Built form, travel behaviour and sustainable urban planning of Indian cities: A case of Ahmedabad city

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Abstract. Metropolitan regions in Asia and Africa are growing in terms of their economy, population and spatial extension and as economies grow and focus of development shifts from Industry based to trade and commerce base. Fast economic and urban growth coupled with planning and control methods practices followed in these contexts have caused decentralization of population, jobs and services from inner dense core of the cities to less densely developed suburbs. The recent reforms and developments in a country like India sets up the need to add to the debate on efficiency of diverse urban forms and its impact on travel behaviour; which till now is mostly focused on the Anglo-American setting. As the area and the context is not well researched several questions need to be answered as to how and if decentralization of jobs has happened, and whether polycentric development as can be witnessed in new employment centre formation has caused a change in travel characteristics like trips length and choice of mode.

The stated paper presents results of research relating built form, travel behaviour, and environment for the case city of Ahmedabad. These relations are used to demonstrate how they can be used for better and more sustainable urban planning in Indian conditions. The presented research has three components. First built form measure that influence travel behaviour are identified, these measures are quantified for the case city of Ahmedabad and built form travel behaviour elasticity presented in [1] are used to study the influence this might have to total distances travelled by individuals and choice of walking and transit modes. Even though the specific elasticity is in Indian situation might differ, but these give an idea as to how the approach can be applied and in the Indian context.

Introduction

Cities are considered engines of economic and demographic growth. They also represent human spatial and material relationships with nature. Their pattern of urban development and growth is a matter of concern within the framework of sustainable development. Transport is considered fundamental to the manner in which urban development and growth takes place. As one of the largest consumers of fossil fuel, it also contributes substantially to air pollution in urban areas. Increasingly many cities, especially those in rapidly developing countries like India are observing changes in spatial spread, economic transformation and the related social processes. These changes put an enormous pressure on sustainable development; the resulting growth pattern is often incessant. These incessant growth patterns result in wide intra-urban variation of physical and socio-demographic characteristics of urban form. The basic concerns are built around the planning of land uses in the cities, its integration with transport [2] and poor understanding of how these relate with travel behaviour. This fact is also recognized by the Indian government and is reflected in the recently formulated National Urban Transport Policy [3]. However, this realization is nascent and there is very little contextual evidence on what these relations are in Indian context. Lessons need to be learned from empirical work done on this subject and adapted in the context of India.

Review of literature on urban form and travel suggests that physical and socio-demographic elements of urban form affect travel behaviour. Common outcomes examined include distance travelled, travel mode choice, trip frequency and use of transit. The first empirical evidence on the literature is the study by Mitchell and Rapkin [4] and this study subsequently has led to several other researches and the creation of new urban development principles, for example, ‘Smart Growth’, ‘New urbanism’, ‘Location efficient development’ and others that advocate sustainable land use practices which are directed to reduce vehicle travel and shortening of commuting time and distance. That may improve the overall efficiency of the transport system and reduce its negative externalities on the environment. Most of the empirical evidence on the relation is from the United States of America and Western Europe. There are also some recent studies in the context of China [5, 6] and a few examples validating these relations of cities in other developing countries [7]. In the Indian context, Srinivasan and Rogers [8] have studied the relation of travel behaviour with the difference in accessibility to service and employment at two different settlement locations in Chennai. Ewing and Cervero [1] present a very useful meta-analysis of built environment and travel behaviour literature, and they presented weighted average elasticity values of regression analysis done in all the studies. They note that such elasticity values can be applied as sketch planning approach to estimate vehicle miles travelled and possible use of walking and transit in relation to the base case [9, 10]. Nevertheless, conclusions drawn from experiences in the developed countries may not directly be applicable in countries like India; one might expect some very different associations between the key variables as elasticity between different variables can be different depending upon the contextual situations. But still the weighted elasticity values computed by [1] should give an indication on how built from in an Indian city influence travel. The following section is a literature review, followed by introduction to the study area and quantification of built form. This is followed by presentation of elasticity values observed by [1] and how its implication on travel in Ahmedabad, last section concludes the paper.

