13                          | -0.09                      | .00   | .12                                      | .02   |
| Pro travel   | -0.09                         | 0.10                       | .75   | .36                                      | .03   |
| Car dependent  | -0.12                         | 0.07                       | .12   | .01                                      | .02   |

SOURCE This study

<sup>a</sup> Scores normalised to a mean value of 0 and variance of 1

<sup>b</sup> p-value for F-statistics from analysis of variance (ANOVA)

 Significant at 5% level

bigger variation between different neighbourhoods. The high VMD average in British suburban neighbourhoods suggests that this type of residential development is much different compare to the American suburbs but that the British suburb exhibits even higher levels of car travel.

Comparison between traditional and suburban neighbourhoods

The results of an ANOVA are shown in Table 4 where p-values indicate significant at 5% level are shaded. This table shows that for the perceived neighbourhood characteristics have many significant intra-group differences for the traditional and for the suburban neighbourhoods. In addition, whilst there are some intra-group variation in the preferred neighbourhood characteristics, this is less than for the perceived characteristics. Despite these intra-group differences, the ANOVA shows that there are significant differences between traditional and suburban in all of the perceived neighbourhood factors. The traditional neighbourhood group score significantly higher than suburban neighbourhood group on factors for ‘travel accessibility’, ‘social factors’ and ‘shopping/facilities accessibility’ but lower on ‘safety’, ‘residential spaciousness’, ‘outdoor space accessibility’ and ‘neighbourhood attractiveness’. Comparing travel attitudes, the traditional

| TABLE 5. Ordinary Least Square Regression: model result for ln(VMD + 1) |                             |                           |        |      |
|---|-----------------------------|---------------------------|--------|------|
| Model   | Unstandardized Coefficients | Standardized Coefficients | t      | Sig. |
|   | B                           | Beta                      |        |      |
| (Constant)  | .370                        |                           | 2.140  | .033 |
| Female  | -.263                       | -.066                     | -2.789 | .005 |
| Employed  | .599                        | .146                      | 5.464  | .000 |
| Driving license to H/H  | .953                        | .403                      | 14.337 | .000 |
| Cars per adult  | 1.421                       | .289                      | 10.753 | .000 |
| Pro-walking   | -.078                       | -.039                     | -1.663 | .097 |
| Pro-public transport  | -.280                       | -.141                     | -5.494 | .000 |
| Safety of car   | .132                        | .066                      | 2.827  | .005 |
| Car dependent   | .266                        | .135                      | 5.444  | .000 |
| Shopping / facilities accessibility preference                          | -.128                       | -.064                     | -2.708 | .007 |
| Suburban (dummy, suburban = 1, traditional = 0)                         | .217                        | .054                      | 2.283  | .023 |

SOURCE This study

N = 659, R-square = 0.651, Adjusted R-square = 0.645 (significant with p-value of 0.000)  
 Dependent Variable: LnVMDplus1  
 Predictors: (Constant), Suburban, Shopping accessibility preference, Safety of car, Female, Pro-walking, Pro-public transport use, Cars per adult, Car dependent, Employed, Driving license to H/H.

neighbourhood group score significantly higher on the factors of 'pro-public transport use', 'pro-walking' and 'pro-travel' but lower on 'car dependent' attitude. However, these results are only descriptive and to examine the relative importance of these characteristics in explaining the amount of private car use, a multivariate modelling exercise was undertaken which is reported in the next section.

An interesting finding which also shows a significant difference between the UK and the US is that the traditional neighbourhoods in the UK case study were reported as less attractive by its residents as compared to the suburban neighbourhoods. This contrasts with the US evidence where the traditional neighbourhoods were reported to be more attractive than the suburban neighbourhoods. For planning authorities this is an important finding. As this case study is in Tyne and Wear, the planning authorities may wish to support an improvement to make traditional neighbourhoods more attractive to live in whilst maintaining the operation of frequent public transport service and promoting a walking lifestyle so as to meet better sustainable travel mobility practice.

### Cross-sectional analysis of VMD

An Ordinary Least Square model was constructed using log weekly VMD household ( $\ln \text{VMD}$ ) as the dependent variable. In anticipating respondents who were reporting zero VMD, a value of one was added to all the zero reported VMD so the true dependent variable is  $\ln (\text{VMD} + 1)$ . The model regression initially included variables identified as important in US work before testing a wider variety of variables. The results are presented in Table 5. The single equation approach was adopted from Handy et al. (2005)

In the US analysis, 'age' was included in the model but in the British data this was found to be highly correlated with 'employment status' and it was felt that this predictor should therefore be excluded. In the US, the 'car dependent' attitude was the strongest predictor but in British case, the presence of a driving license is the strongest predictor of VMD (shown by the highest standardised coefficient). Being employed (and in general being older, given the high correlation between employment status and age) and having a car dependent attitude also serve the increase VMD whereas, with similar magnitude but opposite in direction, having a pro-public transport attitude will reduce the number of VMD. This finding suggests that in British neighbourhoods, travel by car or public transport can be considered as substitute modes in contrast to American neighbourhoods where there are less alternatives to driving.

A dummy variable was included to see if there were differences between the responses from the respondents living in traditional or suburban neighbourhoods. This is significant at the 5% level suggesting that land-use type also a good predictor in the model. Furthermore the magnitude

TABLE 1. Summary of literature review of urban form and travel behaviour relationships

| Author                 | Place of study                      | Year | Type of analysis | Urban form considered                         |
|------------------------|-------------------------------------|------|------------------|---|
| Newman and Kenworthy   | Global worldwide                    | 1999 | D                | Cities  |
| Headicar and Curtis    | Oxford, UK                          | 1998 | D                | Suburban vs Town                              |
| Naess and Jensen       | Frederikshavn, Denmark              | 2004 | D, M             | Urban and Peripheral settlements              |
| Dunphy and Fisher      | National Transportation Survey, USA | 1996 | D                | Cities  |
| Van and Senior         | Cardiff, Wales, UK                  | 2000 | D                | High mix, low mix, and no mix                 |
| Meurs and Haaijer      | The Netherlands                     | 2001 | D, H, M, L       | Rural vs village vs suburban vs urban         |
| Simmonds and Coombe    | Bristol, UK                         | 2000 | H                | Trend vs Compact City vs Alternative scenario |
| 1000 friends of Oregon | Oregon, Portland, USA               | 1996 | H                | No build vs Highways vs LUTRAQ                |
| Cervero and Kockelman  | San Francisco Bay, California USA   | 1997 | M                | Neighbourhoods chosen according census tract  |
| Kitamura et al.        | San Francisco Bay, California USA   | 1997 | M                | 5 neighbourhoods                              |
| Dieleman et al.        | Dutch National Travel Survey        | 2002 | M                | Cities, Regions                               |
| Stead                  | UK                                  | 2001 | M                | 8400 wards in England                         |
| Boarnet and Crane      | San Diego, California, USA          | 2001 | M                | Traditional vs Suburban                       |
| Handy et al.           | California, USA                     | 2005 | M, L             | Traditional vs Suburban                       |
| Krizek                 | Central Puget Sound, Seattle, USA   | 2003 | M, L             | Neighbourhood accessibility high vs low       |
| Bhat and Guo           | San Francisco Bay, California, USA  | 2007 | M                | Transport analysis zones                      |

D = Descriptive; H = Hypothetical; M = Multivariate analysis; L = Longitudinal

| <b>Travel measurement</b>                                     | <b>Empirical Result</b> (+ is positive result of land use-contributing to sustainable travel and – is the opposite conclusion) |   |
|---|--|---|
| Density, Energy, Journey to work distance, Mode               | +  | Density and mixed land-use contribute to sustainable travel patterns  |
| Modes share, travel distances, public transport service       | +  | Public transport provision associated with lower mode share per car and lower distance travel by car  |
| Total travel distance and mode choice                         | ++   | Urban structural characteristics influences travel activity even after accounting socio-economic and attitudinal characteristics  |
| Public transport use, density                                 | +  | Public transport use high and lower car travel in higher density communities  |
| Travel mode, frequency, distance, trip purpose,               | +/-  | Residents with some local shops may make just as many, or even more, car journeys than residents of neighbourhoods with no shops, although such car journeys are likely to be shorter |
| Total journey, home, street, n'hood characters.               | ++   | Home, street and neighbourhood characteristics have a clear impact on mobility  |
| Travel mode, Time, and frequency                              | +/-  | Slight reduction in total travel but no answer to number of trips, travel mode and other decision   |
| Trip mode, VMD  | +  | LUTRAQ doubles the mode share for community trips by public transport use trips and VMD by car drop accordingly   |
| Travel diaries, VMD, mode choice, density                     | +/-  | Land-use variables had significant effect but elasticities implied by regression coefficients were small compared to socio-economic variables   |
| Travel diaries, VMD, land-use and travel attitudes            | -  | High density related to proportion of non car trips. Residential attitude explains the travel pattern better than land-use characteristics  |
| Trip purpose, Mode travel, and distance                       | -  | Regression models revealed that personal attributes and circumstances have impact on modal choice and distance travelled  |
| Distance, mixed use, density                                  | -  | Socio-economic factors explain more than 50% of variation in travel patterns. Land-use explains less than a third of variation.   |
| Time, Density, Socio-economic variables                       | -  | Complex conclusion; street patterns and commercial concentrations are associated with fewer non-work car trips  |
| VMD, Built environment, socio economic, attitudes             | -/+  | Cross-sectional analysis shows attitude and socio-economic variables are predictors of VMD but longitudinal analysis shows land-use variables effect VMD                              |
| VMD, Persons miles travelled, no. trips, no. tours            | +  | Increase in neighbourhood accessibility results in reduced VMD and person miles travel (regardless of modes) and reduced no. of trips but increased no. of tours.                     |
| Car ownership, residential location, socio-economic variables | +  | Built environment does effect residential choice decisions as well as car ownership decisions; density is proxy variable to street block density and public transport accessibility   |

SOURCE This study

**TABLE 3.** Factor loadings from CFA on perceived and preferred neighbourhood characteristics (left) and travel attitude characteristics (right) (Source: this study)

| FACTORS (a)                        | STATEMENTS - VARIABLES                    | LOADINGS (b) |
|------------------------------------|---|--------------|
| Safety                             | Safe neighbourhood for walking            | .829         |
|                                    | Low crime rate                            | .777         |
|                                    | Safe neighbourhood for children outdoor   | .686         |
|                                    | Low level of car traffic                  | .673         |
|                                    | Quiet neighbourhood                       | .603         |
|                                    | Good street lighting                      | .364         |
|                                    | High level of neighbourhood's upkeep      | .240         |
|                                    | Easy access to highway network            | -.233        |
| Travel accessibility               | Easy access to a good P.T. service        | .877         |
|                                    | Good P.T. service                         | .804         |
|                                    | Easy access to highway network            | .417         |
|                                    | Pavements - easy walking routes           | .394         |
|                                    | Local shops within walking distance       | .353         |
| Residential spaciousness           | Adequate space of garden at the front     | .919         |
|                                    | Adequate space of garden at the back      | .857         |
|                                    | Adequate parking space                    | .560         |
| Social factors                     | Lots of people out and about              | .787         |
|                                    | Lots of interaction among neighbours      | .685         |
|                                    | Diverse neighbours                        | .465         |
|                                    | Economic situation of neighbours similar  | .386         |
| Shopping/facilities accessibility  | Easy access to a district shopping centre | .913         |
|                                    | Easy access to town centre                | .713         |
|                                    | Other amenities/facilities nearby         | .468         |
|                                    | Local shops within walking distance       | .316         |
|                                    | Easy access to highway network            | .217         |
| Outdoor spaciousness accessibility | Parks and open spaces nearby              | .586         |
|                                    | Extension of cycle routes                 | .576         |
|                                    | Other amenities/facilities nearby         | .309         |
|                                    | Pavements - easy walking routes           | .270         |
|                                    | Tree lined street                         | .240         |
| Neighbourhood attractiveness       | Attractive appearance of neighbourhood    | -.771        |
|                                    | High level of neighbourhood's upkeep      | -.723        |
|                                    | Variety in housing style                  | -.440        |
|                                    | Tree lined street                         | -.261        |

| FACTORS (a)                 | STATEMENTS - VARIABLES                        | LOADINGS (b) |
|-----------------------------|---|--------------|
| Pro-public transport use    | Like travel by public transport               | .876         |
|                             | Prefer travel by public transport than drive  | .870         |
|                             | Travel by public transport easier than drive  | .743         |
|                             | Car safer than public transport travel        | -.215        |
| Travel minimizing awareness | Prefer to organise errands for fewer trips    | .634         |
|                             | Fuel efficiency factor in choosing a car      | .617         |
|                             | Limit driving for improved air quality        | .598         |
|                             | Fuel price effects choice of daily travel     | .570         |
|                             | Often use phone/internet to avoid travel      | .399         |
|                             | Buying something from closet store possible   | .393         |
|                             | Vehicle taxed for pollution they produce      | .368         |
| Pro-cycling                 | Prefer cycle rather than drive                | -.930        |
|                             | Like cycling                                  | -.782        |
|                             | Cycle easier than drive                       | -.751        |
| Travel time sensitivity     | Travel time is wasted time                    | -.643        |
|                             | Destination oriented                          | -.618        |
| Safety of car               | Car safer than public transport travel        | .801         |
|                             | Car safer than walk                           | .775         |
|                             | Car safer than cycling                        | .488         |
|                             | Build more roads to reduce traffic congestion | .295         |
| Pro-walking                 | Like walking                                  | .730         |
|                             | Prefer walk than drive                        | .728         |
|                             | Walk easier than drive                        | .582         |
| Pro-travel                  | Importance of journey                         | -.720        |
|                             | Use time productively                         | -.618        |
|                             | Manage well with fewer car                    | -.210        |
| Car dependent               | Need a car to do many things                  | .632         |
|                             | Work without car is a hassle                  | .551         |
|                             | Like driving                                  | .293         |

Extraction Method: Principal Axis Factoring.

Rotation Method: Oblimin with Kaiser Normalization.

(a) Rotation converged in 8 iterations.

(b) Degree of association between the factors and the statements

**TABLE 6. Percent respondents by change in driving or walking or public transport use vs. change in neighbourhood characteristics\***

(a) Change in driving vs change in neighbourhood characteristics

| Change in driving                 | Decrease characteristics |              |                 | Increase characteristics |              |                 | Chi<br>-square<br>** |
|-----------------------------------|--------------------------|--------------|-----------------|--------------------------|--------------|-----------------|----------------------|
|                                   | More<br>driving          | No<br>change | Less<br>driving | More<br>driving          | No<br>change | Less<br>driving |                      |
| Safety                            | 21.4                     | 55.1         | 15.3            | 22.6                     | 53.0         | 19.1            | .703                 |
| Travel accessibility              | 27.4                     | 53.4         | 15.1            | 19.3                     | 54.3         | 18.6            | .227                 |
| Residential spaciousness          | 15.8                     | 61.1         | 15.8            | 27.1                     | 48.3         | 18.6            | .413                 |
| Social factors                    | 25.5                     | 56.6         | 12.3            | 18.9                     | 51.9         | 22.6            | .042                 |
| Shopping/facilities accessibility | 24.6                     | 54.4         | 16.7            | 19.2                     | 53.5         | 18.2            | .451                 |
| Outdoor space accessibility       | 27.7                     | 48.2         | 17.0            | 15.8                     | 60.4         | 17.8            | .176                 |
| Neighbourhood attractiveness      | 17.1                     | 58.6         | 20.0            | 24.5                     | 51.7         | 16.1            | .226                 |

(b) Change in walking vs change in neighbourhood characteristics

| Change in walking                 | Decrease characteristics |              |                 | Increase characteristics |              |                 | Chi<br>-square<br>** |
|-----------------------------------|--------------------------|--------------|-----------------|--------------------------|--------------|-----------------|----------------------|
|                                   | More<br>walking          | No<br>change | Less<br>walking | More<br>walking          | No<br>change | Less<br>walking |                      |
| Safety                            | 29.6                     | 52.0         | 16.3            | 42.2                     | 44.0         | 12.9            | .167                 |
| Travel accessibility              | 30.1                     | 45.2         | 23.3            | 39.7                     | 48.9         | 9.9             | .009                 |
| Residential spaciousness          | 35.4                     | 52.1         | 10.4            | 37.3                     | 44.1         | 17.8            | .277                 |
| Social factors                    | 33.6                     | 47.7         | 16.8            | 38.7                     | 48.1         | 12.3            | .288                 |
| Shopping/facilities accessibility | 34.2                     | 53.5         | 12.3            | 39.0                     | 41.0         | 17.0            | .648                 |
| Outdoor space accessibility       | 33.9                     | 45.5         | 19.6            | 39.2                     | 50.0         | 8.8             | .035                 |
| Neighbourhood attractiveness      | 31.4                     | 54.3         | 14.3            | 38.9                     | 44.4         | 14.6            | .675                 |

(c) Change in public transport use vs change in neighbourhood characteristics

| Change in driving    | Decrease characteristics |              |                  | Increase characteristics |              |                  | Chi<br>-square<br>** |
|----------------------|--------------------------|--------------|------------------|--------------------------|--------------|------------------|----------------------|
|                      | More<br>p.t. use         | No<br>change | Less<br>p.t. use | More<br>p.t. use         | No<br>change | Less<br>p.t. use |                      |
| Safety               | 20.6                     | 53.6         | 16.5             | 27.6                     | 49.1         | 18.1             | .651                 |
| Travel accessibility | 15.1                     | 45.2         | 30.1             | 29.3                     | 54.3         | 10.7             | .000                 |



|                                   |      |      |      |      |      |      |      |
|-----------------------------------|------|------|------|------|------|------|------|
| Residential spaciousness          | 26.3 | 57.9 | 9.5  | 22.9 | 45.8 | 23.7 | .023 |
| Social factors                    | 18.9 | 53.8 | 17.0 | 29.2 | 49.1 | 17.9 | .378 |
| Shopping/facilities accessibility | 18.4 | 62.3 | 17.5 | 31.3 | 38.4 | 17.2 | .202 |
| Outdoor space accessibility       | 25.0 | 45.5 | 21.4 | 23.8 | 57.4 | 12.9 | .299 |
| Neighbourhood attractiveness      | 27.1 | 52.9 | 15.7 | 23.1 | 50.3 | 18.2 | .503 |

SOURCE This study

\* Residents who moved residence within the last 8 years only; n = 214

\*\* Respondents reported no change in travel pattern are not included n = 109

☐ Significant at 5% level

of standardised coefficient shows that land-use type as well as neighbourhood characteristic's preference predictors come after socio-economic and travel attitude variables. This result contrasts with the US evidence where a similar analysis did not report any significant land-use variables. This evidence thus supports the hypothesis that British neighbourhoods are different to the US neighbourhoods.

### Quasi-longitudinal analysis of travel behaviour

The questionnaire was designed to capture changes in travel behaviour that result from different neighbourhood characteristics. This was planned by asking respondents who had moved to their current address within the last eight years to indicate how they drive now as compared to before they moved from 'a lot less', 'a little less', 'about the same', 'a little more', or 'a lot more'. This was combined with asking these same respondents to rate the neighbourhood characteristics of their previous neighbourhood in similar way to the neighbourhood in which they now reside.

In this study, 216 respondents out of a total of 716 respondents reported they had moved to their current residence within the last 8 years. Changes in the neighbourhood design were measured by taking the difference between perceived characteristics of the current and previous neighbourhoods. A bivariate analysis of these variables for movers shows some significant associations between changes in travel behaviour and changes in neighbourhood characteristics as shown in Table 6. This shows that changes in neighbourhood characteristics have stronger association with changes in walking and public transport use as compared to changes in driving.

For changes in driving, Table 6(a) shows that only the 'social factors' characteristic (referring to the characteristics of neighbourhoods which have high association with 'lots of people out and about' and 'high interaction between neighbours' as can be seen in Table 3) is significant. This

finding suggests that if people relocate into a neighbourhood with a higher level of 'social factors' characteristics they are likely to lower their driving level as compared to before they moved. For changes in walking pattern, Table 6(b) shows that for increases in the 'travel accessibility' and the 'outdoor space accessibility' characteristics, a significantly higher share of respondents reported their walking level had increased. This suggests that if people relocated into a neighbourhood which has higher level of travel accessibility (this includes a high association with 'accessibility to public transport service' and 'good public transport service') they are more likely to walk more than before they moved. The significance of outdoor space accessibility (associated with 'parks and open space nearby a neighbourhood') suggests that this neighbourhood characteristic also attracts more walking.

For changes in public transport use as shown in Table 6(c), an increase in the 'travel accessibility' characteristic led to a significant higher share of respondents using public transport and for a decrease in this characteristic, respondents reported less use of public transport. This finding suggests that public transport friendly environment contributes to increase patronage in public transport use. Thus supporting evidence that when people were exposed to a neighbourhood conducive to a public transport friendly environment, they will likely to make use of it, no matter if the residential self-selection has taken place. For a decrease in 'residential spaciousness' characteristics, a significantly higher share of respondents reported more use of public transport. This suggests that public transport patronage is negatively correlated with residential spaciousness (this factor is highly associated with 'garden space' as can be seen in Table 3).