Review of Literature

In theory, built form characteristics can influence travel behavior in several ways. Initial studies on the subject looked at the connection between land use densities and transit use [11].

Table 1-1 presents the built form indicator that are used in empirical studies on built form and travel behavior as mentioned in Ewing and Cervero [1]. The built form variables are grouped in six categories, referred to as six D's by Ewing and Cervero [1]. These indicators are density, diversity, design, destination accessibility, distance to transit, destination, and demand management. The end purpose to study these relations is to determine the competitiveness of transit and non-motorized modes of travel relative to car or self-owned motorized vehicles and achieve lower consumption of fossil fuel by reduction in total vehicle kilometer's or miles travelled. Intensity of the red color in last column (No#) in table 1-1 indicates frequency of use of the particular indicator, the most frequently used built form indicators that are related with VMT are density, diversity, destination accessibility, and design. Likewise, design, diversity and density, design are more frequently studied in relation to mode choice of transit and walk modes.

Table Error! No text of specified style in document.**-1: Travel Behavior and Built form Indicators**

Travel Behavior Indicator	Built form Indicator	No #
Vehicle Distance Travelled	Density	31
	Destination Accessibility	24
	Diversity	23
	Design	22
	Transit Access	7
	Neighborhood type	5
Transit Mode Choice	Design	18
	Diversity	15
	Accessibility to Destination	7
	Transit Access	5
	Neighborhood type	1
Walk choice	Density	55
	Design	30
	Diversity	25
	Destination Accessibility	9
	Neighborhood Type	7
	Transit Access	6

* sourced from [1]
No# = No of times the variable has been used in built from travel behavior analysis

A lot of evidence is present in literature on the use of sketch planning approaches as a tool for long range planning decisions[10]. These models are considered to facilitate the analysis of broad land use and transport strategies, at a smaller spatial scale, with lower data inputs as compared to other conventional space models. Most sketch planning approaches rely considerably on assumed regularities of human behaviour in transport field and assumption that relationships are transferable over time and space. Ewing and Cevero [1] state the possibility of using elasticity values found in their meta study to develop smart growth land use and transport planning strategies. The purpose of this paper is to examine ways in which urban form accommodates transport systems and vice versa at a conceptual level, and to contribute towards quantification of urban form in the context of a developing country.

Study Area and Built form Quantification

Ahmedabad is the seventh largest city in India and has a large urban sprawl extending to the nearby rural areas. Different policies adopted by the state and local governments have resulted in a massive urban sprawl which radiates for more than 20 kilometres in all directions. The present area within the formal city municipal limit totals approx. 190 sq. Km. The city has a bigger urban sprawl [12]. The estimated population living in the urban sprawl is around 5 million [12] This growth has not been uniform across the town resulting in a large variation in densities.

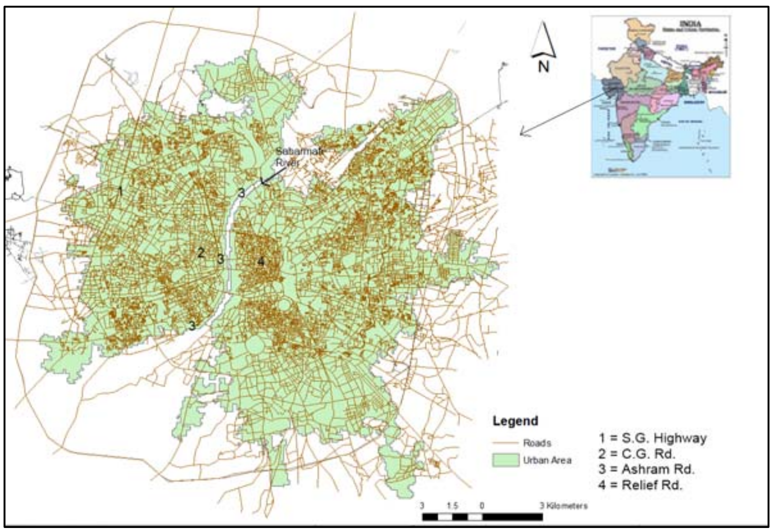

Figure 1: Ahmedabad

(SOURCE: INDIA POLITICAL[13] URBAN AREA AND ROADS (CARTOSAT-1 DECEMBER, 2007),

In Figure 2, images of quantified eight urban form variables are shown, residential density and entropy Index. To compute residential density total residential population is normalized by total land under residential use and likewise, to compute net employment density employment is normalized by total developed areas under commercial or industrial use.

The most commonly used concept to measure the balance land use is to measure the jobs-housing balance, which is generally represented as jobs per household as in [14, 15]. Cervero and Kockelman [16] have used the concept of “Entropy” to explain land use balance and “Dissimilarity Index” to explain mixing of land use. The measure of entropy is expressed as in equation one. This construct as per [17] is normalized with natural log of the number of distinct land uses (J), and therefore, varies between zero and one (with one signifying perfect balance of distinct uses considered. As in ‘equation 1’ total land is considered, this equation is further improved by using only proportions of developed land so that area which have been assigned a use but are not fully developed to get properly represented.

$$Entropy = \sum_j \frac{(Pj \times \ln Pj)}{\ln J} \quad \text{……………………………………………………………………… Equation 1}$$

Where Pj is the proportion of developed land in the jth use type in a census tract

The degree to which these land uses come into contact with one another is also important, as for example if the land uses are uniform clusters, they are likely to encourage fewer small distance trips and thus walking [18]. Cervero and Kockelman [16, 18] propose the concept of "dissimilarity index" with is explained in equation 2. Thus if all the land uses in the immediate contact of the hectare grid cell under consideration are of the same land use then the diversity value will be 0 and if all are different than the value will be 1.

$$Dissimilarity\ Index = Mix\ Index = \sum_k \frac{1}{k} \sum_i^8 \frac{X_{ik}}{8} \quad \text{………….. Equation 2}$$

Where k = number of actively developed hectares in tract and Xik = 1 if central active hectares use type differs from that of neighboring hectare (Xik = 0 otherwise)

Apart from urban form variables mentioned above, ones related to socio-demographic condition of the household and income condition of the households have also been quantified. In figure 3 below poverty line population is shown, to quantify, SJSRY indicators[19] have been used to quantify the same. Design measures are quantified as road junction density and transit route density. These values are computed using kernel density function in ArcGIS software, using 750 m as radius from computations. Access to destination measure is quantified as network distance to the center of the town.

Build form variables are visually examined, for which built form data Voronoi maps are studied, these maps are shown in figure 2. Voronoi maps are developed using the cluster method (quantile clusters). The Voronoi map of all the ten build form variables is shown in figure 4. In the Voronoi map a set of 5 clusters are defined (All cells are placed into five quantile distribution. If the class interval of a cell is different from each of its neighbours, the cell is collared grey to distinguish it from its neighbours). It can be observed that the distribution of population and jobs in Ahmedabad is bi-polar and the effect of the river on values is very apparent, to the right of the river (east Ahmedabad) has more dense population and employment areas in comparison to the western part of the city which has lower and more dispersed residential density values. From the map, it is also clear that grid cells with higher population and job density values have come up in proximity to major roads. Population and job densities seem to have visual autocorrelation with land use mix values; areas closer to major roads have higher land use mix in comparison to interior portions. Population living below the poverty line can be found in large areas covered with slums/chawls or in small pockets across the city. Majority of the poverty pockets are located along the river, in the east, and a few on the western part of the city, locations where the density of population is high. Thus in comparison the local integration values that are computed are little higher and the global integration values found for Ahmedabad are in comparison much lower. Indicating that the local access provided by streets in Ahmedabad is relatively good, but global access is poor.