The US study by Handy et al. (2005) found that changes in most neighbourhood characteristics were sensitive to changes in walking but these results are not confirmative in the British experience. Many of the neighbourhood characteristics are insignificant in relation to changes in walking. However, the British case study has shown that travel accessibility is sensitive to changes in walking and public transport use, suggesting that residents of British neighbourhoods are more aware of public transport service than their US counterparts. This evidence thus supports the hypothesis (again) that British neighbourhoods are different to the US neighbourhoods and that residents of British neighbourhoods are more likely to use sustainable, low carbon means of travel (public transport and walking).

## 5. CONCLUSIONS

The literature review highlights the differences between the US and European experiences. A very noticeable feature which differs between the US and Europe is the way that land-use characteristics impacting on travel behaviour appear to play bigger role in Europe than in US. This is especially true in terms of urban structure variables and their associated characteristics. Whilst there have been European studies, for example Naess and Jensen (2004) and Meurs and

Haaijer (2001), these have not included the role of travel attitudes or perceptions nor at the self-selection issue. The UK studies similarly have not included the role of travel attitudes and perceptions nor have considered residential self-selection. This paper is motivated by a desire to present a convincing UK study that explored possible causal links between travel behaviour on the one hand and neighbourhood design characteristics and travel attitudes on the other. It was based on the belief that there are a number of reasons why the UK might be different, particularly from Europe. For example, the UK transport policy before the Planning White Paper in 1998 was still using a predict and provide approach, and supported significant development for car accessibility with the rationale of enhancing national economic performance, especially during the Thatcher governments (1980s to 1990s). This means that UK travel behaviour may be more similar to the US pattern because of this approach with the motorised mode more important (Cram, 2006) and be more different from that in mainland Europe where multi-modal travel patterns are dominant. The fact that the UK transport land-use pattern is closer to the US than Europe and that the UK level of car dependency is high<sup>2</sup> suggests that US evidence may be more applicable to the UK than might previously been thought, and thus research methods from the US might be appropriately transferred.

In this study, similar questions were asked of respondents as in the US study undertaken by Handy et al. (2005) and yet the results are different suggesting that there are differences between US and UK neighbourhoods. In terms of neighbourhood characteristics, the factor of travel accessibility is present in the British case study but not in the US model and this factor has been shown to be particularly sensitive in the quasi-longitudinal analysis.

However, there are similarities between the US and British studies in the cross-sectional model predicting VMD, especially in relation to attitude characteristics being the better predictors. However, from a land-use planning point of view, the fact that preferences on shopping/facilities accessibility as well as the land-use type are shown to be strong predictors of VMD in Britain means there is a clear role for the planning and redevelopment of new neighbourhoods (See also: Aditjandra et al., 2007).

In general, Britain has a higher incidence of public transport use and this reflected in this study by higher and differentiated factors of accessibility and less strong changes in travel patterns following changes in neighbourhood characteristics. However, this study shows that British suburban neighbourhoods can be as car dependent as their American counterparts.

Concluding their study, Handy et al. (2005) suggested their results showed causality between neighbourhood design characteristics and travel behaviour and that therefore land-use policies to bring residents closer to destinations could be successful in promoting land-use change to reduce driving and thus emissions and promote more sustainable mobility practice. This study

shows that in the UK, as in the US, there is an association between changes in neighbourhood characteristics and changes in travel behaviour but this is not as strong suggesting that land use planning in the UK may have less of an impact on reducing private car travel, as compared to the US. However, the UK evidence suggests that neighbourhood design offering opportunities for sustainable mobility practice does have an impact on walking and public transport use and, for the future, this is an area where land use and transport planners can focus. When the issue of residential self-selection is added to this discussion, the experiences of the US and the UK become more different: residential self-selection is important in the US and this is reinforced by the dichotomous nature of US suburbs and US traditional areas and the extent to which they are served by alternatives to private car travel. In the UK, the influence of residential self-selection appears less important which suggests that land use planning that reinforces the use of sustainable transport modes could have a higher degree of success.

## AUTHORS' BIOGRAPHIES

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## ENDNOTES

1. The Index of Multiple Deprivation (IMD) 2004 is a UK measure of the deprivation of an area. This is available at the LSOA level and where the lower the number, the higher the level of deprivation. In Tyne and Wear, 32,482 is the least deprived area. The IMD is a weighted index, constructed by 7 aspects: income, employment, health, education, barriers to housing and services, crime and living environment.

2. UK is in ranked second in Europe (Commission for Integrated Transport, 2007) in the mode share of distance travelled by car.

## REFERENCES

1000 Friends of Oregon (1996) *Analysis of Alternatives: LUTRAQ Report Volume 5*. Prepared by Cambridge Systematics, Inc. and Parsons Brinckerhoff Quade & Douglass, Portland, Oregon. Cited from Travel by Design (Boarnet and Crane, 2001)

Aditjandra, P.T. (2008) *The relationship between urban form and travel behaviour: A micro-analysis in Tyne and Wear*. Unpublished PhD Thesis. School of Civil Engineering and Geosciences, Newcastle University, UK.

Aditjandra, P.T., Mulley, C.A. and Nelson, J.D. (2007) "Neighbourhood Design Perception and Travel Behaviour in Tyne and Wear, North East England, UK." Paper presented at European Urban Research Association (EURA) 'Vital City' Conference, Glasgow, 12-14 September 2007, accessible at: [http://www.eura2007.org.uk/media/media\\_48196\\_en.pdf](http://www.eura2007.org.uk/media/media_48196_en.pdf).

Babbie, E. (2004) *The Practice of Social Research*. Wadsworth, a division of Thomson Learning, Inc.

Badoe, D.A. and Miller, E.J. (2000) "Transportation-land-use interaction: empirical findings in North America, and their implications for modelling." *Transportation Research Part D* 5: 235-263.

Banister, D. (2005) *Unsustainable Transport: City transport in the new century*. Abingdon, Oxfordshire, Routledge Taylor & Francis Group.

Bhat, C.R. and Guo, J.Y. (2007) "A comprehensive analysis of built environment characteristics on household residential choice and auto ownership levels." *Transportation Research Part B* 41: 506-526.

Boarnet, M.G. and Crane, R. (2001) *Travel by Design; the influence of urban form on travel*. New York, Oxford University Press.

British National Statistics (2001) *British Census 2001*, accessible at <http://neighbourhood.statistics.gov.uk>.

CABE (Commission for Architecture and Built Environment, UK) (2004) *Design Coding: Testing its use in England*. The Report written by CABE in partnership with ODPM and English Partnerships and based on research by Tibbalds Planning & Urban Design, the Bartlett School of Planning, UCL and Rob Cowan. Accessible at <http://www.cabe.org.uk/AssetLibrary/2221.pdf>.

Cao, X., Mokhtarian, P. L., and Handy, S. L. (2007). "Do Changes in Neighborhood Characteristics Lead to Changes in Travel Behavior? A Structural Equations Modeling Approach." *Transportation*, 34 (5), 535-556.

Cervero, R. (2002) "Built environments and mode choice: toward a normative framework." *Transportation*

Cervero, R. and Kockelman, K. (1997) "Travel Demand and the 3Ds: Density, Diversity, and Design." *Transportation Research Part D* 2(3): 199-219.

Cram, J.A. (2006) *Sustainable Suburbs: Neighbourhood Characteristics and Travel Behaviour*. School of Architecture, Planning and Landscape, University of Newcastle upon Tyne. Unpublished PhD Thesis.

Curtis, C. (2007) "Planning for sustainable accessibility: The implementation challenge." *Transport Policy*, Article in Press. doi:10.1016/j.tranpol.2007.10.003.

Dieleman, F.M., Dijst, M. and Burghouwt, G. (2002) "Urban form and travel behaviour: Micro-level household attributes and residential context." *Urban Studies* 39(3):507-527.

Dunphy, R.T. and Fisher, K. (1996) "Transportation, Congestion and Density: New Insights." *Transportation Research Record* 1552:89-96.

Ewing, R. and Cervero, R. (2001) "Travel and the built environment." *Transportation Research Record* 1780:87-114.

Handy, S. (1996) "Methodologies for exploring the link between urban form and travel behaviour." *Transportation Research D* 1:151-165.

Handy, S. (2005) "Critical Assessment of the Literature on the Relationships Among Transportation, Land Use, and Physical Activity." *TRB Special Report 282: Does the Built Environment Influence Physical Activity? Examining the Evidence*. Accessible at <http://trb.org/downloads/sr282papers/sr282Handy.pdf>.

Handy, S. Cao, X. and Mokhtarian, P. (2005). "Correlation or causality between the built environment and travel behaviour? Evidence from Northern California." *Transportation Research Part D* 10: 427-444.

Headicar, P. (2003) "The Contribution of Land Use Planning to Reducing Traffic Growth: the English Experience." *European Journal of Transport and Infrastructure Research* 3, no 2:137-154.

Headicar, P. and Curtis, C. (1998) "The location of new residential development: its influence on car-based travel" in *Transport Policy and the Environment* (ed: Banister, D.) London, E & FN Spon.

Office of Deputy Prime Minister (ODPM) (2004) *Indices of Deprivation 2004 for Super Output Areas in England. Neighbourhood Renewal Unit*. Also available at <http://neighbourhood.statistics.gov.uk>.

Kitamura, R., Mokhtarian, P. and Laidet, L. (1997). "A Micro-Analysis of Land Use and Travel in Five Neighbourhoods in the San Francisco Bay Area." *Transportation* 24: 125-158.

Krizek, K.J. (2003) "Residential Relocation and Changes in Urban Travel: Does Neighbourhood-Scale Urban Form Matter?" *Journal of the American Planning Association* Vol.69, No.3. American Planning Association, Chicago, IL.

Marshall, S. (2005) *Streets and Patterns*. London, Spon Press.

Meurs, H. and Haaijer, R. (2001). "Spatial Structure and mobility." *Transportation Research Part D* 6: 429-446.

Naess, P. and Jensen O.B. (2004) "Urban Structure matters, Even in a Small Town." *Journal of Environmental Planning and Management* 47(1):35-57.

Newman, P. and Kenworthy, J. (1989) *Cities and Automobile Dependence: A Sourcebook*. Brookfield, UK: Gower Technical.

Schwanen, T. and Mokhtarian, P.L. (2005b) "What if you live in the wrong neighbourhood? The impact of residential neighbourhood type dissonance on distance travelled." *Transportation Research Part D* 10: 127-151.

Simmonds, D. and Coombe, D. (2000) "The Transport Implications of Alternative Urban Forms" in *Achieving Sustainable Urban Form* (eds: Williams, K. Burton, E., Jenks, M.) London, E&FN Spon Taylor & Francis Group.

Stead, D. (2001) "Relationships between land use, socio-economic factors, and travel patterns." *Environment and Planning B: Planning and Design* 28: 499-528.

Van, U-P. and Senior, M. (2000) "The contribution of mixed land uses to sustainable travel in cities" in *Achieving Sustainable Urban Form* (eds: Williams, K. Burton, E., Jenks, M.) London, E&FN Spon Taylor & Francis Group.

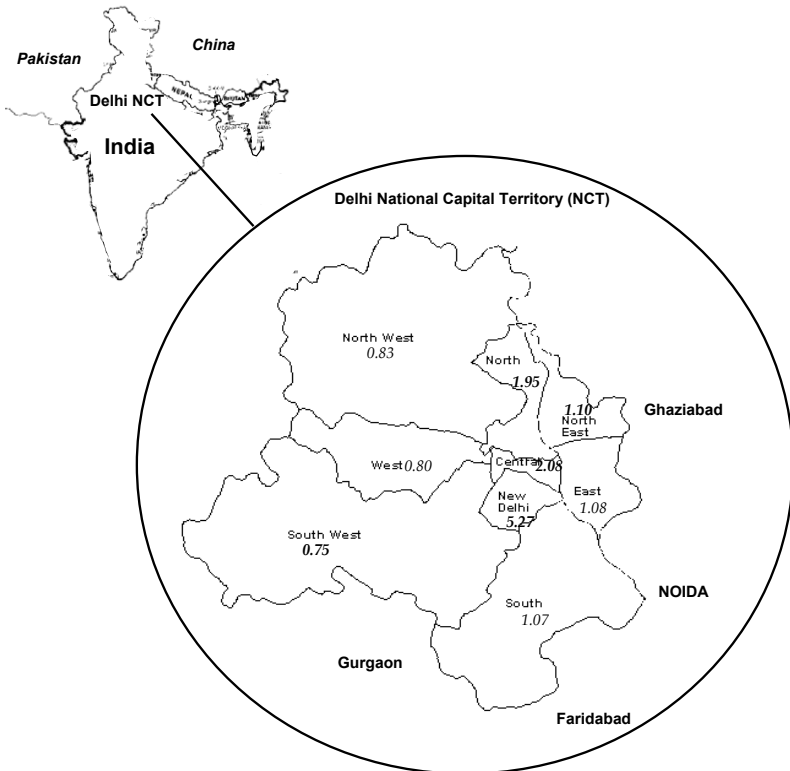
Widaman, K.F. (1993) "Common factor analysis versus principal component analysis: Differential bias in representing model parameters?" *Multivariate Behavioural Research* 28(3): 263-311.





Associate Professor Piyushimita Thakuriah

# TRANSPORTATION AND EMPLOYMENT ACCESSIBILITY IN A CHANGING CONTEXT OF METROPOLITAN GROWTH : THE CASE OF DELHI, INDIA



## ABSTRACT

Phenomenal increases in personal mobility has led to rapid increases in urban traffic congestion worldwide and difficulties in spatial access to economic opportunities. This paper examines the factors that act as drivers of these great increases in the demand for personal transportation by examining the case of the Delhi metropolitan area in India. The Delhi metro area has increased significantly in size due to outward movement of the built-up areas as a result of both planned and unplanned factors since the 1960's. General economic policies to increase motor car production, availability of easier credit to purchase cars, construction of expensive public transportation but lack of concurrent policy to price personal auto travel has greatly facilitated the demand for personal vehicles and increased mismatch between locations of jobs and residential location of workers. The equity aspects of these phenomena have been significant including slum resettlement to inaccessible parts of the metro area with little economic opportunities, large rates of fatalities among non-motorized transportation users who are mostly poor and negative air pollution impacts among roadside dwellers.

While traditional measures of spatial job accessibility measurement are useful in the Indian context, the paper shows that marginal workers, recent migrants, street hawkers, slum dwellers and workers in the transportation sectors, all of whom are low-income, have different job accessibility needs. A new framework is needed for measuring job accessibility, given the data limitations that exist and the multi-pronged nature of the problem, to assist policy-making towards sustainable urban systems and equitable spatial access to economic opportunities.

## INTRODUCTION

India's recent economic growth has received a lot of attention in the media and global commerce. These basic economic factors, together with unprecedented urbanization of Indian cities, rapid increases in urban decenbtralization and growth in demand for personal (motorized) mobility, have essentially led to a situation of explosive growth in traffic congestion. These trends are similar to those in other Asian mega-cities (Shen, 1997 in the case of Shanghai and Bowen, 2006 in the context of South-East Asia's three large mega-cities: Bangkok, Manila and Jakarta.

The consequences of these trends on accessibility to jobs and other locations with social and economic potential by the urban workforce should be paramount, but are often ignored in transportation planning. However, recent strategies have stressed the importance of the social equity aspects of transportation, including the equitable access to jobs and other meaningful opportunities by all segments of the population (for example, the World Bank, 1996; U. S. Executive Order 12989, 1994). Although there is no universally acknowledged definition of accessibility, the concept relates to "an individual's freedom to participate in activities" (Weibull, 1980). Many countries and development programs have now started to respond to the transportation needs of the poor, socially excluded and disadvantaged populations, but there is a need for much better understanding of how different urban processes lead to spatial variations in job accessibility. For example, an extensive literature in the U.S. has examined the link between the economic and social needs of the urban poor to their residential and locational conditions (Kain and Persky, 1969; Wilson, 1987, 1996; Ihlanfeldt, 1999). Others have investigated the connection between job accessibility and labor market outcomes such as employment status, wages earned and related indicators (Bederman and Adams, 1974; Thakuria and Metaxatos, 2000; Raphael, 1998). Although evidence connecting job accessibility to acquiring and sustaining employment in good quality jobs by low-skilled workers is mixed, the importance of the concept as a performance measure in transportation planning cannot be over-emphasized for the purposes of sustainable development and is rightfully achieving a foothold in the evaluation of transportation projects, along with traditional mobility-based measures (such as changes in average speeds or Vehicle Miles Traveled).

In the developing world, investments in transportation infrastructure have been used as a strategy to alleviate poverty and to connect the poor to jobs and markets; however, the literature linking investments to labor market outcomes is more limited (Boarnet, 2006). In addition, the complex dynamics of urban population growth, race and ethnicity of the workforce and the interactions among land-use, housing, labor markets, transportation and economic development and ways in which these affect job accessibility, is not well understood in developing cities. While job accessibility is important for all segments of the urban labor force, it is particularly important to understand in the case of the urban poor. As a group, poor members of the urban workforce find it the hardest to overcome spatial barriers to job destinations because existing

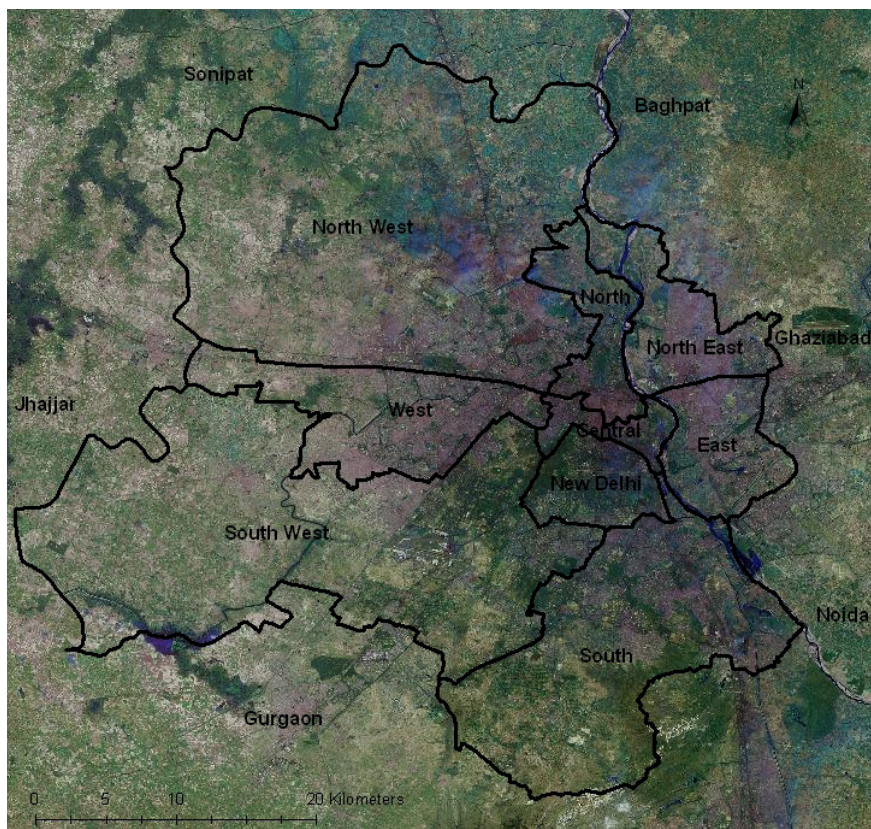
public transportation links can be expensive, too time-consuming or simply non-existent, while walking or bicycling is unsafe in mixed-mode traffic or not an alternative at all, given large distances between home locations and job locations in increasingly decentralizing urban areas. The means to purchase and operate personal vehicles (cars or motorized two-wheeled scooters or motorcycles) or the ability to relocate to housing (including informal housing) in job-rich areas, is also likely to be beyond their means.

Indian cities have been undergoing significant changes in urban form and in the spatial distribution of population and economic activity. Several authors have discussed the transportation needs of the urban poor in the larger Indian cities. For example, Tiwari (2002) discusses the case of Delhi, the capital city, where the existing urban transportation infrastructure does not meet the needs of a large number of city residents, who remain outside the formal planning process, and are almost exclusively dependent on non-motorized transportation. Badami et al. (2004) describe how low-income groups are affected by various transportation impacts, and discuss the travel characteristics and the urban transportation needs and priorities of these groups. Srinivasan (2004) describes access to jobs, shopping and social services by low-income households in the City of Chennai in southern India, while Baker et al. (2005) identified the demands for transportation services by the poor in Mumbai, based on a large-scale survey. These authors also discuss the extent to which urban transportation policy and planning have only marginally responded to the needs of the urban poor.

This paper attempts to add to the discussion on the importance of considering job accessibility in sustainable transportation planning in developing cities, by examining the case of Delhi, India. The paper undertakes an exploratory review of the trends in land-use, housing, economic development and transportation patterns over time in the Delhi metro area and examines how these processes have affected the spatial distribution of workers and jobs, which are the building blocks of job accessibility. The data to estimate detailed accessibility measures are not available in the case of Delhi and while the emphasis of the paper is not to estimate accessibility measures per se, the discussion makes use of an aggregate, zone-based accessibility measure (a jobs-to-worker by district index). The paper begins with a review of urban labor patterns and current mobility and accessibility trends in the Delhi metro area. Spatial variations in job accessibility are explained in terms of an interacting set of urban processes and public policies and an attempt is made to break down the job accessibility needs of different subsets of the low-income workforce. The paper concludes with a set of multi-pronged recommendations about strategies to improve low-income worker accessibility to jobs in developing cities, with the goal of improving sustainable transportation systems.