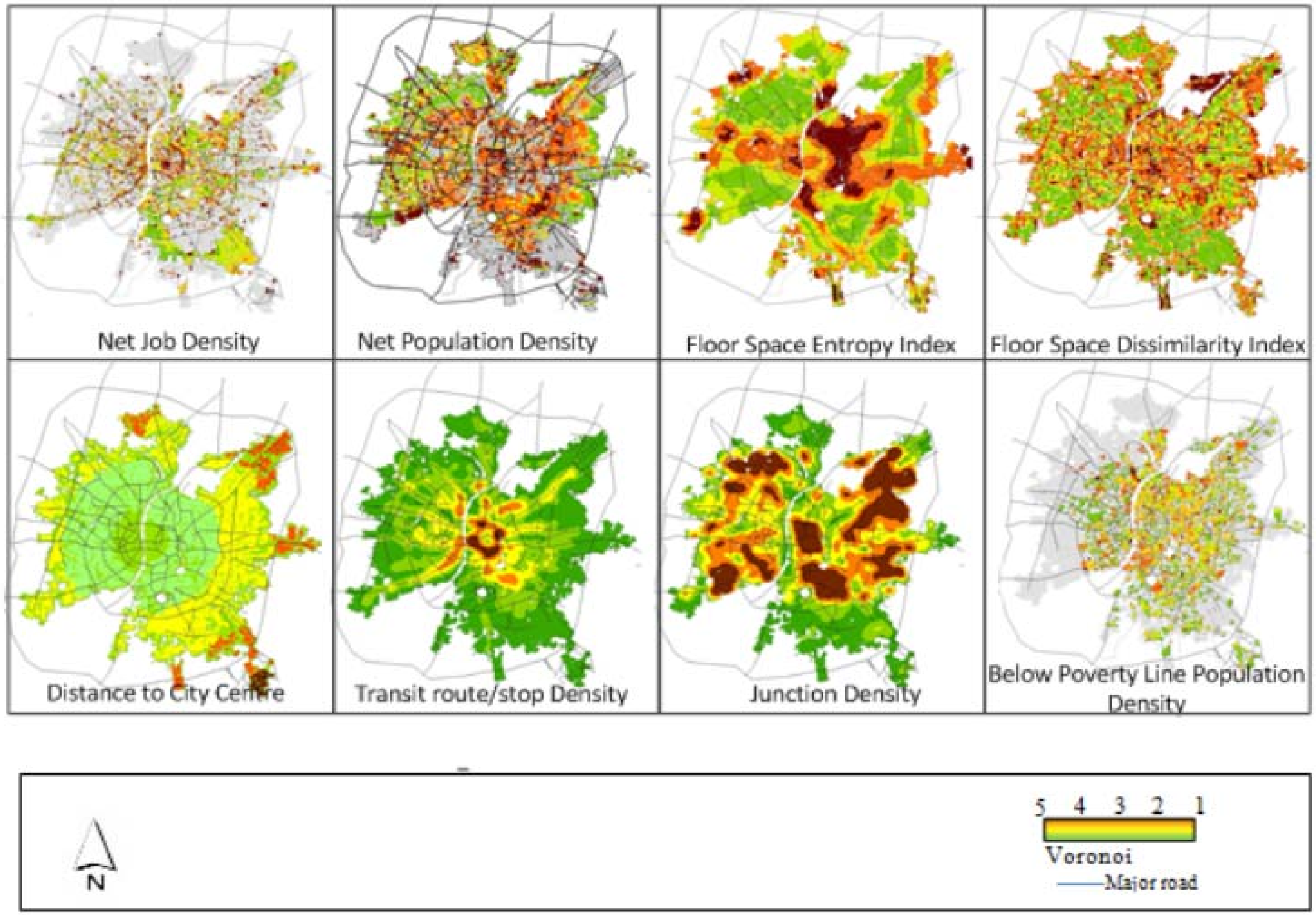

Figure 2: Spatial patterns of quantified built form indicators
Source: Study estimates

Built Form and Travel Behaviour Elasticity Values

In a Meta study on topic weighted elasticity values form empirical literature are presented in Ewing and Cervero (2010), the values are presented in table 1. In general it is observed that an increase in population density, land use mix (entropy or job-housing balance), number of intersections/street density, accessibility to jobs by car or by public transit, distance to central business district and and distance transit the total vehilce miles travelled (VMT) by individuals living at the location and increased possiblity of individuals walking or using transit modes for travel. Density of jobs is generally found to have neutral influence on VMT, and percentage of four way intersection reduced change of choosing to walk for travel. In both their meta studies Ewing and Cevero [1, 20] find accessibility to destination to be the variable having strongest association with VMT followed by intersection density and street connectivity. Population and Job densities have relatively lower association with VMT. Probality to walk best associates in a positive way with intersection density, then land use diversity parameters and accessibility to destination and distance to transit station. The elasticity values of associating densities with walk choice are compartively low. Public transit use is best assoicated with distance to nearest transit stop, then with intersection or street density followed by land use mix (entropy index).