## STUDY AREA

The National Capital Territory (NCT) of India, which includes the capital city of New Delhi, is



**FIGURE 1.** Nine districts of the National Capital Territory of India, including the capital city of New Delhi.

**TABLE 1.** District-Wise Area, Population And Economic Statistics In National Capital Territory.

| District   | Area (km <sup>2</sup> ) | Percent Share of Population | Population Density (per km <sup>2</sup> ) | Percent Decadal Population Growth | Percent of Total Business Enterprises |
|------------|-------------------------|-----------------------------|---|-----------------------------------|---------------------------------------|
| North-West | 440                     | 20.65                       | 6,471                                     | + 60.12                           | 17.33                                 |
| South      | 250                     | 16.37                       | 9,033                                     | + 50.27                           | 14.16                                 |
| West       | 129                     | 15.37                       | 16,431                                    | + 47.81                           | 13.39                                 |
| North-East | 60                      | 12.77                       | 29,395                                    | + 62.52                           | 12.02                                 |
| South-West | 420                     | 12.67                       | 4,165                                     | + 61.29                           | 8.26                                  |
| East       | 64                      | 10.57                       | 22,637                                    | + 41.61                           | 12.22                                 |
| North      | 60                      | 5.64                        | 12,996                                    | + 13.30                           | 10.56                                 |
| Central    | 25                      | 4.67                        | 25,760                                    | -1.91                             | 10.29                                 |
| New Delhi  | 35                      | 1.29                        | 4,909                                     | + 2.47                            | 1.73                                  |
| NCT Delhi  | 1,483                   | 100.00                      | 9,294                                     | + 46.31                           | 100.00                                |

SOURCE: ECONOMIC SURVEY OF DELHI 2003-04

approximately 1,483 square kilometers and has a population of 12.9 million (Census of India, 2001). Administratively, the territory has nine districts, shown in Figure 1. Table 1 gives basic information on the Delhi Metro Area at the district level. The North-West district is the largest in land area, has the greatest share of NCT population and enterprises and has witnessed the third-highest rate of decadal growth in the NCT region. The North-East district, on the other hand is the most densely populated and has witnessed the greatest share of decadal growth.

**FIGURE 2.** Annual Growth in Motorized and Man-Animal Driven Vehicles in Delhi (1991-2006)

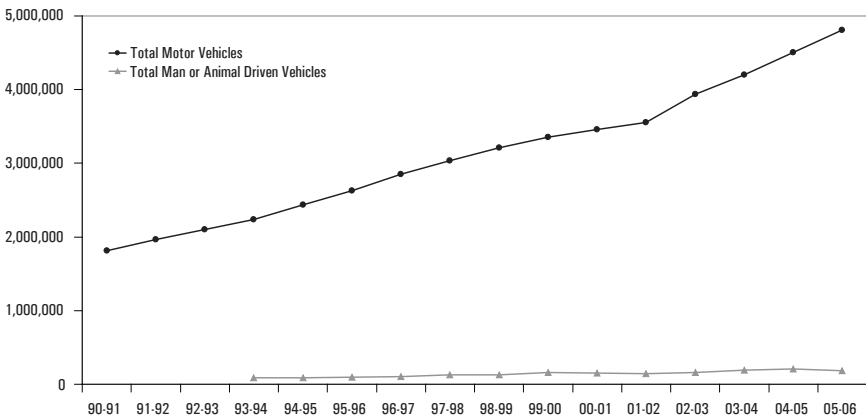


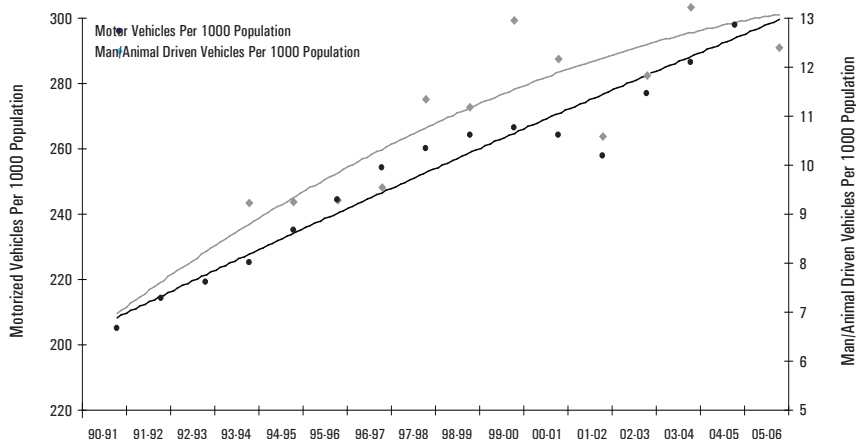
Figure 2 shows the growth in motorized and non-motorized vehicles in the Delhi metro area during the period 1991 through 2005. In contrast to motorized transportation, which exhibits a strong upward trend, non-motorized transportation has remained more or less constant over time. A variety of factors have contributed to the increases in personal motorized vehicle ownership.

### *Personal Motorized Transportation*

Ingram and Liu (1997) estimated that saturation levels for the market penetration of cars and total motor vehicles are at 770 cars and 1,180 total motor vehicles per 1,000 population. Figure 3 shows the smoothed trends in motorized and man-animal driven vehicles per 1,000 population in Delhi. In 2005-2006, motorized vehicle penetration per 1,000 population was an estimated 250. The largest share of motorized transportation is composed of two-wheeled transport such as scooters and motorcycles. Although it would seem that Delhi is far away from reaching the predicted saturation point, the factors described below are likely to continue to boost these trends in the future.

- *Changes in Economic Policy:* Despite high gas prices, the Indian market for motorized transportation, especially the car market, is booming. Sales of passenger vehicles crossed the million-figure mark (1,044,597 units) in 2004, making India the fastest-growing in this segment (Basu, 2005). In terms of affordability of cars to a bigger segment of the total market,

**FIGURE 3.** Smoothed Annual Growth in Motorized\* and Man-Animal Driven Vehicles\*\* Per 1000 Population in Delhi (1991-2006)



perhaps no other phenomenon is more likely to foster greatly increased car ownership than a new generation of ultra-cheap cars, which are intended to be “introductory” cars and will quite possibly attract two-wheelers into the car market. India produces 1.3 million cars a year. With the market growing at 10% to 12% per year, this could reach 3 million within a decade. In terms of changes in governmental policies, steps to make auto manufacturing competitive by creating export promotion zones, expanding infrastructure such as power, roads and ports, bringing down transaction costs, developing industry-specific clusters and freeing industries from excessive regulations are cited to be important auto ownership boosters (Basu, 2005).

- *Great Increases in Personal Wealth and Disposable Incomes:* In constant (1993-1994) prices, the per capita income growth in Delhi between 1993-1994 and 2004-2005 was 4.29% while that of the rest of India was 3.97% (Economic Census of Delhi, 2005-2006). The number of double-income families has gone up, with resultant increases in disposable income. These changing lifestyles have led to greater preferences for personal mobility. In addition, the percentage of households below poverty in Delhi decreased more steeply during 1974-2004 period, compared to the rest of India (Economic Census of Delhi, 2005-2006), leading to increases in purchasing power, on the aggregate, for personal cars.
- *Liberalization of Credit and Lending Mechanisms:* The availability of credit is another major booster of car ownership (Thakuriah and Liao, 2006). It is estimated that about 80% of cars currently sold in India are financed through the credit system (Basu, 2005) in contrast to earlier decades, where cars would be purchased by well-off households by means of up-front payment of the entire cost. Interest rates on car loans have witnessed a surge of at least 3% points since December 2005 (Venkatakrishnan, 2006), but motor vehicle sales



have nevertheless remained buoyant. The chief reasons attributed to this trend are the sales incentives and discounts offered by vehicle manufacturers, which are operating in a highly competitive market. These financial strategies add a layer of complexity to car ownership growth rates in India, beyond what simple income-based measures would predict.

### *Road Infrastructure and Public Transportation*

In spite of booming car ownership rates, public transportation continues to be the choice for the majority of trips in Delhi. Close to 34% of trips are made by bus, followed by bicycles, motorized two-wheelers and then private cars. The total length of the road network in Delhi has increased from a mere 652 kms in 1981 to 1,122 kms in 2001. The trip length by private car and bus was 11.28 km and 10.66 km in 1993 respectively and forecasted to be 17.74 km and 14.58 km in 2021 (DUEIP, 2001).

In response to these motorizing trends, the government has undertaken several large-scale transportation infrastructure projects, including limited access expressways, road-widening, flyover construction and Intelligent Transportation Systems projects, as well as an extensive rapid transit system project, the Mass Rapid Transport System (MRTS). However, considerations regarding the urban poor are either weak or entirely missing in these projects. While the construction of a high-speed, high-capacity public transportation system is commendable, rail forecasts in general have been significantly optimistic compared to reality. Actual ridership is usually lower than forecast, and actual costs are higher (Shoup, 2006); other authors have raised similar concerns (Pickrell, 1992; Richmond, 2005). In the case of the Delhi MRTS, while some reviews regarding its congestion mitigation and air quality improvement potential have been positive (Murty, et al., 2006), others have criticized its low ridership levels, enormous levels of subsidy and its unresponsiveness to the needs of poor commuters (Mohan, 2006; Advani and Tiwari, 2005). The other major initiative is a Bus Rapid Transit (BRT) system; at the time of writing this paper, an initial demonstration of such a system had been made. Irrespective of governmental interventions of this type, the fundamental job accessibility considerations for workers remain open, as these were not a factor in the planning process in the first place.

### **Job Accessibility in the Delhi Metro Area: Jobs-to-Worker Ratio by District**

Although there is no universally acknowledged definition of accessibility, researchers have proposed various indicators of accessibility (Ingram, 1971; Weibull, 1976; Morris et al., 1978; Handy and Niemeier, 1997; Miller, 1999; Harris, 2001), which range from simple counts of jobs within commuting distances of residential origins, to more complex measures based on spatial interaction models and random utility models. Baradan and Ramjeri (2001) summarize the literature on classification of accessibility measures. One way to classify accessibility measures is zone-based versus individual measures. Zone-based measures try to capture the overall accessibility for a zone, while individual measures try to capture the accessibility of

individuals based on detailed characteristics of space, available time, and means to overcome space (Berglund, 2001).

Several considerations enter into adequately estimating zone-based job accessibility measures for low-income workers: First, low-wage or “entry-level” jobs that are appropriate for the skill-levels of low-income workers should be identified, from the total pool of jobs in a zone (as in Sen et al, 1999). Second, in order to estimate “potential” or “opportunities” for low-income workers, it is not the total number of entry-level jobs per se that is important, but rather job openings (also in Sen et al, 1999). The second point warrants further discussion and is relevant due to recent U.S.-based research based on the “job chain” approach (Persky and Felsenstein, 2006). Specifically, the results of a simulation model used to estimate non-user benefits of a federally-funded U.S. transit program targeted to connecting workers from low-income residential locations to job-rich areas – the Job Access and Reverse Commute program – shows that when such services link low-wage workers to job locations where the existing jobs are already filled by workers with similar skills and there are no net new jobs (created as a result of, say, an economic development program), the consequence can be job loss by the existing workers, deflation of wages and other movements down the job chain, as the new workers serve as substitutes for the existing workers (Thakuriah, et al, 2008). Third, data on commuting flows by mode and precise estimates of travel costs or impedances between zonal pairs by mode (which might be available from travel demand models) are necessary.

In terms of measuring job accessibility rigorously in Delhi according to these requirements, a number of problems arise:

- *Extreme Levels of Mixed Land Use:* As in many developing cities, Delhi has a high level of mixed land uses, with no clear-cut concentric zones of different activities (Tiwari, 2002). While there are several core areas with high levels of commercial development, such development patterns can co-exist with high concentrations of housing. Further, income levels at residential origins tend to be mixed because high-income housing may co-exist in the same zone with squatter dwellings. Thus, the location of low-income workers and areas where appropriate economic opportunities exist for them, are somewhat ubiquitous over the urban space.
- *Data Limitations including Spatial Resolution of Information on Labor Market, Travel Demand and Commuting Costs:* Most data on the labor market aspects of the analysis (number of jobs, type of jobs etc.) are available only at the district level, which can be fairly large. Recent origin-destination travel demand and commuting cost data such as travel times or out-of-pocket costs between zones are not known at a small enough spatial resolution to be meaningful to estimate accessibility measures.

- *Porous Labor Markets:* In order to estimate job accessibility by district, what we ideally need is an origin-destination matrix, where the origins are home locations and destinations are job locations. The cells of the matrix would give the commuting flows for each O-D pair. In the case of Delhi, unlike many U.S. metro areas, the labor market borders are very porous, i.e., workers from neighboring states commute to Delhi, thus creating an ill-defined labor shed and further complicating accessibility-based analysis.

For these reasons, this paper considers a preliminary zone-based measure of job accessibility in the case of Delhi. The measure is a jobs-to-worker ratio by district, ie,  $[(\text{total number of jobs in a district})/(\text{total number of workers residing in that district})]$ . A surplus of jobs per worker may be indicative of in-bound commuting flows to a district and would potentially call for improvements in transportation connections; a deficit of jobs per worker in a district potentially indicates out-bound commuting flows from that zone, thus calling for economic development or job-creation programs in those areas or perhaps even the relocation of the low-income workers residing in those areas, to areas with greater economic opportunities.

**TABLE 2. District-Wise Employment Statistics in National Capital Territory**

| District   | Total Jobs | Total Workers by Residence | Total Jobs to Worker Ratio | Number of Persons Usually Working | Main Workers by Residence | Persons usually Working to Main Workers |
|------------|------------|----------------------------|----------------------------|-----------------------------------|---------------------------|---|
| North-West | 768,560    | 919,483                    | 0.83                       | 585,635                           | 872,278                   | 0.67                                    |
| South      | 836,554    | 778,495                    | 1.07                       | 685,596                           | 739,276                   | 0.92                                    |
| West       | 582,463    | 720,848                    | 0.80                       | 463,510                           | 686,572                   | 0.67                                    |
| North-East | 554,362    | 500,361                    | 1.10                       | 432,019                           | 471,011                   | 0.91                                    |
| South-West | 452,764    | 602,505                    | 0.75                       | 377,713                           | 569,861                   | 0.66                                    |
| East       | 516,153    | 475,371                    | 1.08                       | 405,069                           | 456,198                   | 0.88                                    |
| North      | 501,702    | 256,574                    | 1.95                       | 395,125                           | 244,851                   | 1.61                                    |
| Central    | 467,062    | 223,843                    | 2.08                       | 389,495                           | 213,307                   | 1.82                                    |
| New Delhi  | 356,779    | 67,596                     | 5.27                       | 45,871                            | 64,426                    | 5.36                                    |

*SOURCE* Economic Survey of Delhi 2003-04

Table 2 gives district-wise employment information that is relevant to the current discussion. The total number of persons usually working is 4,080,024 (Directorate of Economics and Statistics, 2005). Out of the total number of workers, over 76% were hired workers and the rest were household or informal workers. About 41% of the informal sector workers are in retail trade followed by about 11% in the transport sector and 10.5% in manufacturing and trade. Details on the spatial distribution of these jobs and the estimated jobs-to-worker ratio are as follows (note that these overall remarks are about all types of jobs and workers, and not just the low-income sector; the case of low-income workers is considered later on in the paper):

- *District-Wise Share of Jobs:* The district-wise share of jobs (given in column 2 of Table 2) gives the total number of jobs that the Census collects from establishments (the share of establishments or enterprises is given in Table 1). This figure includes both the number of hired persons usually working as well as the number of non-hired persons usually working (workers who typically work in households or in non-enterprise premises). The total number of workers by residence (Column 3) gives all workers (main workers as well as marginal workers; main worker is a person who has worked a major part of the year, i.e. for 183 days or six months or more, whereas marginal worker is a person who might have worked any time during the previous year, but not for the major part of the year).
- *Jobs-to-Worker Ratio and Surpluses, Deficits and Commuting Needs:* The ratio of all jobs per district to all workers per district is given in column 4. From these numbers, it is possible to get a rough idea of potential commuting patterns. We see that the New Delhi, Central, North, North-East, East and South districts have a surplus of jobs per worker, meaning that it is most likely that workers from other areas are commuting into those areas. The North-West, South-West and Western districts, in that order, have the greatest deficit between total jobs and total workers, potentially resulting in the need of the residents in these districts to commute to other districts.

If we consider the case of jobs where persons are defined to be usually working (all jobs where the person is hired to work in all types of enterprises, perennial or non-perennial) as a proxy for formal sector jobs and main workers as formal sector labor, we see that the New Delhi, Central and North districts have the highest ratios for persons usually working to main workers. The districts with the greatest difference between the number of formal sector jobs and workers are the North-West, West, South-West and Eastern districts. This indicates that formal sector workers in these locations are more likely to have to compete for appropriate jobs with others like them in their district or potentially face long commutes to areas where the formal sector jobs to workers ratios are more advantageous.

### *Indirect Drivers of Demand for Transportation*

Job accessibility is the both the cause and the result of a myriad set of interwoven urban processes relating to demographic, land-use, social and economic changes over time. These factors in the Delhi NCT have contributed to variations in job accessibility as currently observed and have led to the development of a large, multi-nucleated city. While natural increases in population and the workforce have played a major role, a number of previous planning activities that had a basis in India's former socialist, state-driven planning paradigm, appear to have contributed significantly to the decentralization of urban population and economic activities away from the central core, towards outlying areas of the metro area. In this section, the reasons underlying the spatial variability in job accessibility are explored.

*Changes in Urban Growth and Structure:* Phenomenal urban growth trends in the Delhi metro area (with over 46% growth from 1991 to 2001, more than double the national rate) have contributed significantly to the demand for motorized transportation and variations in job accessibility. DuPont (2003) estimated that natural increase in population contributed to 35% of the total population growth, net in-migration from rural and urban areas surrounding the NCT (as well as from states that are located far away) about 40% and the reclassification of the urban-rural population, an additional 25%. Women are also entering the workforce in greater numbers. While the total number of women in formal sector jobs in India remain small, the number of female main workers increased 40% since 1981, compared to an increase in male main workers of 23% (Dunlop and Velkoff, 1999). Moreover, the average household size has decreased marginally from 5.5 persons to 5.4 persons during the 1990's (United Nations, Department of Economic and Social Affairs, 2001); in urban and rural NCT combined, the average family size is 5.1 whereas in urban Delhi, over 45 percent of families were composed of 4 or fewer persons. This phenomenon has also led to increased demand for independent incomes (jobs) and housing. As a result of these factors, the sheer size of the workforce which contributes to travel demand today is much greater than what it was 10 years ago.

**Decentralization of the Delhi Metro Area:** Dupont (2003) noted three spatial factors between 1991 and 2001 that are symptomatic of urban decentralization: (i) absolute decrease in population, indicating net outward movement, that has occurred in the historical core called the Old City, (ii) decrease in population in some parts of New Delhi, which is the capital city with mostly government buildings, government-provided housing and some commercial activity and (iii) great increases in population (over 10%) in neighborhoods in the outskirts; although the outskirts do not have the low-density patterns of U.S. cities, they are still far less densely populated than the inner, core areas. Some of the key drivers of the Delhi metro area decentralization are:

- *Planned Development of Outlying Areas:* The population increases in the peripheral areas are the result of both governmental policy and private action. DuPont (2003) notes that since the 1960's, there was deliberate planning to develop townships in the periphery of Delhi to accommodate urban growth; eventually these areas grew faster than the central agglomeration of Delhi. Eventually, transportation connections (roads and rail) propelled the outward movement of population from the urban core to these peripheral towns, leading to the development of one very large, multinodal urban area. In addition, the local governmental acquired large amounts of agricultural land in the peripheral areas from the 1960's for the purpose of constructing apartment buildings, leasing of land to private households and cooperative group housing, as well as land for resettling evicted slum dwellers.

The economic base of these peripheral areas was strengthened in an attempt to improve jobs-housing balance with the development of industrial centers and parks in these areas.

Over time, households relocated close to these areas, further adding to the decentralization process. These industrial areas were developed in the 1970s and over the years have deteriorated considerably in terms of physical infrastructure (IF&LS Ecosmart Ltd., 2006). In the case of New Okhla Industrial Development Area (NOIDA), a peripheral area just east of the South district, about one-fourth of its working inhabitants now commute daily to work outside their town of residence (DuPont, 2003). It is most likely that commuters in this area are employed in the surplus jobs in the South, New Delhi, Central and East districts; however, almost 98 percent of the workers living in the slums in NOIDA work in or close to NOIDA, due to dependencies on non-motorized modes of transportation.