Table 1: Weightage average VMT elasticity values as observed by [1]

		Weighted Average Elasticity Values
Density	Household/Population Density	-0.04
	Job Density	0.00
Diversity	Land use mix (Entropy Index)	-0.09
	Job Housing Balance	-0.02
Design	Intersection/street density	-0.12
	% of 4-way intersections	-0.12
Destination	Job accessibility by auto	-0.20
Accessibility	Distance to down town	-0.22
Distance to transit	Distance to nearest transit stop	-0.05

These elasticity values have been used to estimate NMT and transit mode choice probabilities for the city of Ahmedabad, this has been presented in figure 3, where five most common built form variables have been used to compute the reduction in vehicle miles mix and chances of increase in walking and transit use as a combination of these factors. From the figure, the east –west divide induced by the river is also apparent in the patterns of urban form also influence the mode choice and increase/decrease in Vehicle miles travelled. The eastern part of city has more built form measure which favors use of NMT and transit, whereas the western part favors use of personalized vehicles. Even though, the specific elasticity values between travel behavior and built form variable can be different for Ahmedabad. These values give an idea as location which favors NMT and transit modes, and which does not. These can be used as inputs in the future land use plan, which from transport sustainability point of view can be aimed at increase transit and NMT mode use and reduction in vehicle miles travelled.