*Private Development of Outlying Areas:* The private development of outlying areas has also greatly facilitated the deconcentration of urban population and employment opportunities. A classic example is that of Gurgaon, south of the city, in the adjoining state of Haryana. Because of its close proximity to Delhi, Gurgaon has become one of the most important corporate and industrial hubs of India and is home to several auto manufacturing plants, IT companies and Call Centers. The Government of India has embarked on an economic development policy of creating Special Economic Zones (SEZ's), which are intended to be engines for economic growth by attracting larger foreign investments to India. Eight of the 154 SEZ's identified in 2005 will be in Gurgaon, leading to an increase in the number of jobs and attraction of international capital and service jobs associated with such investment. One survey found that about half of the employed inhabitants surveyed in DLF Qutab Enclave, a residential area within Gurgaon, worked in the city of Delhi (DuPont, 2003). It is likely that these commuters are filling the surplus jobs in the South, New Delhi and Central districts. Virtually all these trips are undertaken by private motorized transportation, given the lack of adequate public transportation such as bus or charter bus and the image issues often associated with public transportation by the affluent.

### **Consequences on Job Accessibility for the Urban Poor**

The above motorization, congestion and commuting trends potentially have the following major effects on the accessibility of poor urban labor in Delhi:

- Exposure to high rates of traffic fatalities in the increasingly mixed-mode streets (where the affluent are in cars or buses and the poorer inhabitants in non-motorized modes);
- Exposure to very high pollution intensities, which affect the poor disproportionately, because these inhabitants are more likely to live and work road-side, where air pollution levels are typically higher than farther away (Badami, 2004);
- Reduction of employment opportunities and dampening effect on wages, due to lack of adequate access to job sites that are located far away from home locations and are not accessible by non-motorized modes or inexpensive public transportation;

- Housing in slum dwellings close to temporary or seasonal jobs, which are often lacking in basic amenities.

While the above points apply broadly, the urban poor are not homogeneous and can be divided into the following groups, based on the type of occupation they work in and their residential location:

- Low-income labor with salaried positions who work in the formal sector and who live in low-rent (permanent) housing;
- Marginal but full-time workers in the informal economy many of whom are migrant workers or are slum dwellers and reside in slum housing;
- Abject poor, who are homeless and out-of-work or are transient labor.

The transportation needs of these three groups might be quite different. The author synthesized the following remarks from published writings, because a formal analysis of the differences among the groups would be possible only on the basis of a large-scale travel behavior survey and accompanying labor market information.

- *Low-income labor with Salaried Positions in the Formal Sector:* The first group may have the need to access jobs in formal job premises at large distances away from where they reside. Table 3 gives the distributions of mode choice by income category. The mode used most often by higher-income households is bus, followed by two-wheelers and private car. In contrast, the mode used most often by low-income households is bicycle, followed by bus and walking. This is not surprising because low-income households are most likely to be involved in low-

**TABLE 3. Mode Shares by Low and Higher-Income Households in Delhi**

| Mode of Transportation | Low-Income Share | High-Income Share | Total      |
|------------------------|------------------|-------------------|------------|
| Private Car            | 0                | 28.35             | 14.175     |
| Bus                    | 31.43            | 36.2              | 33.815     |
| Rail                   | 1.79             | 0                 | 0.895      |
| Auto-rickshaw          | 0.96             | 1.74              | 1.35       |
| Taxicab                | 0                | 0.04              | 0.02       |
| Motorcycle & Scooter   | 2.48             | 29.29             | 15.885     |
| Bicycle                | 38.8             | 2.75              | 20.775     |
| Walked                 | 22.12            | 1.62              | 11.87      |
| Other                  | 2.34             | 0                 | 1.17       |
| <b>Total</b>           | <b>100</b>       | <b>100</b>        | <b>100</b> |

SOURCE Tiwari, 2002)

wage, informal sector jobs close to their home location. Perhaps given better transportation connections, low-skilled workers might be able to travel farther away and obtain secure jobs with higher pay and better benefits.

*Marginal or full-time workers in the informal economy:* The second group is more likely to work close to where they are currently residing. The areas with the greatest number of marginal workers and adults out of the labor force are in the North-East, West, South-West and Southern districts of the NCT. Many of these workers are slum dwellers. As a result of prior policy, slum dwellers were evicted from the city to the periphery but at the present time, informal housing clusters are scattered over many parts of the city and attempts to relocate slum-dwellers continue. Slum inhabitants tend to work in the service sectors, which includes occupations such as domestic help, hawkers and vendors, low paid workers in the industrial, commercial and trade or business sectors etc. A large number of these housing settlements have no access from the arterial and sub-arterial roads in the city, making access to formal public transportation modes difficult. Some of these workers might be part-time workers in multiple jobs, calling for access for transportation that links them for the home-to-work, work-to-work and work-to-home trips.

Street hawkers and others in occupations that work by the streets would also fit into this category. The term “street vending” brings to mind two definite activities: that of the trader who walks around the city offering goods and services without a fixed place from which to operate, and that of the trader who sells merchandise or provides services from a fixed point on public thoroughfares (Aurora and Tagore, 2002). Both types of hawkers are vulnerable to increasing motorization; the first from the risk of street accidents and fatalities and the second from being dislocated from motorizing streets. Aurora and Tagore (2002) also note that street vendors are routinely beaten and driven out of public spaces. As a response to these atrocities, the Government of India has passed National Policy for Urban Street Vendors in 2004. The policy calls for a paradigm shift away from “prohibition” towards regulation. The metropolis must be divided into “green, amber and red” zones, signifying free access, fee-based access and prohibited access by hawkers, respectively. The division into the three categories may vary with the time of the day, the day of the week and the week of the month.

- *Transient Labor and the Abject Poor:* The travel patterns of the third group are unknown from previous studies. Where they live and ways in which they search for jobs or travel to work are the topics of much-needed research and newly collected primary data.

### **Recommendations to Improve Job Accessibility of the Urban Poor**

In response to the various problems afflicting the urban poor, the Government of India has adopted an ambitious program, called the Jawaharlal Nehru National Urban Renewal Mission



(JNNURM) (IF&LS Ecosmart Ltd., 2006). Several transportation projects are eligible for funding under the JNNURM directorate for Basic Services to the Urban Poor. However, these policies are somewhat isolated from the larger workforce development, housing, land-use and economic growth trends that affect job accessibility. The following recommendations could be considered, in addition to the positive steps already taken, to improve job accessibility of the urban poor:

*Transportation planning should be coordinated with real-estate developers, employer representatives, municipal governments and social service agencies:* Much greater coordination is needed in integrating land development and social services, including human services, workforce development and job placement strategies, with transportation. The current pattern of fragmented policies can be alleviated only if the key stakeholders responsible for land-use, economic development and social policies are formally and actively a part of the process. Business leadership is indispensable in this phase of the city's growth since the great economic growth trends have significant implications for attraction of a larger workforce and the generation of freight transportation. Economic development and job creation strategies in neighboring satellite cities should be vigorously pursued to address the continuing rates of urbanization. Moreover, planned land development should be sustained over time, in contrast to previous planned activities that were started in the 1960's, in the periphery of the city.

*Greater investment is needed in fundamental transportation infrastructure that supports the urban poor:* It is clear that a complex urban area like Delhi will need a variety of solutions to address the fast-paced growths in personal mobility. The current investments in rail and BRT are a step in the right direction, but increased investments in feeder services to these systems and high-quality express bus should be a part of the strategy. Most importantly, investments are needed in safe pedestrian and bicycle facilities and in the physical coordination of such facilities with facilities for motorized transportation. Given the narrow roads, emphasis on BRT and the wide-spread practice of street parking, dedicated bike lanes have not received political support. However, given that close to 40 percent of low-income commuters use bicycles and rickshaws, a practice of rush-hour bike-only road segments might be instituted in secondary roads and supplemented by strict enforcement of no-parking in primary roads.

*Employer participation, tax incentives and jobs-housing balance should be a part of the strategy:* Many low-wage workers will simply not have the means to commute to jobs in far-away locations; hence a strategy needs to be in place to directly address job-housing balance and the financial needs of workers to afford public transportation. Key in this strategy will be the participation of employers (or groups of employers) in providing transportation to their employees, which can be increased by creating a system of corporate tax incentives for providing employment transportation and worker housing. In order to increase affordability of existing public transportation, a system of tax credits can also be created to subsidize commutes by low-

wage workers. The government should also attempt the dedication of land for informal housing near job-rich locations or near transportation hubs.

*Incentives and information regarding informal, community-based transportation should be instituted:* Informal, community-based transportation (called jitneys in some developed countries), paratransit services, ridesharing programs and self-organized vanpools should be actively pursued and incentives provided for participation in such transportation.

*Information Technology should be leveraged in personal transportation:* The idea of “New Mobility Hubs” (Zielinski, 2006), which connect a variety of sustainable modes of transportation and services through a network of physical locations or “mobile points”, by physically and electronically linking the elements necessary for a seamless, integrated, sustainable door-to-door trips, should be explored. India’s significant investments on Intelligent Transportation Systems and the telecommunications sector, and the rapid adoption of mobile phones, can greatly facilitate the use of such hubs. Many specially designed mobile phones are now in the market, putting these devices within reach of the poor. Facilities that connect pedestrians, bike-rentals, bike-sharing stations and indigenous modes of non-motorized transportation such as rickshaws to rail and BRT stations, and that are integrated with these high-speed systems by means of real-time travel and connection protection information, as well as subscription and payment systems, are a part of a concept. For longer trips, these fixed-route transit services can also be connected to auto-rickshaws (motorized rickshaws), station cars and ridesharing programs.

*Investment in data programs are needed:* In order to effectively include job accessibility for all income groups as a performance measure in the transportation planning process, far greater investments are needed in household travel surveys and special purpose surveys on the travel behavior, activity patterns and residential location of low-income workers. It is equally important to link such transportation data with information on labor markets, workforce development housing and land-use. Researchers should also be given special access to small-area transportation, economic and workforce-related data, so that the fundamentals that drive transportation demand and job accessibility are better understood.

## CONCLUSIONS

Job accessibility should become an essential ingredient in planning sustainable transportation systems, so that the social equity aspects of metropolitan areas in developing cities can be enhanced. Accessibility to jobs is recognized to be important in achieving beneficial labor market outcomes, but is often ignored in the practice of transportation planning and in the prioritization of expensive infrastructure projects .

This paper attempts to add to the discussion on the importance of considering job accessibility

in sustainable transportation planning in developing cities, by examining the case of Delhi. The paper shows that job accessibility is affected by a myriad of economic development, housing, land-use and demographic processes and the solutions to enhance accessibility should likewise be multi-pronged and based on a combination of transportation and urban development, workforce development and human services strategies. As the transportation policy environment evolves in response to choking congestion, bad air and road fatalities, it is essential that the job accessibility considerations of the urban poor become an integral part of the overall agenda towards planning sustainable transportation systems in developing cities. The strategies that need to be leveraged in order to improve job accessibility are likely to be different in different cities, but sustainable transportation planning necessitates that planners attempt to understand where workers live and where the jobs are and the underlying processes, which contributed to spatial distribution of jobs and workers.

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## REFERENCES

- Advani, M. and G. Tiwari (2005). "Evaluation of Public Transport Systems: Case Study of Delhi Metro." In Proceedings of START-2005 Conference held in IIT Kharagpur, India.
- Arora, S. and A. Tagore (2002). "Street Vendors: Exploitation by the State." Centre for Civil Society Working Paper No. 0017.
- Badami, M, G. Tiwari and D. Mohan. (2004). "Access and Mobility for the Urban Poor in India: Bridging the Gap between Policy and Needs." Paper Presentation at the Forum on Urban Infrastructure and Public Service Delivery for the Urban Poor. Organized by the Woodrow Wilson International Center for Scholars, Washington, DC and National Institute of Urban Affairs, New Delhi.
- Baker, J., R. Basu, M. Cropper, S. Lall and A. Takeuchi. (2005). "Urban Poverty and Transport: The Case of Mumbai." World Bank Research Working Paper No. 3683.
- Basu, I. (2005). "India Zips Ahead." In *Asia Times Online*. At [http://www.atimes.com/atimes/South\\_Asia/GB24Df05.html](http://www.atimes.com/atimes/South_Asia/GB24Df05.html). Accessed on September 15, 2007.
- Baradan, S. and F. Ramjerdi. (2001). "Performance of Accessibility Measures in Europe." In *Journal of Transportation and Statistics*, Vol. 4, No. 2/3, pp. 15-30.
- Bederman, S. H. and J. S. Adams. (1974). "Job Accessibility and Underemployment." In *Annals of the Association of American Geographers*, Vol. 64, No. 3, pp. 378-386.
- Berglund, S. (2001). "Path-Based Accessibility." In *Journal of Transportation and Statistics*, Vol. 4, No. 2/3, pp. 15-30.
- Boarnet, M. (2006). "Conducting Impact Evaluations in Urban Transport. Doing Impact Evaluation Series No. 5, Thematic Group on Poverty Analysis, Monitoring and Impact Evaluation." The World Bank.
- Bowen, J. (2006). "Tigers in a Traffic Jam? Urban Transport in Southeast Asia." Chapter 4 of *Challenging Sustainability: Urban Development and Change in Southeast Asia*. Ed. Wong, T., B. J. Shaw and K. Goh.
- DDA (1996), *Master Plan for Delhi*, New Delhi: Delhi Development Authority.
- Delhi Metro Rail Corporation (2003), Official website, available at <http://www.delhimetrorail.com/home/index.htm>.
- Delhi Statistical Handbook*. (2000). Directorate of Economics and Statistics, Government of the NCT of Delhi.
- Delhi Urban Environment and Infrastructure Improvement Project*, DUEIIP (2001). Government of India, Ministry of Environment and Forests and Government of National Capital Territory of Delhi, Planning Department.
- Directorate of Economics and Statistics*. (2005). Provisional results of Fifth Economic Census – 2005 in Delhi.
- Dunlop, J. E. and V. A. Velkoff. (1999). "Women and the Economy in India." Women of the World, International Programs Center, U.S. Department of Commerce, Economics and Statistics Administration, Bureau of the Census. January.
- DuPont, V. (2003). "Urban Development and Population Redistribution in Delhi: Implications for Categorizing Population." Chapter 9 in *New Forms of Urbanization: Beyond the Urban-Rural Dichotomy*. Edited by A. G. Champion, Graeme Hugo and Tony Champion. Ashgate Publishing.

- Handy, S.L. and D.A. Niemeier. (1997). "Measuring Accessibility: An Exploration of Issues and Alternatives." In *Environment and Planning A*, Vol. 29, No. 11, pp. 75–94.
- Hansen, W. G. (1959). "How Accessibility Shapes Land Use." In *Journal of the American Institute of Planners*, Vol. 25, pp. 73-76.
- Harris, B. (2001). "Accessibility: Concepts and Applications." In *Journal of Transportation and Statistics*, Vol. 4, No. 2/3, pp. 15-30.
- IF&LS Ecosmart Ltd. (2006). *City Development Plan, Delhi*. For Jawaharlal Nehru National Urban Renewal Mission (JNNURM), October.
- Ingram, D.R. 1971. "The Concept of Accessibility: A Search for an Operational Form." In *Regional Studies* 5:101–7.
- Ingram, G.K. and Liu, Z (1997) "Motorization and the Provision of Roads in Countries and Cities." World Bank Policy Research Working Paper No. 1842.
- Ihlanfeldt, K. R. (1999). "The Geography of Economic and Social Opportunity in Metropolitan Areas." In *Governance and Opportunity in Metropolitan America*. National Academy Press, pp. 213-252.
- Kain, J. F. and J. Persky. (1969). "Alternatives to the 'Gilded Ghetto'." In *The Public Interest*, Winter, pp. 77-91.
- Misra, B., R. B. Singh, and Anupma Malik (1998). "Delhi Metropolis: Housing and Quality of Life." In R. P. Misra and Kamlesh Misra, eds. *Million Cities of India: Growth Dynamics, Internal Structure, Quality of Life and Planning Perspectives*. New Delhi: Sustainable Development Foundation.
- Mohan, D. and G. Tiwari (1997), *Road Safety in Low Income Countries -- Issues and Concerns Regarding Technology Transfer from High Income Countries*, Report prepared for the Global Traffic Safety Trust, New Delhi: Indian Institute of Technology.
- Mohan, D. (2006). "Squandering Public Funds for Handful of People." In *Business Standard*, Oct 7, available at <http://www.business-standard.com/india/storypage.php?autono=260942>. Accessed 12/30/2008.
- Morris, J.M., P.L. Dumble, and M.R. Wigan. (1978). "Accessibility Indicators for Transport Planning." In *Transportation Research A*, Vol. 13, pp. 91–109.
- Murty, M N., K. K. Dhavala, M. Ghosh and R. Singh (2006). "Social Cost-Benefit Analysis of Delhi Metro. Institute of Economic Growth," Delhi University Enclave, Working Paper, 273. Available at [http://iegindia.org/workpap\\_273.pdf](http://iegindia.org/workpap_273.pdf). Accessed 10/02/2007.
- NCTD (2001). *Economic Survey of Delhi 2000-2001*, New Delhi: Government of the National Capital Territory of Delhi.
- Persky, J. and D. Falsenstein. (2006). "Restricting Access in a Job Chains Model of Local Employment Creation." In *Annals of Regional Science*, Vol. 40, pp. 423-435.
- Pickrell, Don. 1992. "A Desire Named Streetcar: Fantasy and Fact in Rail Transit Planning," *Journal of the American Planning Association*, 58(2), 158–176.
- Raphael, S. (1998). "Spatial Mismatch Hypothesis and Black Youth Joblessness: Evidence from the San Francisco Bay Area." In *Journal of Urban Economics*, Vol. 43, pp. 78-111.

- Richmond, J. (2005). *Transport of Delight: The Mythical Conception of Rail Transit in Los Angeles*. Akron, Ohio: University of Akron Press.
- RTES/ORG (1994), *Household Travel Surveys in Delhi, Final Report, New Delhi and Baroda*: Rail India Technical and Economic Services Ltd. and Operations Research Group.
- Sen, A., P. Metaxatos, S. Soot and P. Thakuria (1999). "Estimation of Demand due to Welfare Reform." In *Papers in Regional Science*, Vol. 78, No. 2.
- Shen, Q. (1997). "Urban Transportation in Shanghai, China: Problems and Planning Implications." In *International Journal of Urban and Regional Research*, Vol. 21, No. 4, pp. 589-606.
- Shoup, D. (2006). "Review of Transport of Delight: The Mythical Conception of Rail Transit in Los Angeles." In *Journal of Regional Science*, Vol 40, No. 3.
- SIAM (2002), *The Indian Automobile Industry – Statistical Profile 2000-2001*, New Delhi: Society of Indian Automobile Manufacturers.
- Srinivasan, S. (2004). "Influence of residential Location on Travel Behavior of Women in Chennai, India." In *Research on Women's Issues in Transportation; Report of a Conference*. Conference Proceedings 35, Vol. 2: Technical Papers. Transportation Research Board.
- Thakuria, P. and Y. Liao. (2006) "An Analysis of Variations in Vehicle-Ownership Expenditures." In *Transportation Research Record, Journal of the Transportation Research Board*, No. 1926, pp. 1-9.
- Thakuria, P. and P. Metaxatos. (2000). "Effect of Residential Location and Transportation on Employment Opportunities." In *Transportation Research Record, Journal of the Transportation Research Board*, No. 1726, pp. 24-32.
- Thakuria, P., P.S. Sriraj, S. Soot and J. Persky (2008). "Economic Benefits of Employment Transportation." Final Report to Federal Transit Administration, U.S. DOT and Community Transportation Association of America, June for Grant No's DOT IL-37-X007-00 4 and DOT IL-37-5002-00. Summary can be viewed at [http://www.utc.uic.edu/research/reports/Thakuria\\_Summary\\_report2008.pdf](http://www.utc.uic.edu/research/reports/Thakuria_Summary_report2008.pdf) and the full report at [http://www.trb.org/news/blurbs\\_detail.asp?id=9268](http://www.trb.org/news/blurbs_detail.asp?id=9268).
- Tiwari, G. (2002). "Urban Transport Priorities – Meeting the Challenge of Socio-economic Diversity in Cities; A Case Study of Delhi, India." In *Cities*, Vol. 19, No. 2, pp. 95-103.
- United Nations, Population Division (2002), *World Urbanization Prospects – The 2001 Revision, Data Tables and Highlights*, New York: United Nations Population Division, Department of Economic and Social Affairs, United Nations Secretariat.
- United Nations, Department of Economic and Social Affairs (2001). "Demographic and Social Trends Affecting Families in South and Central Asian region." Occasional paper. Available at <http://www.un.org/esa/socdev/family/Publications/mtdesilva.pdf>. Accessed on 10/02/2007.
- U. S. Executive Order 12898 (1994). *Federal Actions to Address Environmental Justice in Minority and Low-Income Populations*.
- Venkatakrishnan, K. (2006). "Will a Rise in Reverse Repo make Auto Financing Dearer in India?" Available at <http://www.frost.com/prod/servlet/cif-econ-insight.pag?docid=7622163>. Accessed on September 15, 2007.
- Weibull, J.W. 1980. "On the numerical measurement of accessibility." *Environment and Planning A*, Vol. 1, pp. 53-67.

Wilson, W. J. (1987). *The Truly Disadvantaged: The Inner City, the Underclass and Public Policy*. Chicago, University of Chicago Press.

Wilson, W. J. (1996). *When Work Disappears*. New York. Alfred A. Knopf.

World Bank (1996). *Sustainable Transport: Priorities for Policy Reform*. The World Bank, Washington, D. C.

Zielinski, S. (2006). "New Mobility: The Next Generation of Sustainable Urban Transportation." In *Bridge*, Vol. 36, Number 4 - Winter 2006.





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# ROAD PRIVATIZATION AND SUSTAINABILITY



## ABSTRACT

Almost all road infrastructure is treated as a public good and seen as a governmental obligation. But roads differ from other public goods such as national defense in both non-rivalry and non-exclusiveness features. Moreover, Financing construction and maintenance of road infrastructure is challenging because in most countries, government revenues for road construction and maintenance are insufficient. Here, the idea of road privatization is introduced as a possible alternative. Although there are many political and societal hindrances in implementing this idea, its potential to solve problems in transportation is indisputable. The road owner pays the government for the externalities produced from his property (pollutions or accidents) but can make money by charging users (passing the externalities burden to users, while easing congestion and free rider problems) and because the road is privately constructed and owned, the opportunity cost of the road construction and maintenance is better accounted for. By assigning the road's property to private sectors, the supply side might become more efficient based on the transformation from a publicly subsidized market to an open market framework. The equity problem of the new pricing scheme can be partially solved with a rebate policy similar to credit-based congestion pricing (CBCP).

## INTRODUCTION

The road network is a major component of a transportation system. Roads, together with vehicles and drivers and their behaviors, establish a road system. But little effort has been done to incorporate a clear framework of road ownership and the related regulations especially compared with the two other components of the system. Since vehicles and drivers have their own identity, it is easier to think about implementing policies to affect them; however, this is not the case for roads. The ownership of roads is not clearly defined and regulated. Although one counter-argument is that governments or states are the owners of roads, an unambiguous way to solve the ownership problem is to privatize roads.

About two hundred years ago, hundreds of turnpike companies operated miles of toll roads in the UK and the USA. In 1830, 1116 turnpike trusts maintained 22,000 miles of toll roads in Great Britain (one fifth of the total road system) (Jeffreys, 1949) and by 1845, 1562 toll companies had been chartered in the USA (Klein et al, 2006). The tolled roads comprised a substantial part of the economy at that time. The turnpikes were successful even though they disturbed the flow of traffic. The concept of a dedicated road fund, financed from the fuel taxes and established in Oregon in 1919, changed the balance of transportation financing from private toward public sector investment (Roth, 2006).

Privatization of transportation infrastructure has gained more attention in the recent years. The potential depletion of public financial resources due to fuel tax revenue reduction, increased in alternative fuels' consumption, and the demand for better service requires a revolution in the road infrastructure. Moreover, advances in toll collection technologies, Electronic Toll Collection (ETC) in Singapore (Uskkusuri et al, 2004), have lowered the transaction costs of revenue collection from roads.

Road privatization transforms road ownership from public to private ownership. In recent years, the long-term concession agreements or public-private partnerships (PPPs) have emerged as a potential source of significant new revenue for transportation (Ortiz et al., 2008). The transformation has been accomplished in two different ways. In the first approach, build operate transfer (BOT), a private entity is granted the right to construct, operate, maintain, and finally transfer the property to the government through an auction (Chen et al., 2007). Although some other similar methods exist, such as build own operate (BOO), all the methods can be categorized as constructed private roads. Under this approach, roads should be built by the private sector. Thus, the cost of the construction is considered in the decision making process and consequently in the revenue collection. Some examples of this approach are the Dulles Greenway (Euritt et al, 1994) and Median California State Route 91 (Sidney, 1996) in the United States, Super Highway project in China (Yang et al, 2002), and Guadalajara project in Mexico (Huang, 1995).

The second approach is leasing existing roads to the private sector for some period. Here, the

private entity only considers maintenance costs while evaluating a renting decision. However, the opportunity cost of construction is considered through bidding. In fact, if the leasing creates more revenue than BOTs, private entities only have incentives to invest in renting instead of BOT projects. Thus, the renting price of leasing contracts increases to a level which indirectly includes construction costs. However, existing infrastructure could be a great source of benefit under this approach. The first long term lease of an existing toll road in the USA was the Chicago Skyway lease for 99 years and \$1.83 billion in 2004 (Ortiz et al., 2008). Another controversial example is the Indiana East West Toll Road (157 miles), which is leased for a nearly four billion dollar concession fee. Debates are ongoing about financial and public acceptance of this contract (Crowe Chizek, 2006), (Graves, 2007).

In both approaches, firms (private entities) collect money by charging tolls on their roads. Previously, it was impossible to gather tolls without disturbing the traffic flow. But with the electronic devices, it is easy to charge vehicles with little interruption, at low cost, and with high flexibility (Uskukuri et al, 2004), (Litman, 2003). Present pricing schemes for privately owned roads are odd because they are not demand-responsive (based on the contracts, tolls are usually applied only for peak-hour periods or should remain the same for all periods of day). The road pricing flexibility, as its main strength, is almost ignored in even governmental owned congestion pricing schemes, although there are no tight price limits for the public roads.

The rest of the paper is organized as follows. The second section reviews the main problems of the road system and the methods to improve it. The third section describes public goods and discusses if roads are public goods. The fourth section reviews privatization strategies. The fifth section analyzes administrative or governmental prices against market or private prices. The sixth section reviews potential risks of privatization. The seventh section explains possible outcomes and results of privatization. The following section discusses the implementation issues aroused from few practical examples. The ninth section addresses the question of matching between privatization and sustainability. The tenth section tries to answer the question of whether privatization matches sustainability goals. The eleventh section provides an outline for privatization policy and the possible remedy for equity problems. Finally, conclusions summarize the main points.

## IMPROVING ROAD SYSTEM

In general, sustainable development entails three dimensions: economic, environmental, and social sustainability or equity. With no exception, sustainable roads should provide economic efficiency, ecological stability, and social equity (Schwaab et al, 2001). Nevertheless, all the dimensions can be converted to monetary terms. Financial improvement can cover other aspects as will be discussed later. However, a sustainable policy should consider different impacts of pursuing this goal. The present trends in the road systems do not seem sustainable.

Congestion is a growing concern for road networks. The average traffic congestion costs for OECD countries account for about 3% of their gross domestic product (GDP), about \$810 billion annually: this proportion is 4.4% for South Korea (Schwaab et al, 2001). Congestion also increases greenhouse gas (GHG) emissions, losses in energy and time, and criteria pollutant emissions.

Reducing vehicle miles traveled (VMT) through demand management and increasing efficiency (sending an efficient price signal) are two broad policies to address congestion or in general external costs from roads. Adding capacity is another solution on the supply side. Although additional capacity may increase demand, taking into account that VMT and GDP are highly correlated (Choo et al, 2001) (even if no causal relationships are found) supports the trend of adding capacity rather than reducing VMT. In other words, the efficiency increase through adding capacity will not only decrease our fuel consumption, pollution, and accidents by providing a better service, but also increase GDP by providing a better access to socio-economic systems. For instance, a study by the World Bank found that although a better road network increases motor vehicle usage, it can reduce GHG emissions by improving agricultural and heating practices (better access to fuels and inputs) (EU road federation, 2007). Thus, the attempts to increase the efficiency of roads might be superior to policies restricting demand-VMT. Those attempts do not restrict people's travel activity and seek to be more efficient overall. However, a combination of the two approaches can be implemented as well.

Financing is another problem in transportation systems. Not only are the funds insufficient, but they are also inefficiently allocated. Transportation costs are not passed to users in the present transportation finance structure. By including the internal costs (construction and maintenance costs) and external costs (congestion, pollution, accidents) of travel, the efficiency of roads can be increased (Schwaab et al, 2001).

### **ARE ROADS PUBLIC GOODS?**

A common definition of a public good is "A good which once provided to one user must be provided to others in the same amount" (Public good def-a), in other words, everyone can simultaneously obtain benefits. This means that the good should be 1) Non-rivalrous (one's consumption does not impede that of others') and 2) Non-exclusive (no one can be excluded from its consumption). Do roads fit this definition? Even in non-congested conditions, each driver's entrance to a road lowers other drivers' utility by reducing overall speed. When roads become congested, one person's benefit definitely reduces that of others. Thus, they are rivalrous. This becomes worse with congestion. The second argument is that some people's consumption is much less than others' (less VMT). Some people cannot afford a car, which means roads are partially exclusive. Since the rich consume more and have higher VMT, public roads provide a kind of progressive subsidy for society, with a higher subsidy for people with higher income. This creates an inequality.

The other definition for a public good is “A good that is hard or even impossible to produce for profit” (Public good def-b). This is not true for roads anymore. A \$4 billion concession fee contract for the Indiana Toll Road (Crowe Chizek, 2006), for example, shows huge profits can be gained from road infrastructure. Users’ willingness to pay is seemingly high enough to compensate for the travel cost increase. This can constitute a profitable industry which increases GDP directly and indirectly.

One general conception about roads is that they are strategic goods like national defense, and should be under national control and treated as public goods. Leasing instead of selling roads complies with this conception to some extent. Government does not sell its property and applies some control levers on these roads. Thus, this relation will not be out of control.

Finally, transportation infrastructure should improve with economic growth. Considering the lack of financial resources limits this growth, there may be no other solution than at least a partial private road system. In this regard, the Public-Private Partnerships investments have grown in the transportation sector (IRF, 2007).

## PRIVATIZATION STRATEGIES

A transformation from public to private arrangement can be made through different strategies and on different levels. Each strategy has unique characteristics which should be commensurate with the nature of the particular good or service under application. Three broad strategies have been used: Divestment, Delegation, and Displacement. It should be noted that each strategy can be applied in different roles of governments: Planning or paying for, or producing goods or services (Savas, 1989).

### Divestment

Divestment means shedding an enterprise through selling, donation, or liquidation. Denationalization is another term for divestment. This is generally a one-time act by governments. This option is frequently used in transportation systems. The attempt to sell state-owned freight rail road to Conrail in the USA (Savas, 1989), the sale of the National Freight Corporation (state-owned trucking company) in Great Britain (Savas, 1989), the sale of the share of mass transit railway in Hong Kong (Asian economic news, 2000), and the giving away of the English Channel hovercraft ferry service to its management (Savas, 1989) are some famous examples.

### Delegation

Governments can delegate different parts of a service to the private sector. Delegation can be carried out by contract, franchise (concession), grant, or mandate. This option needs a continuous role for governments (Savas, 1989). The Indiana East West Toll Road lease (Crowe Chizek, 2006), grants for operating mass transit (Rebello, 1999), (Kwak, 2002), and concessions

of airports in China (Hooper, 2002) are of this type. Giving away roads to the real owners, the tax payers who mostly financed roads, is another hypothetical option (Carnis, 2001).

### Displacement

Inadequate service due to lack of public funds will result in displacement of governmental owned enterprises with private ones. Marketization is another term used for this process. Displacement is a passive process that does not require active efforts by governments (Savas, 1989). Displacing parts of public road funds, maintenance, or even ownership with private ones such as BOO and BOT projects (Euritt et al, 1994), (Sidney, 1996), (Yang et al, 2002), (Huang, 1995), and the rapid growth of express mail services (freight transportation) by private companies show that this can be a common strategy in transportation systems (Savas, 1989).

Privatization can be done by each of the mentioned strategies or combinations of them. However, privatization should connote directionality and the related strategy(s) can be considered form(s) of privatization only when this leads to a lesser, not greater, role for governments (Savas, 1987). Public-private partnerships can be considered as other types of privatization in transportation, like the use of R&D partnerships to increase the efficiency of vehicles (Sperling, 2001). Table 1 presents some of the examples of privatization in the transportation sector.

**TABLE 1. Examples of privatization in the transportation sector**

| STRATEGY     | CASE  | COMMENT  |
|--------------|---|--|
| DIVESTMENT   | Selling rail service in the US                            | State-owned freight rail road to Conrail                         |
|              | Mass transit in Hong Kong                                 | Sale of shares   |
|              | English Channel hovercraft ferry service                  | Giving away to its management                                    |
| DELEGATION   | Indiana East West Toll Road lease                         | 75 year lease  |
|              | Rail and subway concessions in Rio de Janeiro             | Initially Suburban rail for 10 years and the subway for 20 years |
|              | Taiwan High Speed rail                                    | Concession project   |
|              | KL Light Rail transit in Malaysia                         | Concession project   |
|              | BAA's airports in China                                   | Multiple concessions through establishing a joint venture        |
| DISPLACEMENT | Guadalajara project in Mexico                             | BOT- toll road   |
|              | Median California State Route 91                          | BOT- toll road   |
|              | Super Highway project in China                            | BOT- toll road- Connecting industrial cities                     |
|              | Partnerships to increase efficiency of vehicles in the US | R& D Public-Private partnership                                  |



## ADMINISTRATIVE VERSUS MARKET PRICES

Congestion pricing is an example of externalities pricing in transportation practices. At present, it seems possible to consider that pollution and accidents can also be included. Researchers have developed detailed models for calculating the amount of pollution from different types of vehicles at different levels of speed (congestion). The number of accidents can be determined by referring to traffic records. Nevertheless, there is no, or at least little, incentive for either users or governments to address these from the perspective of road infrastructure. Pollution and accidents are usually not attributed to the road designs and their owners. From the official's perspective, these externalities are produced by vehicles or drivers, but part of these emissions, especially congestion related emissions, and accidents may be due to the poor road-way supply. However, public roads are in most cases out of reach due to the ownership structure. This problem can be addressed by transferring the property to clear entities such as the private sector. After privatization, public officials are more willing to blame roads and their private owners for their poor services. This paradox can be called property rights paradox (Buitelaar et al, 2007).

The poor quality of transportation systems and the lack of financial resources urge the need for implementing a pricing scheme. A crucial question is about the choice between centralized-administrative or decentralized-market decision for pricing (Carnis, 2001). It is not easy to answer this question mainly because there is no widespread experience of decentralized or even centralized road pricing in practice.

Road networks can be nationalized, privatized, or a combination of these two, all of which need a clear definition of property rights (Zhang et al, 2006). Nationalized (or centralized) ownership means that governments should control roads. This can be done by imposing administrative prices. But when roads are privatized, governments do not have full control over road tolls and market forces determine the decentralized prices.

Both administrative prices imposed by the public officials and market prices in a private framework have advantages and disadvantages. One important advantage of the privatization is the probable improvements in the price signal of the system. It has been known that the unhampered price signal based on decentralized ownership is the key for correct resource consumption (Carnis, 2001). This is also true for transportation, with the exception that the price of externalities could not be internalized without intervention. Therefore, it seems that decentralized control should be applied together with some regulations or fines for transportation. On the other hand, the administrative prices mislead entrepreneurs from doing real benefit and cost analyses, which will result in a full of risk environment for investment (Carnis, 2001).

Commercialization, pricing publicly owned roads with administrative control, can only provide a partial solution to the problem based on the public ownership inefficiencies (Carnis, 2001). The

inefficiency of public ownership has been shown in different studies (Dal Bo et al, 2007), (Mises, 1983). Bureaucracy and the large size of the publicly owned firms are the main contributors to the inefficiency (Dal Bo et al, 2007). In addition, private methods cannot be efficiently combined with socialist structures (Mises, 1983). Socialist structures are problematic in internalizing not only the transportation costs but also other public expenditures. Thus, it might be better to implement those structures without private methods than to implement a hybrid structure. Carnis (2001) concluded that “To solve fully the problems associated with clearly defined and exchangeable property rights in the roads network and land, if the road network is to be subject to market discipline, it must be decentralized, not merely commercialized”.

Moreover, there are some inevitable difficulties in implementing administrative prices. Officials should decide to change the price or the price scheme and different institutions involved should agree with this decision, while the strength of road pricing should be based on the flexibility of prices and their responsiveness to demand (Zhang et al, 2006). The flexibility of prices is not considered in most of the present practices, especially for road pricing; instead, fixed charges are used for different periods of day (Engel et al., 2003). Furthermore, administrative prices may threaten the privacy of users. The 10 Downing street e-petition against congestion pricing in the UK was an important signal to downgrade the idea of tracking vehicles (Richards, 2008).

Finally, either pricing method can change the balance toward the public transit as a result of higher costs of driving after introducing a new pricing scheme. In addition, the revenue from roads can be spent on public transportation development leading to a better service, and the resulting increase in demand for public transportation can smooth the traffic on roads, which leads to a decrease in congestion, gas consumption, and emissions as a secondary effect of privatization.

## POTENTIAL RISKS OF PRIVATIZATION

The first and most important risk of privatization is equity. New ownership of road infrastructure causes great losses and benefits to different groups of people. Companies or individuals who spend higher proportions of their income on transportation will lose money at least in the short run. For instance, trucking companies opposed the privatization trend based on this rationale (Graves, 2007). On the other hand, road owners possibly gain a huge profit. Generally, transportation costs changes in an unclear resource-efficient manner after privatization. Some of these companies should be losers and winners; present transportation costs are far from their reasonable level (Crowe Chizek, 2006).

The possible gain of peripheral land owners is an equity issue for new road construction. But through auctioning the construction of a private road, landlords can participate and gain from their land's appreciation after the construction. The participation can be beneficial to society.

Landlords can lower the price of construction or, as a substitute, lower the toll revenue, which simply leads to less expensive services (Engel et al, 2005).

The possibility of a new monopoly (or oligopoly) formation is another important risk. The spatial restriction of road development and the possible barriers to enter the market may result in an imperfect competition. Alternative roads are restricted for any origin-destination pair, and a new competitive alternative is costly to construct and hard to allocate space for. This is accompanied by high levels of tolls (monopolistic behavior) and even over-investment in road networks. The risk of a new monopoly necessitates regulation. With regulation, a decentralized structure can outperform a centralized one by being more responsive to travel demand patterns if flexible prices are allowed (Zhang et al, 2006). Another argument against private roads is that their revenues (may) go to the private sector and shareholders rather than government. But government can charge the private companies for the externalities produced from the roads and raise revenue for other public expenses. Moreover, area residents can be the possible shareholders of private roads. Thus, the higher revenue can be justified.

Road network ownership has a vague framework. Examination of all of its aspects is essential to prevent an unpleasant outcome. This examination should consider all the parties or institutions which are involved and the associated strategies (further explanation in the “Policy Analysis” section).

### **WHAT ARE SOME POSSIBLE OUTCOMES?**

Fundamental changes affect transportation structure through creating dramatic changes in the public roles, road way system, land use, people’s behavior (driving and purchasing car), and alternative fuel usage. Government will not be responsible for the road’s externalities. This leads to easier fining and charging scheme designs. In this new environment, Asset Management (AM) can play a critical role. Roads as assets of nations should be taken care of in a wise manner while privatized (Dornan, 2002).

From the road owners’ perspective, interestingly, private benefits instead of private costs (costs of driving) will be the goal. But this can be dangerous for the transportation service. Social welfare is the goal, not making more profits. Regulations are essential to direct the investment to the more socially superior projects (Sperling, 2001). On the other hand, the private sector’s objective to minimize costs can address internal costs (cost of construction and maintenance), and by maximizing benefits, the private sector can provide better and more efficient service to attract demand.

An indisputable strength of the private market for roads is that market levers would increase supply, constructing new roads or increasing capacity when there is a shortage and would

decrease it, closing some roads or decreasing capacity, when demand is lower than its equilibrium level. In this new environment, public roads' existence can be dangerous. Many users might shift to these roads, due to the absence of fee charges, and the congestion might become much higher than plausible levels (DeCorla-Souza 2008). As a result, it seems essential to think about the privatization of most of the roads unless worse congestion and poorer service is acceptable to some groups of people. A regime including main public roads may not be efficient, but it can provide different goods (roads) with different prices so that different classes of users can use them.

After privatization, a road network becomes a collection of substitute and complement goods. In this new environment, substitute roads compete for attracting demand while complements probably cooperate to improve their service. Generally, substitute roads are the roads on alternative routes and complement roads are the roads on the same route. This creates a competition between road owners to determine the optimized price for their roads. Interestingly, some road segments will be complements for some routes and substitutes for others. This makes prediction of the result harder. However, it seems that cooperation between road owners can help the efficiency of the network (Zhang et al, 2006). After privatization, the junctions' performance can also pose a problem unless road owners and public officials cooperate.

Privatization might result in two possible broad outcomes: an oligopoly or a competitive framework. These two are the same in providing better service than the present conditions. Figure 1 shows the transition from present conditions to two possible outcomes based on the Van Aerde model (Rakha et al, 2002), a more complicated model version of the Greenshields model (Greenshields, 1934). It should be noted that this model estimates different points of the intersection of supply and demand for each road with speed, flow, or density as variables. The left curve of the figure shows some hypothetical data which are close to average present conditions and the other two curves show two possible outcomes (speed and flow diagram).

By representing private roads and the consequent pricing regime, both the demand and supply change results in less congested roads. Rufolo et al (2008) showed that mileage fees result in reduction in driving even with the same total money gathered as the gas tax spent to drive. The difference between competitive and oligopoly outcome is based on the power of firms to change prices. In a competitive framework, firms do not have any power to change tolls (prices), so they probably try to increase the demand, maximize the traffic, and stay at the maximum flow part of the curve to increase their revenue. But the competitive behavior of roads owners is less probable (Zhang et al, 2006).

The oligopoly structure is more probable based on the spatial restrictions of roads' construction. Adding that changing routes may be time-consuming and users may not have any other options,

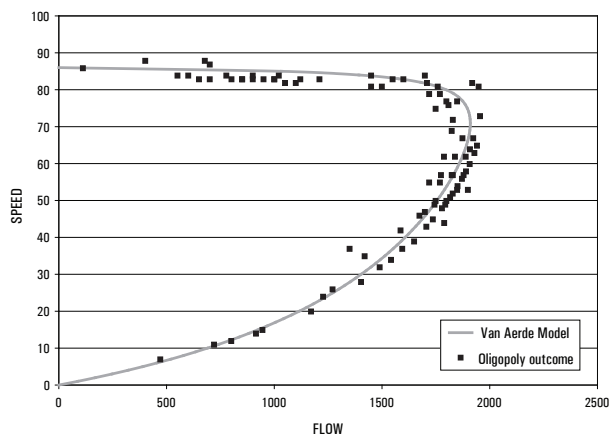
the owner can overcharge and consequently increase his/her profits and gain a monopolistic power. In addition to the spatial restrictions, land purchasing problems and high construction costs are barriers to entering the market, which may lead to a monopoly or some kind of oligopoly (Zhang et al, 2006). For several practices, the tolls are the highest in the world; the prime example is a 13-mile stretch outside Mexico City that costs \$6 to use, twice the daily minimum wage in Mexico (Porter, 1997). However, charges decrease the demand for travel. Thus, both frameworks reduce congestion. The private owners try to prevent the congested part by increasing prices when demand increases. They try to sustain their revenues and decrease their maintenance costs by restricting the demand. If the demand is not restricted, the traffic flow (consumption) decreases and as a result, their revenue will decrease due to both lower demand and the poorer service.

An oligopoly, which is commensurate with less consumption- lower VMT, is superior to a competitive outcome without regulating emissions due to the higher charges required. Generally, private marginal costs instead of social marginal costs govern the transportation market (concept of externalities). To approach the social optimum, consumption should be reduced. In fact, oligopoly behavior and externalities cancel or reduce the effect of each other. It should be noted that the road owners can smooth the change in travel demands by applying different prices for different periods of the day (changes in supply).

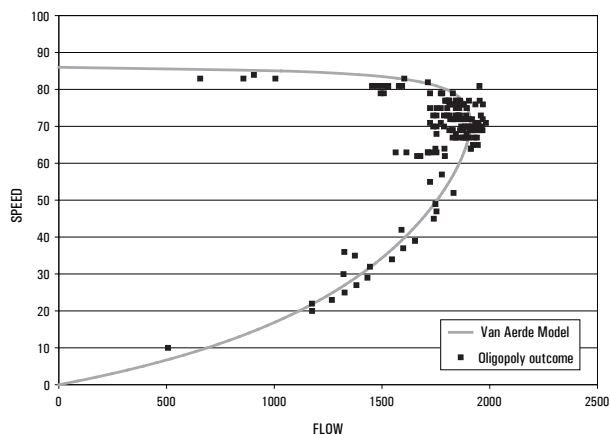
Not only can privatization decrease congestion, but it can also decrease emissions by shifting speeds to more efficient parts and decreasing travel time. The speed of approximately 80 kilometers per hour represents both maximum flow and lowest emissions including GHGs (for most of the vehicle models), which is the peak part of the model. The competitive outcome is desirable from this aspect: the target of a competitive market would be providing the service mostly at the peak point of the graph. As an example of increasing efficiency by charging, each priced lane in the median of State Route 91 in Orange County, Cal carries twice as many vehicles per hour as the adjacent toll-free lanes during peak-hours based only on a good balance of demand and capacity (DeCorla-Souza, 2008).

However, publicly owned roads are strongly accepted goods. The hardest part of implementing this policy is the essential change in people's view about the ownership. People might resist this change (Philadelphia Business Journal, 2007) not only because they prefer their stable conditions and are afraid of changes, but also because they are afraid of being worse off with the introduction of new charges. The equity issues around toll pricing can exacerbate the situation. Nevertheless, opinion surveys showed that people favor tolled express lanes against a gas tax increase (Samuel, 2005). People's satisfaction is the key for the success of the policy. This can be addressed by a Christmas Tree legislation; all should benefit from the policy (Christmas Tree Bill); CBCP in section 11.

PRESENT  
CONDITION



COMPETITIVE  
CONDITION



OLIGOPOLY  
CONDITION

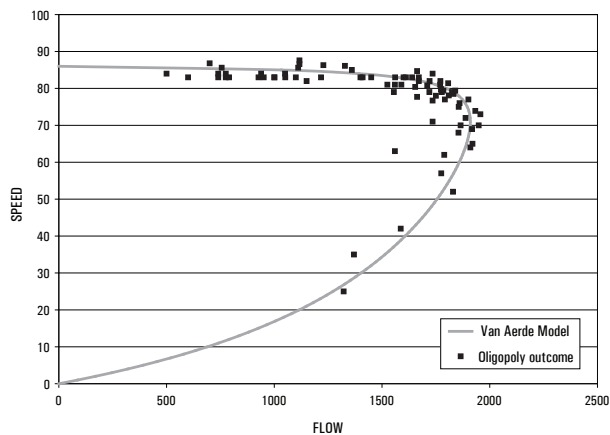


FIGURE 1. The possible outcomes of privatization.

## POLICY ANALYSIS

Different parties are affected by road privatization in different ways. Buyers or renters, who try to maximize their benefit; government, who should pursue social welfare; road users, who want to minimize their costs of travel; and other related groups such as shipping companies that suffer from this change and adjacent landlords who benefit from this transition. An integrated framework of road privatization should consider them all together. There are several facts in this new structure:

### Government

1. The goal of increasing social welfare does not always comply with the new owners' or renters' goal. As a result, a complete study of the necessary regulations in different scenarios is essential (Engel et al, 2002).
2. Government role changes. Government will not be responsible for roads maintenance, construction, and even emissions. The road owners will become responsible for their roads' externalities.

### Private industries

3. Road owners try to maximize their benefits from roads. Their income depends both on the quantity of demand and prices charged. Roads owners are responsive to the demand, trying to price their roads to increase not only their profits (by charging effective tolls) but also the demand (by providing a better service). Both of these two objectives are neglected in the centralized-public structure.
4. A gigantic industry will be formed. Long term and stable revenue streams encourage the private sector to invest in this industry. A significant part of the industry would be formed just by leasing the existing roads. Consequently, government can make profits from an industry that is in a near breakdown condition now.
5. Some companies will substantially suffer from privatization because transportation costs account for a high proportion of their costs, and introducing this policy will increase their costs by great amounts. They may be compensated by being offered shares of the private firms running tolled roads or travel credits.
6. Landlords will benefit from their property appreciation when a new road is constructed. They can participate in the construction by purchasing bonds, or they can be taxed to maintain equity (Engel et al, 2005).

### Road Users

7. Road users will probably oppose the privatization. Thus, it is important to offer them some benefits. These benefits can range from the increase in public expenditures to the direct payment

to all the people in each region based on the revenue gathered in that region. Transparency can also be an important factor for public support. However, different groups behave differently. For instance, the rich might welcome this policy because their compensated time is worth more than the price they pay. Section 11 tries to address the equity problem of this policy.

Superior to all of those facts, the transformation from the public to private ownership may result in a more efficient system; e.g. the electricity sector (Dal Bo et al, 2007). This is the main advantage of privatizing roads. This policy can represent a Pareto efficient solution. By drawing out all the transactions of money among different parties, the system will be better off because the private sector will be more efficient.

## IMPLEMENTATION ISSUES

The trend of improvement in pricing technologies is an important factor driving the privatization process. A variety of pricing schemes is available: Congestion pricing, mileage-based charges, value pricing, cordon-based pricing, bridge tolls, HOT lanes and etc. Each of the schemes has advantages and disadvantages. It is not the intention of this paper to review these schemes; the interested reader is referred to Victoria Transport Policy Institute TDM encyclopedia. However, it should be noted that a satellite-based technology at an affordable cost is still not available to implement some types of the pricing schemes (Richards, 2008). Furthermore, the public is concerned about their privacy in some methods of charging. However, the charging technology, although not complete, is available (Kim et al., 2008).

Addressing public concerns is the key to the success of privatization. The public is concerned about the conflicting objectives of private owners or operators and the public goal of safe and reliable transportation. Undervaluation of facilities, use of the revenue outside the transportation sector or even outside the origin state, transparency of contracts, forgoing of non-profitable projects, operation and maintenance of facilities, and length of lease agreement are other concerns of the public (Ortiz et al. 2008).

There are some specific concerns about contract terms both for the public and private sector. For the lease agreements, the length of long-term agreements is a concern related to the ability to protect the public interest. The Chicago Skyway was leased for 99 years and the Indiana Toll Road was leased for 75 years, both of which are more than the typical length of such agreements (30-40 years). Longer term agreements are supposed to be less capable of controlling the private sector.

Another main and important concern of the public is about non-compete clauses included in some concession agreements. Non-compete clauses prevent the state and local government from adding capacity within a specified distance of the facility or otherwise paying for the



lost revenue. This can give monopolistic power to the concessionaire (Ortiz et al. 2008). On the other hand, the winner of bidding may overestimate the demand for the road at the toll ceiling, a winner's curse, since a significant percentage of drivers can choose alternative roads without guarantees like non-compete clauses (Fischer et al., 2002).

The flexibility in pricing is not considered in most of the contracts. Tolls and even their periodic increases are determined or limited prior to implementation. This will limit the concessionaire to specific, usually inefficient, price(s). The other limitation is the fixed-term franchise which has been reported as the main reason of the disappointing performance of private highways in Latin America. Most of the Latin American concessions were awarded as a fixed-term franchise, thereby creating a demand for guarantees and contract renegotiations (Engel et al., 2003). Interoperability of the entire highway network and other transportation modes is another concern (Ortiz et al. 2008). Accompanied encouragement of flex-time, telecommuting, car pool and van pool options, and provisions of high-quality transit system is required for the success of the policy (DeCorla-Souza 2008).

Radical policies like widespread privatization require strong, committed, and stable leadership. To succeed in the privatization, political establishment should provide the basic information for the public. Richards (2008) reported unwillingness to create the vision as the key to the failure of national road pricing plan of Blair administration. The Minnesota department of transportation opinion study showed that users may be more accepting of a change in funding method if the reasons are clearly explained (DeCorla-Souza, 2008).

## **MORE SUSTAINABLE TRANSPORTATION?**

A successful development relies on "simultaneous achievement" of all the Three Es of sustainability: environment, economy, and equity (Jepson, 2001). A sustainable development should provide a better quality of life for all, now and into the future (Agyeman et al, 2003). In this regard, a sustainable transportation system focuses on providing people access to different destinations while minimizing the negative effects of transport and maximizing economic prosperity and social equity. The question is whether privatization matches these needs.

The efficiency goal of the private sector can ensure a more efficient transportation system. A better pricing signal can direct users' behavior to a more efficient use of scarce resources, including the environment. Fuel taxes are incapable of providing the required flexibility to efficiently guide this behavior. As a sign of the incapability in the US, House Bill 3946 mandates Oregon State to examine alternatives to the current system of taxing fuels (Kim et al., 2008). Nevertheless, renegotiations of concession agreements and inflexibility of charges can reduce the private sector's incentive to be efficient. Engel et al. (2003) reported opportunistic renegotiations as the main reason for the failure of the highway privatization in Latin American countries.

In addition, transformation from publicly owned to privately owned facilities, which provides clear property rights, can ease the process of emission charging. The private owner or leaser can be held responsible for the pollution produced by his/her property. Consequently, the owner will pass on the charges to the users. To avoid other externalities, the owner will automatically address/charge for traffic accidents and congestion. Thus, a more environmental friendly system is conceivable.

“Lack of cash has led virtually every state in the USA to explore innovative finance techniques” (Ortiz et al., 2008). According to the June 2006 US DOT statistics, about 50% of current highway mega projects (> \$500 million) in the USA involve PPPs. Some concession agreements involve billions of dollars transactions in total (Zhang 2008). As a sad example, the collapse of I-35W Mississippi River bridge in Minnesota can be attributed to the lack of funding for proper inspection and maintenance. Officials have expressed concerns about many other bridges in the USA (Davey et al., 2007). The concession agreements have grown from the reality that transportation system needs far more money than is available because of declining fuel taxation funds (Ortiz et al., 2008). However, the potential of the private funds can be overestimated. For instance, the Latin American experience with highway privatization provided lower funds than expected because part of the public funds were diverted to bail out franchise holders in financial trouble (Engel et al., 2003).

The available funds in transportation will shrink if the transportation sector is held responsible for its GHG emissions. The nature of the transportation system, with its highly dispersed emission sources and less carbon-intensive energy substitutes, avoids efficient control of GHG emissions. The significant new revenue from PPPs can offset transportation share by investing in other more efficient sectors leading to a more sustainable life.

The main problem of privatization in terms of sustainability is related to the last E; equity. It should be noted that the current fuel taxation is unfair because such taxes are totally unrelated to the actual amount and impact of the usage. The users pay the same on a highway with low costs as a superhighway with billion dollars of costs (DeCorla-Souza, 2008). As discussed before, road subsidies (no charge on a system that should be charged) represent a progressive subsidy, a higher subsidy for richer people. Nevertheless, the public’s concern about the conflicting objectives of a private owner or operator and the public goal of safe and reliable transportation is legitimate. Furthermore, a variety of groups will be affected by privatization, and some of them should be compensated for their loss. The next section introduces a possible remedy to address the equity concern.

## THE EQUITY PROBLEM AND A POSSIBLE REMEDY

In spite of the advantages of pricing schemes and privatization, the process has encountered

public resistance. One main reason is the equity issues accompanied by the pricing. Opposite to the current structure - a progressive subsidy for roads- privatization might approach a progressive taxation scheme. Nevertheless, the poor are more affected by the privatization because they spend a higher proportion of their income on transportation and will pay more with higher costs. In the congestion pricing context, some studies even found that average commuters would be worse off without implementing redistribution policies (Small, 1983), (Hau, 1992). A rebate policy, credit-based congestion pricing (CBCP) (Kalmanje et al, 2004), (Kockelman, 2005), can be welfare enhancing for all the users.

Under a CBCP, drivers receive monthly travel credits in a revenue neutral approach. Users do not pay money unless they go beyond all of their travel credits. The travel credits can be in terms of money or can be traded and converted to money. The supporting argument for this approach is that roads are owned by tax payers (Savas, 1989) and the possible revenue should be returned to them (Kockelman, 2005).

However, the revenue neutral aspect of the CBCP is questionable due to the free rider problem. In the basic approach, an average driver pays nothing and the driver with high value of time pays the low income users to stay off the congested roads. But even without privatization, the charges should include externalities to force people to pay for the burden they impose on others. Thus, it should not be revenue neutral. The CBCP, equipped with the possible revenue gathering to solve the free rider problem and charge the externalities, can be used not only for congestion pricing but also for road pricing.

Clearly, no private owner will be willing to provide travel credits for the users, which means free of charge service. City or state officials should provide the travel credits through part of the revenues gathered by leasing the existing infrastructure or charging for the externalities from road owners. But the credit allocation may entail a complex and problematic role. Questions related to the boundaries of the geographic region, providing funds, and determining those entitled to the credits should be taken care of. However, this might be counter to the privatization goal. As mentioned before, privatization should lead to a lesser, not greater role, for governments.

To address another aspect of sustainable transportation, the CBCP policy has a great potential to provide an externality pricing scheme especially for GHG emissions. More travel credits can be allocated to environmentally friendly vehicles. A fuel cell car can gain more credits based on its GHGs' emission reductions. On the other hand, road owners may pass on the externality charges or fines on their roads to the users. As a similar approach, Forkenbrock (2008) proposed different charges for different vehicle classes through mileage-based charges. To set up an effective policy, a thorough study is needed to determine how to efficiently allocate travel credits and who is eligible for them.

## CONCLUSION AND FURTHER WORK

Privatization of transportation infrastructure has gained increasing attention in recent years mainly due to the lack of funds in the transportation sector. Privatization can be considered as an approach to roadway sustainability. Two different aspects of privatization can help sustainability. Private participation increases funding and investment opportunities and transformation to private ownership, which provides clear property rights can help the process of environmental charging.

On the other hand, increasing the efficiency of roads through optimal pricing and optimal investment, a byproduct of privatization, can indirectly decrease the externalities produced by transportation. Transportation sector revenue increase, another byproduct of privatization, can be used to fund transit systems and other publicly owned infrastructures. Differentiating between vehicle classes can help the process of emissions reduction using a rebate policy. Further work will focus on how this rebate policy should be designed.

Although privatization seems capable of improving two of the E's of sustainability, equity issues and users' resistance are the main obstacles for this policy. With some modifications, CBCP can address the last E. However, road privatization will likely be a step-by-step process which will need time for public and political acceptance.

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## REFERENCES

- Agyeman, J., Bullard, R., and Evans, B. (2003). *Just sustainability: Development in an unequal world*. Cambridge, MA and London: MIT Press.
- Asian Economic News (2000). "Hong Kong to privatize mass transit railway," Sept 18, 2000.
- Buitelaar, E., Van der Heijden, R., Argioli, R. (2007). "Managing traffic by privatization of road capacity: A property rights approach," *Transport Reviews*, 27 (6), 699-713.
- Carnis, L. (2001). "Management versus ownership: The road privatization debate." *The Quarterly Journal of Austrian Economics*, 4 (2), 51-59.
- Carnis, L. (2001). "New directions in road privatization." On the Proceedings of the 7<sup>th</sup> Austrian Scholars Conference.
- Chen, A., and Subprasom, K. (2007). "Analysis of regulation and policy of private toll roads in a Build-Operate-Transfer scheme under demand uncertainty." *Transportation Research A*, 41 (6), 537-558.
- Choo, S., Mokhtarian, P.L., and Salomon, I. (2001). "Impacts of home-based telecommuting on vehicle-miles traveled: A nationwide time series analysis." Prepared for the California Energy Commission, Institute of Transportation Studies, Davis, CA. Available at <http://www.its.ucdavis.edu/publications/2002/UCD-ITS-RR-02-05.pdf>.
- Christmas Tree Bill Definition, available from: [http://en.wikipedia.org/wiki/Christmas\\_tree\\_bill](http://en.wikipedia.org/wiki/Christmas_tree_bill), and [http://www.senate.gov/reference/glossary\\_term/christmas\\_tree\\_bill.htm](http://www.senate.gov/reference/glossary_term/christmas_tree_bill.htm).
- Crowe Chizek and Company LLC (2006). "State of Indiana East-West toll road financial analysis." Submitted Report to the State of Indiana, Indiana Finance Authority by: Crowe Chizek and Company LLC, Indianapolis, Indiana.
- Dal Bó, E., and Rossi, M. A. (2007). "Corruption and inefficiency: Theory and evidence from electric utilities." *Journal of Public Economics*, 91 (5-6), 939-962.
- Davey, M., and Wald, M. L. (2007), "Potential flaw is found in design of fallen bridge," *The New York Times*, <http://www.nytimes.com/2007/08/08/us/09cnd-bridge.html?hp>, retrieved on 2007-08-09.
- DeCorla-Souza, P. (2008). "New road financing system for U.S. metropolitan areas." *Transportation Research Record*, 2079, 45-52.
- Dornan, D. L. (2002). "Asset management: Remedy for addressing the fiscal challenges facing highway infrastructure." *International Journal of Transport Management*, 1 (1), 41-54.
- Engel, E., Fischer, R. D., and Galetovic, A. (2002). "A new approach to private roads." *Regulation*, 25 (3), 18-22.
- Engel, E., Fischer, R. D., Galetovic, A. (2003). "Privatizing highways in Latin America: Is it possible to fix what went wrong?" Working Papers 866, Economic Growth Center, Yale University.
- Engel, E., Fischer, R., and Galetovic, A. (2005). "Highway franchising and real estate values." *Journal of Urban Economics*, 57 (3), 432-448.
- Euritt, M.A., Machemehl, R., Harrison, R., and Jarrett, J.E. (1994). "An overview of highway privatization." Report FHWA/TX-94-1281-1, Center for Transportation Research, University of Texas at Austin.

European Union Road Federation (2007). Sustainable Roads. Discussion paper, The Brussels programme center of the international road federation, Brussels, Belgium. Available at [http://www.erf.be/images/IRF\\_BPC\\_on\\_Sustainable\\_Roads\\_April\\_2007.pdf](http://www.erf.be/images/IRF_BPC_on_Sustainable_Roads_April_2007.pdf).

Fischer, R., Gutierrez, R., Serra, P. (2002). "The effects of privatization on firms and on social welfare." Documentos de Trabajo 131, Centro de Economía Aplicada, Universidad de Chile.

Forkenbrock, D. J. (2008). "Policy Options for Varying Mileage-Based Road User Charges." *Transportation Research Record*, 2079, 29-36.

Graves, B. (2007). National surface transportation policy and revenue study commission. American Trucking Associations, Inc., 2200 Mill road, Alexandria, VA. Available from <http://www.truckline.com/NR/rdonlyres/EEC7D8A8-CCFA-486E-8ED2-86548DF356CC/O/NationalSurfaceTransportCommission.pdf>.

Greenshields, B. D. (1934). "A study of traffic capacity." *Proceedings of Highway Research Board*, 14, 448-477.

Hau, T. D. (1992). "Economic fundamentals of road pricing: A diagrammatic analysis." World Bank Policy Research Working Paper Series, WPS No.1070, World Bank, Washington, DC, US, 1-96.

Hooper, P. (2002). "Privatization of airports in Asia," *Journal of Transport Management* 8, 289-300.

Huang, Y.L. (1995). *Projects and policy analysis of Build-Operate-Transfer infrastructure development*. A Dissertation for the Degree of Doctor of Philosophy in Civil Engineering, University of California at Berkeley.

International Road Federation-IRF (2007). *Special Edition: Public Private Partnership*, IRF-Bulletin, available from <http://www.irfnet.org>.

Jeffreys, R. (1949). *The king's highway*. London: The Batchworth Press.

Jepson, Jr., E. J. (2001). "Sustainability and planning: Diverse concepts and close association." *Journal of Planning Literature*, 15(4), 499-510.

Kalmanje, S., and Kockelman, K. (2004). "Credit-based congestion pricing: Travel, land value, and welfare impacts." *Transportation Research Record*, 1864, 45-53.

Klein, D., and Majewski, J. (2006). "America's toll road heritage: The achievements of private initiative in the nineteenth century." *Street Smart: Competition, Entrepreneurship and the Future of Roads*, 280-281.

Kim, D. S., Porter, J. D. et al. (2008). "Technology evaluation of Oregon's vehicle-miles traveled revenue collection system- Lessons learned." *Transportation Research Record*, 2079, 37-44.

Kockelman, K., and Kalmanje, S. (2005). "Credit-based congestion pricing: A policy proposal and the public's response." *Transportation Research Part A*, 39, 671-690.

Kwak, Y. H. (2002). "Analyzing Asian infrastructure development privatization market," *Journal of Construction Engineering and Management*, 128 (2), 110-116.

Litman, T. (2003). "London congestion pricing: Implications for other cities." Victoria Transport Policy Institute, Victoria, BC, Canada, Available from <http://www.vtpi.org/london.pdf>.

*Macquarie Infrastructure 2008 annual report*. Released on 16 September 2008. Accessed at [http://www.frostdesign.com.au/MIG\\_annual\\_report\\_2008/asset-html.html](http://www.frostdesign.com.au/MIG_annual_report_2008/asset-html.html).

Mises, L. V. (1983). *Bureaucracy*. Spring Mills, Libertarian Press, Pennsylvania.

Ortiz, I. N., Buxbaum, J. N., and Little, R. (2008). "Protecting the public interest- Role of long-term concession agreements for providing transportation infrastructure." *Transportation Research Record*, 2079, 88-95.

Porter, D.R. (1997). "Privatized roads." Newsletter of the Growth Management Institute, 4 (1).

Public Good Definition-a, Available from [http://ec.europa.eu/research/biosociety/library/glossarylist\\_en.cfm?Init=P](http://ec.europa.eu/research/biosociety/library/glossarylist_en.cfm?Init=P).

Public Good Definition-b, Available from [http://en.wikipedia.org/wiki/Public\\_good](http://en.wikipedia.org/wiki/Public_good).

Rakha, H., and Crowther, B. (2002). "Comparison of Greenshields, Pipes, and Van Aerde car-following and traffic stream models." *Transportation Research Record*, 1802, 248-262.

Rebello, J.M. (1999). "Rail and subway concessions in Rio de Janeiro: Designing contract and bidding process." *Public Policy for the Private Sector*, 183, The World Bank Group Finance, Private Sector, and Infrastructure Network.

Richards, M. G. (2008). "Congestion pricing- An idea whose time has come – But not yet, at least not in England." *Transportation Research Record*, 2079, 96-108.

Roth, G. (2006). "Federal financing of infrastructure: Advantages and disadvantages." Prepared for presentation to the First International Conference on Funding Transportation Infrastructure.

Rufolo, A. M., Kimpel, T.J. (2008). "Responses to Oregon's experiment in road pricing." *Transportation Research Record*, 2079, 1-7.

Samuel, P. (2005). "Landslide victory! tolls 60% taxes 30%." In Washington DC Metro area poll. *Toll Roads News*, Feb 16.

Savas, E. S. (1987). *Privatization: The key to better government*. Chatham House Publisher, Chatham, NJ.

Savas, E. S. (1989). "A taxonomy of privatization strategies." *Policy Studies Journal*, 18 (2), 343-355.

Schwaab, J. A., and Thielmann, S. (2001). "Economic instruments for sustainable road transport: An overview for policy makers in developing countries." Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) and the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), Eschborn, Germany.

Sidney, M. L. (1996). *Build, operate, transfer: Paving the way for tomorrow's infrastructure*. John Wiley & Sons Inc., New York.

Small, K. (1983). "The incidence of congestion tolls on urban highways." *Journal of Urban Economics*, 13, 90-111.

Sperling, D. (2001). "Public-private technology R&D partnerships: Lessons from US partnership for a new generation of vehicles." *Transport Policy*, 8 (4), 247-256.

Philadelphia Business Journal (2007). "AAA South Jersey poll: Most oppose privatizing toll roads." Published March 20, 2007. Available from <http://biz.yahoo.com/bizj/070320/1434321.html?v=1>.

Ukkusuri, S., Karoonsoontawong, A., Waller, S.T., and Kockelman, K.M. (2004). "Congestion pricing technologies: Synthesis and an evaluation framework." Presented at the 84<sup>th</sup> Annual Meeting of the Transportation Research Board.

Victoria Transport Policy Institute (2008) "Road pricing, congestion pricing, value pricing, toll roads and



HOT lanes." Online TDM encyclopedia, Available from <http://www.vtpi.org/tm/tm35.htm>.

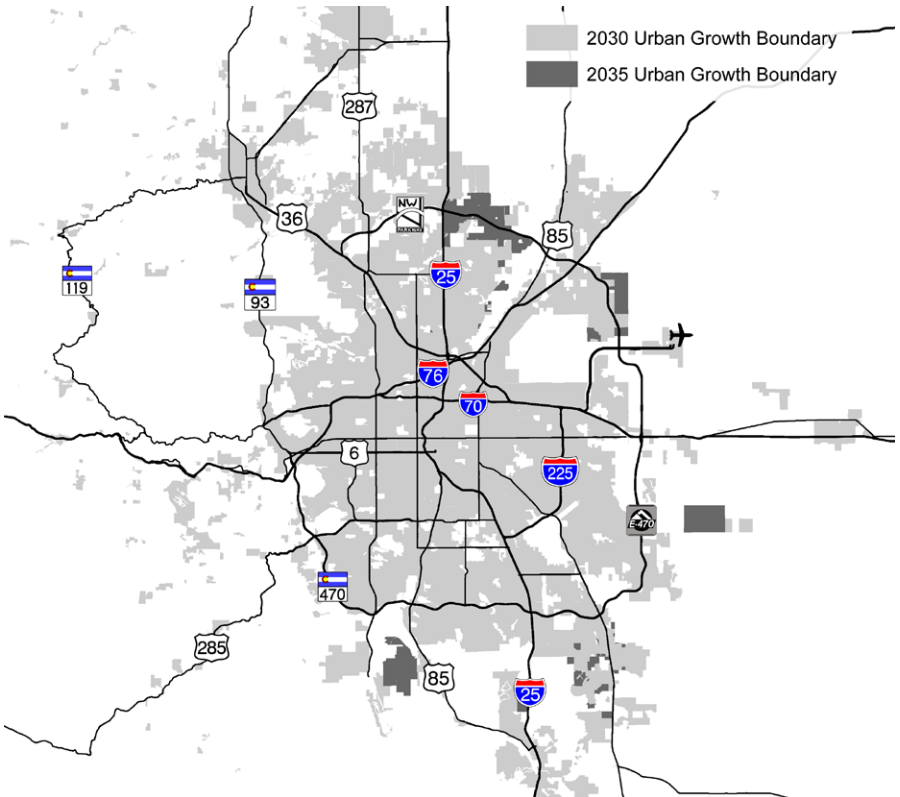
Yang, H., and Meng, Q. (2002). "A note on highway pricing and capacity choice in a road network under a Build-Operate-Transfer scheme." *Transportation Research Part A*, 36, 659–663.

Zhang, L., and Levinson, D. (2006). "Economics of road network ownership." University of Minnesota: Nexus Research Group, Working Papers, Dept. of civil Engineering, Minneapolis, MN.

Zhang, L. (2008). "Welfare and financial implications of unleashing private-sector investment resources on transportation networks." *Transportation Research Record*, 2079, 96-108.

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# SCENARIO ANALYSIS HELPS IDENTIFY SUSTAINABLE LAND USE AND TRANSPORTATION POLICIES



## ABSTRACT

The Denver Regional Council of Governments (DRCOG) recently updated Metro Vision, the region's long-range plan for growth, transportation and the environment. As part of the update process, DRCOG explored future scenarios reflecting different land use and transportation policies. On the land use side, scenarios ranged from compact to expansive development patterns. On the transportation side, scenarios ranged from an emphasis on roadway improvements to an emphasis on transit improvements. Scenarios that favored compact development patterns and transit investments performed best on a variety of outcome measures including transportation system performance, infrastructure costs, accessibility and environmental impacts. In contrast, scenarios that significantly expanded the region's urban "footprint" did not perform as well and resulted in greater overload of key regional transportation facilities. The results of the scenario analysis influenced the DRCOG Board's deliberations regarding how much to expand the region's urban growth boundary to accommodate additional growth between 2030 (the previous planning horizon) and 2035. Before the scenario analysis, the Board was considering expanding the boundary by 70 square miles; after the analysis the Board decided to expand the boundary only 21.8 square miles. The adopted 2035 urban growth boundary represents an ambitious effort to curb current trends toward expansive development, and will require a significant increase in overall density in the Denver region.

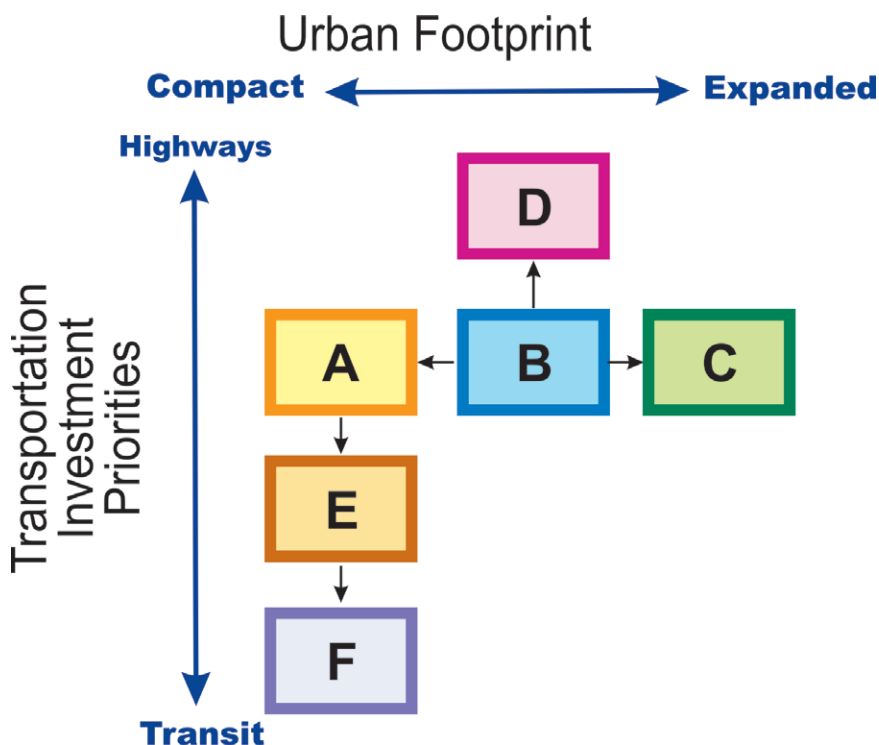
## Scenario Analysis Helps Identify Sustainable Land Use and Transportation Policies

Metropolitan areas across the country stand at an important transition point as development patterns that prevailed for the past half century come under intense public scrutiny. Congestion, pollution, competition for water, infrastructure funding shortfalls, global economic trends and concerns about energy sustainability and climate change all come together with unprecedented demographic changes resulting from the aging of the baby boomer generation (see for example Ewing, Bartholomew, Winkleman, Walters and Chen, 2007; Nelson, 2006; Puentes, 2008; Regional Plan Association, 2006; Richie, 2001; ULI-The Urban Land Institute and Ernst & Young, 2008). The metropolis as we know it is changing.

Cognizant of these forces, the Denver Regional Council of Governments (DRCOG) conducted a comprehensive scenario analysis as part of the recent update to Metro Vision, the region's long-range plan for growth and development (Denver Regional Council of Governments, 2007). Since its initial adoption in 1997, Metro Vision has promoted sustainable growth through policies such as an urban growth boundary (UGB), support for higher-density, mixed-use urban centers and the development of a balanced, multi-modal transportation system.

Scenario analyses are used widely in the private sector to prepare for future contingencies beyond organizational control (Smith, 2007). By contrast, the public sector typically uses scenarios to decide how best to influence the future, incorporating stakeholder input and values (Avin, 2007). Over the past 20 years, land use-transportation scenario analyses have become increasingly common in regional planning and often explore the potential benefits of increased density. A recent review of 80 scenario analyses from more than 50 U.S. metropolitan areas (Bartholomew, 2007) found that a median density increase of 11% was associated with median decreases of 2.3% in vehicle miles traveled (VMT) and 2.1% in NO<sub>x</sub> emissions. Similarly, a study of alternative development futures for 11 major metropolitan areas in the Midwestern U.S. concluded that a 10% increase in density would result in a 3.5% reduction in VMT and associated emissions (Stone, Mednick, Holloway & Spack, 2007). Bartholomew (2007) criticizes many of these previous efforts, however, for being disconnected from the planning process and not leading to concrete action or implementation steps.

DRCOG's scenario analysis, in contrast, was directly connected with the Metro Vision planning process and focused on the agency's two main areas of influence: the allocation of transportation funds and the extent of urban development (Figure 1). On the transportation side, scenarios ranged from an emphasis on roadway improvements to an emphasis on transit improvements. On the land use side, scenarios ranged between compact and expansive development patterns. All scenarios included the build-out of FasTracks, the taxpayer-funded plan to build 120 new miles of rapid transit throughout the Denver region by 2016 (Regional Transportation District, 2004). DRCOG developed the scenarios by starting with the then-current Metro Vision 2030



**FIGURE 1.** Distribution of the scenarios across policy space.

plan, extending the horizon to 2035 and examining changes to the UGB, fiscally constrained roadway and transit networks, and pricing of driving versus taking transit. Table 1 describes the specific parameters associated with each scenario.

### Scenario Outcomes

We evaluated the performance of each scenario on 12 outcome measures reflecting conditions in 2035 (Table 2). The measures relate to Metro Vision policy goals, and are broadly grouped into land use, transportation, and environment. DRCOG's land use model (Denver Regional Council of Governments, 2008) produced the land use measures. The model allocates jobs and households to transportation analysis zones based on each zone's utility (attractiveness) and capacity to accommodate growth. Zone utilities and capacities were adjusted to reflect each scenario's land use assumptions. We then used output from the land use model to calculate cost- and water-related measures based on the assumptions in Table 3, derived from previous research (Denver Regional Council of Governments, 2006; Guimond & Arbogast, 1995; Mullen, 2005; Nelson 2004).

TABLE 1. Scenario Descriptions

| Scenario | Expansion of 2030 UGB | Density increase (2000-2035) <sup>a</sup> | Change to 2030 fiscally constrained roadway network  | Change to 2030 fiscally constrained transit network | Pricing changes                            |
|----------|-----------------------|---|--|---|--|
| A        | None                  | 23%                                       | None   | None  | None                                       |
| B        | + 70 square miles     | 12% <sup>b</sup>                          | + 300 miles of minor arterials and collectors <sup>c</sup>   | None  | None                                       |
| C        | + 150 square miles    | 0%  | + 600 miles of minor arterials and collectors <sup>c</sup>   | None  | None                                       |
| D        | + 70 square miles     | 12%                                       | + 300 miles of minor arterials and collectors <sup>c</sup> ; + 300 miles new freeway/tollway capacity <sup>d</sup> | None  | None                                       |
| E        | None                  | 23%                                       | - 100 miles of highway capacity <sup>e</sup>   | Additional rail and bus rapid transit <sup>f</sup>  | None                                       |
| F        | None                  | 23%                                       | - 100 miles of highway capacity <sup>e</sup>   | Additional rail and bus rapid transit <sup>f</sup>  | Auto operating costs doubled; transit free |

<sup>a</sup> Assumes the number of households within the UGB increases from 869,000 in 2000 to 1,654,000 in 2035.

<sup>b</sup> Based on the Metro Vision goal of increasing density 10% between 2000 and 2030. Extended out to 2035, this results in a density increase of 12% compared to 2000.

<sup>c</sup> New facilities serving the expanded UGB area.

<sup>d</sup> Estimated cost of \$8 billion.

<sup>e</sup> Estimated cost savings of \$1.5 billion.

<sup>f</sup> Estimated cost of \$2.5 billion.

**TABLE 2. Performance of Scenarios on Outcome Measures Reflecting 2035 Conditions**

| Measure (units)<br>"Better" outcome  | Scenario   |            |            |            |            |            |
|--|------------|------------|------------|------------|------------|------------|
|  | A          | B          | C          | D          | E          | F          |
| Land use   |            |            |            |            |            |            |
| Additional land developed compared to 2030<br>(sq. miles)                                  | 0          | 70         | 150        | 70         | 0          | 0          |
| <i>Less land consumption</i>   |            |            |            |            |            |            |
| Public infrastructure costs <sup>a</sup> (\$ billions)                                     | 14.2       | 16.5       | 19.3       | 16.5       | 14.2       | 14.2       |
| <i>Less spending on infrastructure</i>   |            |            |            |            |            |            |
| Households and jobs within 1/2 mi. of high-<br>capacity transit (thousands)                | HH<br>151  | HH<br>145  | HH<br>138  | HH<br>139  | HH<br>198  | HH<br>198  |
| <i>More development around transit</i>   | Emp<br>619 | Emp<br>602 | Emp<br>584 | Emp<br>585 | Emp<br>728 | Emp<br>728 |
| Population and employment in urban centers<br>(%)  | Pop<br>23  | Pop<br>20  | Pop<br>19  | Pop<br>19  | Pop<br>23  | Pop<br>23  |
| <i>More development in urban centers</i>   | Emp<br>47  | Emp<br>44  | Emp<br>42  | Emp<br>43  | Emp<br>47  | Emp<br>47  |
| Population and employment in Denver CBD (%)  | Pop<br>1.6 | Pop<br>1.3 | Pop<br>1.1 | Pop<br>1.3 | Pop<br>1.6 | Pop<br>1.6 |
| <i>More development downtown</i>   | Emp<br>8.6 | Emp<br>8.4 | Emp<br>8.1 | Emp<br>8.4 | Emp<br>8.6 | Emp<br>8.6 |
| Transportation   |            |            |            |            |            |            |
| Vehicle miles traveled (millions)  | 117.3      | 121.6      | 125.1      | 124.6      | 116.5      | 114.0      |
| <i>Less driving</i>  |            |            |            |            |            |            |
| Vehicle hours of delay (millions)  | 1.17       | 1.21       | 1.35       | 1.15       | 1.16       | 1.10       |
| <i>Less congestion</i>   |            |            |            |            |            |            |
| Transit trips (thousands)  | 494        | 465        | 447        | 420        | 501        | 613        |
| <i>More transit use</i>  |            |            |            |            |            |            |
| Low income/minority access to employment by<br>transit (% zones < 45 min. to 100,000 jobs) | 50         | 48         | 45         | 48         | 52         | 53         |
| <i>Better access to transit</i>  |            |            |            |            |            |            |
| Environment  |            |            |            |            |            |            |
| Air pollutant emissions <sup>b</sup> (tons/day)  | 1,289      | 1,347      | 1,373      | 1,365      | 1,282      | 1,246      |
| <i>Cleaner air</i>   |            |            |            |            |            |            |
| Water demand (billions of gallons/year)  | 208        | 313        | 315        | 313        | 308        | 308        |
| <i>More efficient water use</i>  |            |            |            |            |            |            |
| New wastewater treatment service<br>needed (millions of gallons/day)                       | 29         | 45         | 56         | 45         | 29         | 29         |
| <i>Less need for new service</i>   |            |            |            |            |            |            |

<sup>a</sup> Excludes regional transportation and wastewater treatment facilities<sup>b</sup> Includes Carbon Monoxide, NO<sub>x</sub>, VOC and PM<sub>10</sub>

**TABLE 3. Assumed Relationship between Land Use, Public Infrastructure Costs, Water Demand and Wastewater Flows**

|  | Public infrastructure costs <sup>a</sup> |                          | Water demand <sup>b</sup>                          | Wastewater flows <sup>c</sup>                  |
|--|--|--------------------------|--|--|
|  | Greenfield<br>(2005 \$/acre)             | Infill<br>(2005 \$/acre) | (Gallons per year<br>per household or<br>employee) | (Gallons per day<br>per person or<br>employee) |
| Residential, 1 to 12<br>dwelling units/acre          | \$82,600                                 | \$66,080                 | 144,880  | 85   |
| Residential, 12<br>dwelling units/acre<br>or greater | \$140,420                                | \$112,336                | 67,440   | 85   |
| Retail   | \$90,860                                 | \$72,688                 | 18,300   | 50   |
| Office   | \$107,380                                | \$85,904                 | 18,300   | 50   |
| Industry   | \$41,300                                 | \$33,040                 | 18,300   | 50   |

<sup>a</sup>Net cost for new development only. Excludes regional facilities, such as new principle arterials or new wastewater treatment plants.

<sup>b</sup>Demand for municipal water supplies only; excludes self-supplied industrial.

<sup>c</sup>Calculated for new development located outside existing wastewater treatment facility service areas. Excludes industrial flows treated on-site.

The land use model also provided input to DRCOG’s four-step travel demand model (Denver Regional Council of Governments, 2005), which produced the transportation measures. The model’s roadway and transit networks, as well as user costs for each mode, were modified to reflect the transportation assumptions of each scenario. The travel model in turn provided input to the latest EPA air pollution emission model, MOBILE6 (U.S. Environmental Protection Agency, 2008), which produced the air quality measure.

Figures 2 through 4 graphically compare the scenario outcomes. These figures display each outcome measured along one of the “spokes” of the diagram.<sup>1</sup> Results covering a larger area of the diagram reflect better (more desirable) outcomes. Figure 2 compares the scenarios that varied along the land use dimension, and shows that the most compact scenario (A) produced the best outcomes. Figure 3 shows that the additional highway capacity in Scenario D resulted in less congestion, but also more driving, less transit use, and greater pollution than Scenario B. Figure 4 shows that the additional transit capacity in Scenario E resulted in only marginally better outcomes compared to Scenario A. This result suggests that FasTracks will go a long way toward meeting the region’s transit needs, with only minimal benefit derived from the additional



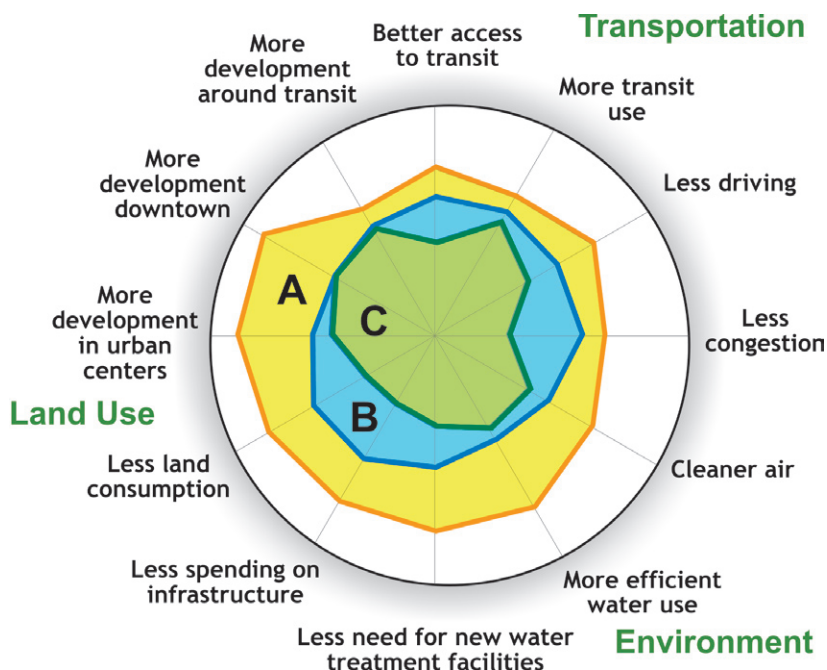


FIGURE 2. Outcomes of Scenarios A, B and C.

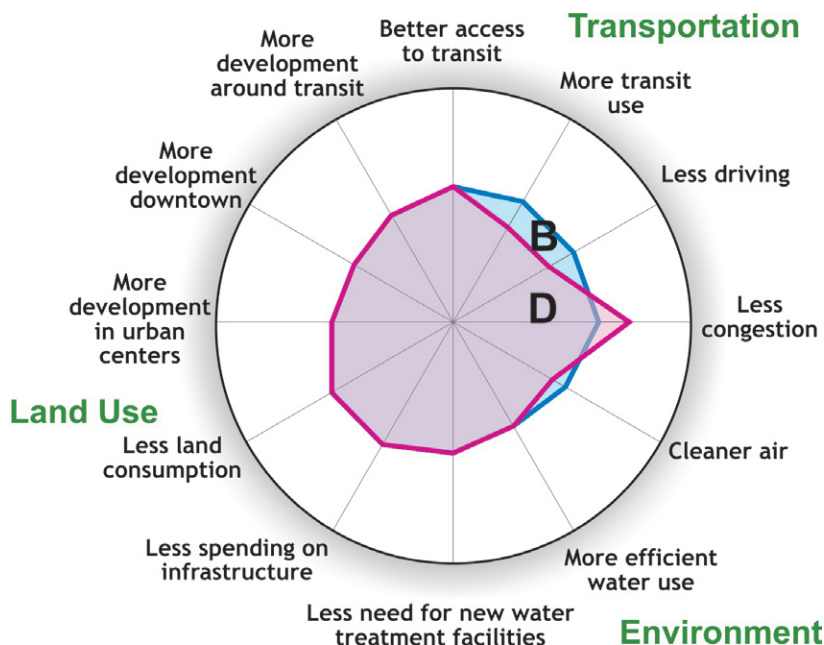
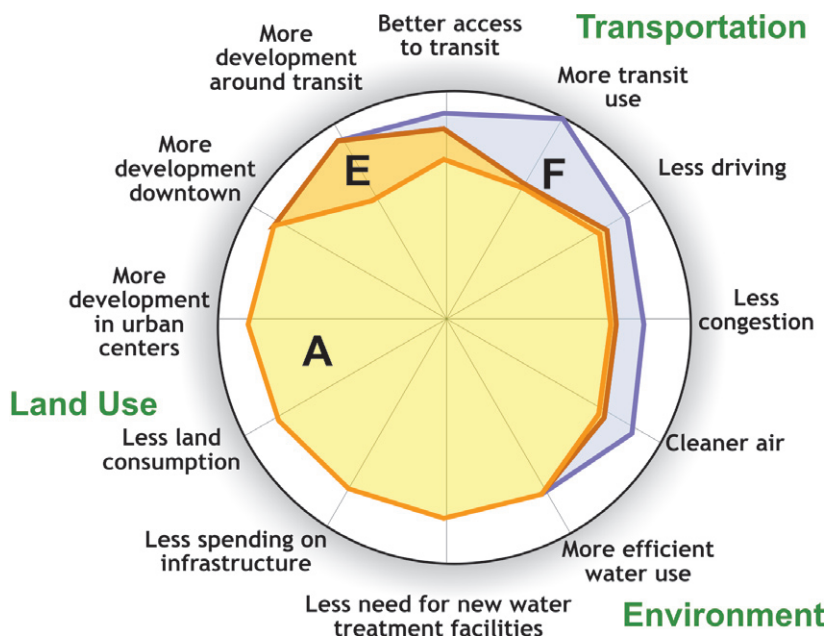


FIGURE 3. Outcomes of Scenarios B and D.



**FIGURE 4.** Outcomes of Scenarios A, E and F.

transit improvements examined. Figure 4 also shows, however, that the inclusion of transit-favorable pricing in Scenario F resulted in a more dramatic shift toward desirable outcomes. In fact, Scenario F performed best of all the scenarios in the analysis. This result indicates that travel behavior is sensitive to pricing and that transit-favorable pricing can result in increased transit use and the related benefits of less congestion and pollution.

### Limitations

Many of the assumptions underlying the outcome measures are based on observations of past trends and behavior. It is uncertain how valid these assumptions are when considering unprecedented changes, such as the dramatic shift in the cost of driving versus taking transit in Scenario F. Furthermore, traditional four-step travel demand models like DRCOG's deal only indirectly with non-motorized trips and do not capture the effect of fine-grained land use patterns such as mix of use and walkability (Cervero, 2006). Our analysis may therefore have underestimated the impact of compact development patterns and transit investments on the use of alternative modes and the related benefits for regional sustainability. DRCOG is currently developing a disaggregate activity-based model that will address some of these shortcomings (Sabina and Rossi, 2008).

### Conclusions

DRCOG's scenario analysis is consistent with other analyses indicating the benefits of compact

development. This provided the DRCOG Board of Directors with meaningful, actionable information for their regional decision-making. Before staff conducted the scenario analysis, the Board was considering expanding the UGB 70 square miles, as in Scenario B, to accommodate growth between 2030 and 2035. After reviewing the results of the analysis, the Board decided to expand the UGB a modest 21.8 square miles and to make only minor updates to the 2030 transportation network. The adopted 2035 urban growth boundary represents an ambitious effort to curb current trends toward expansive development, and will require a significant increase in overall density. DRCOG's experience demonstrates the tangible benefit of scenario analyses in exploring policy alternatives and identifying the optimal transportation investment and land use strategies for achieving regional sustainability goals.

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## ENDNOTES

<sup>1</sup> In order to present the outcomes in this format, each parameter was normalized using a z-score statistic.

## REFERENCES

- Avin, U. (2007). "Using scenarios to make urban plans." In L.D. Hopkins and M. Zapata (Eds.), *Engaging the future: Forecasts, scenarios, plans, and projects* (79-101). Cambridge, MA: Lincoln Institute of Land Policy.
- Bartholomew, K. (2007). "Land use-transportation scenario planning: Promise and reality." *Transportation* 34(4), 397-412.
- Cervero, R. (2006). "Alternative approaches to modeling the travel-demand impacts of smart growth." *Journal of the American Planning Association* 72(3), 285-295.
- Denver Regional Council of Governments. (2005). "Integrated regional model – Model refresh project: Documentation for the Denver regional travel model." Denver, CO: Author.
- Denver Regional Council of Governments. (2006). "Metro Vision 2020 clean water plan: Policies, assessments and management programs." Denver, CO: Author. Available: <http://www.drcog.org/documents/06CWPFinal.pdf>.
- Denver Regional Council of Governments. (2007). "Metro Vision 2035 plan." Denver, CO: Author. Available: <http://www.drcog.org/index.cfm?page=MetroVision>.
- Denver Regional Council of Governments. (2008). "Background and summary assumptions underlying DRCOG's land use model." Denver, CO: Author.
- Ewing, R., Bartholomew, K., Winkelman, S., Walters, J., and Chen, D. (2007). *Growing cooler: The evidence on urban development and climate change*. Washington, D.C.: Smart Growth America.
- Guimond, D., and Arbogast, D. (1995). "Infrastructure costs – Metro Vision 2020" (Memo prepared for the Denver Regional Council of Governments). Denver, CO: BRW, Inc.
- Mullen, C. (2005). "2005 national impact fee survey." Austin, TX: Duncan and Associates. Available: <http://www.impactfees.com/publications%20pdf/2005%20impact%20fee%20survey.pdf>.
- Nelson, A.C. (2004). *Planner's estimating guide: Projecting land use and facility needs*. Chicago: American Planning Association.
- Nelson, A.C. (2006). "Leadership in a new era." *Journal of the American Planning Association*, 72, 393-407.
- Puentes, R. (2008). "A bridge to somewhere: Rethinking American transportation for the 21st century." Washington, D.C.: The Brookings Institution. Available: [http://www.brookings.edu/papers/2008/06\\_transportation\\_puentes.aspx](http://www.brookings.edu/papers/2008/06_transportation_puentes.aspx)
- Regional Plan Association. (2006). "America 2050: A prospectus." New York: Author. Available: <http://www.america2050.org/pdf/America2050prospectus.pdf>.
- Regional Transportation District. (2004). "FasTracks plan." Denver, CO: Author. Available: [http://www.drcog.org/documents/2004\\_FasTracks\\_Plan.pdf](http://www.drcog.org/documents/2004_FasTracks_Plan.pdf).

Richie, M.F. (2001). "The implication of changing U.S. demographics for housing choice and location in cities." Washington, D.C.: The Brookings Institution. Available: [http://www.brookings.edu/reports/2001/03demographics\\_martha-farnsworth-riche-farnsworth-riche-and-associates.aspx](http://www.brookings.edu/reports/2001/03demographics_martha-farnsworth-riche-farnsworth-riche-and-associates.aspx).

Sabina, E. and Rossi, T. (2008). "Using Activity-Based Models for Policy Decision Making." Conference Proceedings 42: Innovations in Travel Demand Modeling Conference, 1, 20-21. Available: <http://pubsindex.trb.org/document/view/default.asp?lbid=876473>.

Smith, E. (2007). "Using a scenario approach: From business to regional futures." In L.D. Hopkins and M. Zapata (Eds.), *Engaging the future: Forecasts, scenarios, plans, and projects* (79-101). Cambridge, MA: Lincoln Institute of Land Policy.

Stone, B., Mednick, A. C., Holloway, T. and Spak, S. N. (2007). "Is compact growth good for air quality?" *Journal of the American Planning Association*, 73(4), 404-418.

ULI—the Urban Land Institute and Ernst & Young. (2008). *Infrastructure 2008: A competitive advantage*. Washington, D.C.: ULI—the Urban Land Institute.

U.S. Environmental Protection Agency. (2007). "MOBILE6 technical documentation." Retrieved from: <http://www.epa.gov/oms/models/mobile6/m6tech.htm>.



**Professor David Banister**

**CONCLUSION**

# **THE DILEMMAS OF SUSTAINABLE TRANSPORT**



This set of five international papers builds on the burgeoning literature on sustainable transport, taking the three pillars of sustainability or 3Es (the economic, equity and environmental pillars) and applying them to a range of topics, mainly based on cities. The focus is primarily, but not exclusively urban, and in each case different elements of the 3Es are taken. The first paper on Sydney highlights the importance of looking holistically at urban sustainability, arguing for the need to make assessments over time, through monitoring and linking explicitly the sometimes conflicting aims of development and transport. Its focus is economic and environmental. This is in contrast to the much more local concern of the second paper that examines different design principles at the neighbourhood level in Newcastle (UK), by exploring the means to reconcile the demands of traffic with those of the local community through different patterns of layout and the use of urban space. The concern here is with equity and the environment.

The priorities of cities in the developing world are very different, and here the example of Delhi is taken to promote the importance of accessibility in determining access to jobs in both the formal and informal sectors. But the principal concern is over access for the urban poor to jobs, and the problems they have to overcome in situations where rapid urbanisation and motorisation are taking place, resulting in longer distance journeys and low levels of accessibility. The focus is on economic and equity factors. The fourth paper does not have a locational focus, but explores the ownership of the road infrastructure, arguing that if it was seen as a private rather than a public good, it would be clear as to whom it belongs and the environmental externalities of transport could be internalised. The concern is over the reconciliation of the economic and the environmental priorities.

The final paper looks at six different scenarios for transport and land use policies in Denver, taking the reader through the thinking and comparison of alternatives to the realities of implementation. The options consider the trade-offs between more or less intensive use of land, and a greater or lesser priority given to public transport. Here again the interest is over the economic and environmental arguments. All five papers seem to focus more on the economic and environmental elements of sustainable transport, and to a lesser extent on the equity problems, but none of them considers all three pillars of sustainability at the same time. This observation encapsulates the difficulty of thinking holistically on sustainable transport as it relates to cities. The Sydney and Denver papers get closest, but in both cases the equity elements are restricted to spatial variations, rather than the more commonly used social and intergenerational definitions of equity (as stated in the Brundtland Report, 1987).

There seems to be a basic dilemma here, particularly when sustainable transport is based within the more recent debates on climate change and the contribution that transport should make in achieving reduction targets for the emissions of carbon dioxide. All people like talking about sustainable transport, but there is little enthusiasm about changing the ways in which travel is actually undertaken. When city transport is considered, the common reaction is to look at

technological innovation as the way forward, so that existing patterns of travel can continue, but with the use of less carbon. In principle, this preferred alternative appeals to most people, but the reality is more complex.

Even if the most efficient cars and other forms of urban transport are used, there is still the substantial growth in traffic, and this severely reduces any positive impacts resulting from the technology. The purchasing patterns of individuals do not match up to expectations, as very few people buy the most energy efficient options, selecting higher performance vehicles instead, and even the current optimism for electric city vehicles has a time horizon of 2020, as it will take at least ten years to switch the electricity supply industry from carbon energy sources to renewables. There are also the substantial costs of switching from one well established carbon based infrastructure to another non carbon based system. The transition costs are high. In addition to using the most efficient technologies, behavioural change is essential. Technological futures are important, but on their own they will not provide the elusive sustainable transport system.

Cities provide us with the best opportunity for moving towards sustainable transport. The starting point needs to be a view as to the sustainable city of the future, in terms of its economic functions (e.g. employment, government, housing, education and health), as well as its attractiveness (e.g. cultural, social and community). The city should be inclusive and cater for all sections of the population. The quality of life should be high, with city living based around good quality affordable housing, strong neighbourhoods and good facilities that are easily accessible. This would seem to match up with the three pillars of economic, equity and environmental elements of the sustainable city. The city must be seen as a place for people, providing opportunities for all, in a safe and secure neighbourhood, with green space and other recreational facilities accessible to all. It is then that we consider what sort of sustainable transport system might be most appropriate to fit this vision of the city - transport serves the city.

In many European cities, over 50% of all trips are made by walk and cycling, and this target could be even higher. The quality of the public transport system should be so good that it is not necessary to own a car in the city. The car spends most of its time parked, occupying valuable urban space. It is expensive in terms of the capital and running costs, its depreciation and its insurance costs. The car should be seen as a functional form of transport, not an icon or an identity statement. If a car is needed, then it could be hired for a specific purpose, and this would ensure the right sized vehicle is being used in each situation. These hire vehicles would all be "clean", probably small electric or plug-in hybrid city vehicles, using the latest technology. Smart card hire schemes could also be operated for delivery vans, scooters and bicycles. All public transport would be powered by renewable energy, either electric (trams) or hydrogen fuel cells (buses, bus rapid transit and flexible minibus transport). All transport in the city would be "clean", with low energy costs and power coming mainly from renewable electricity.

Many of the streets could be closed to vehicles, either permanently or at particular times, so that space can be reallocated to priority users, or for markets, or for safe travel to schools. Such a change would have health and safety benefits, as would very low speeds in residential and shopping areas where people outnumber vehicles. Cities would be designed around their public transport networks, with high densities at public transport accessible interchanges, and new residential locations could be designed as car free developments. So much is possible.

What conclusions can be drawn from these papers? First, as noted above, we need to move away from belief that technology can provide a low carbon transport system. It underestimates the scale of the problem to be addressed in the transport sector, which is characterised by a steady and continuous increase in travel with no real contribution to carbon dioxide reductions. There needs to be a much greater focus on the role that land use planning can have in determining the urban form of the sustainable city at all levels from the city wide to the local neighbourhood (see papers 1 and 2). There must be a much greater concern over the disadvantaged, as cities should be inclusive of all people (see paper 3), and this includes important issues concerning the ownership and use of space (see paper 4). There should also be a much greater recognition of the problems of translating good ideas into practice, in particular when the complexity of the relationships between pricing, urban form and transport are considered (see papers 4 and 5).

In addition, the young people need to be engaged in the process of serious debate, as they are the ones that have to sort out the problems that today's decision makers have failed to address. The intergenerational equity argument introduced by Brundtland (1987) has come full circle. The planet is not being passed onto future generations in as good or a better shape as it was inherited. Current young researchers and decision makers need to have the commitment and courage to reverse the inaction of previous generations. This means that there must be effective leadership that places environmental issues and social equity at the same level, or even above, economic growth. Too often, key environmental and equity concerns are ignored when economic growth is possible, but this option tends to emphasise the short term gains rather than the longer term losses.

Effective leadership must look at new visions of the city and implement effective strategies that are both politically and publicly acceptable. It is unlikely that there is going to be any substantial increase in the supply of city infrastructure for transport, and so the biggest challenge for urban planners is to decide how that infrastructure can be managed in the most sustainable way. This includes the allocation of space to different types of use (perhaps by time of day and day of week), substantial increases in the costs of access by car to that space, and decisions about who actually owns that space.

This is the basic dilemma facing society in terms of climate change and sustainable transport. People like travelling and much more travel is being undertaken, yet there is also an awareness

of the environmental and social costs of travelling, and the individual responsibilities, both locally and globally. Social networks are growing, and they are increasingly international in their scope, and the global economy is also totally dependent on long supply chains. To some extent individual behaviour can be modified and travel substituted through technological innovation. But in many cases, there is no substitute for face to face contact, and people want to experience other places and cultures. It presents a classic case of the conflict between individual preferences and choices, as opposed to the wider concerns of society to protect the environment and future generations. This is why there are no simple answers to the question about what is sustainable transport, and even the understanding of the complexities of the choices available are also embryonic, and serious debate between all parties now needs to become central to all decisions on the future of cities.

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# 2050 AN INTERNATIONAL PERSPECTIVE

## SUSTAINABLE TRANSPORTATION