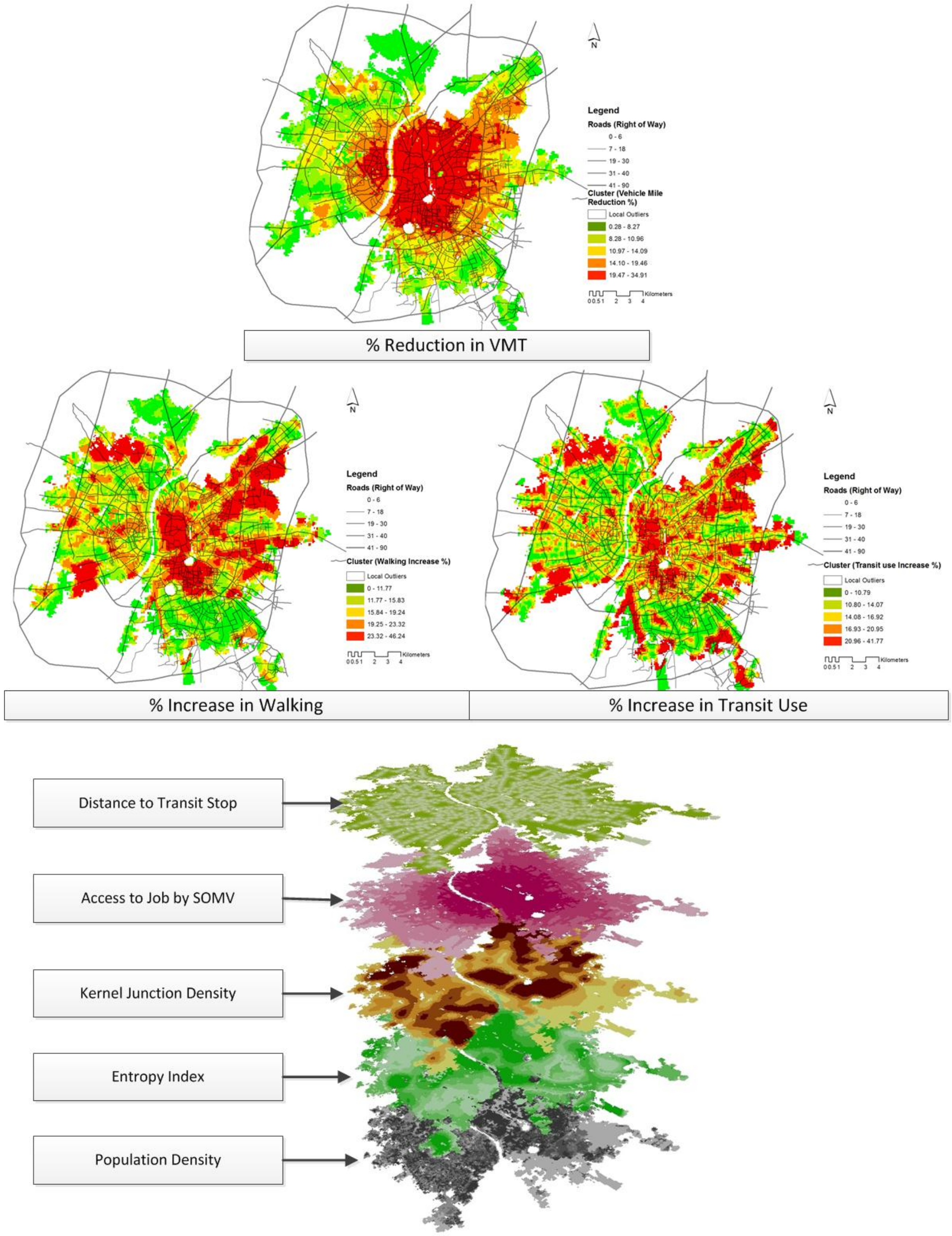

Figure 3: Built form and its influence on VMT and mode choice

* **Elasticity's from [1] are used**

Source: Study estimates

Conclusion

The analysis presented in this paper predicts the changes in travel behaviour on the basis of built form travel behaviour relations presented in [1]. Distinct patterns of mode choice and demand to travel observed for Ahmedabad is able to highlight locations, which do not favour transit and NMT use. But as the elasticity values used in this research are from [1], there arises a need to monitor or understand how one system (travel behaviour) reacts to changes made in the other system (built form), particularly in the context of fast developing cities in India.. Overall, there is enough evidence of using the stated approach for informed decision making in Indian context.

References

1. Ewing, R. and R. Cervero, Travel and the Built Environment. Journal of the American Planning Association, 2010. 76(3): p. 265-294.
2. Adhvaryu, B., Enhancing urban planning using simplified models: SIMPLAN for Ahmedabad, India. Progress in Planning, 2010. 73(3): p. 113-207.
3. MOUD, G., National Urban Transport Policy, 2006: India.
4. Mitchell, R. and C. Rapkin, Urban traffic: A function of land use1954: Columbia University Press.
5. Chao, L. and S. Qing, An empirical analysis of the influence of urban form on household travel and energy consumption. Computers, Environment and Urban Systems, 2011.
6. Chen, C., H. Gong, and R. Paaswell, Role of the built environment on mode choice decisions: additional evidence on the impact of density. Transportation, 2008. 35(3): p. 285-299.
7. Estupi án, N. and D.A. Rodríguez, The relationship between urban form and station boardings for Bogota's BRT. Transportation Research Part A: Policy and Practice, 2008. 42(2): p. 296-306.
8. Srinivasan, S. and P. Rogers, Travel behavior of low-income residents: studying two contrasting locations in the city of Chennai, India. Journal of Transport Geography, 2005. 13(3): p. 265-274.
9. Sosslau, A.B., et al., Quick response urban travel estimation techinques and transferable paramters, N.R. 817, Editor 1978, National Cooperative Highway Research Program, Transport Research Board: Washington D.C.
10. Downes, J., et al., Urban Transport Modelling with Fixed Travel Budgets: An Evaluation of the UMOT Process, in TRRL Supplementary Report SR 7991983, Transport and Road Research Laboratory: Crowthrone.
11. Pushkarev, B.S., J.M. Zupan, and R.P. Association, Public transportation and land use policy1977: Indiana University Press Bloomington.
12. GIDB and CEPT, Corridor Identification: Bus Rapid Transit System, 2006: Ahmedabad.
13. mapsofindia. February 10, 2010].
14. Ewing, R., P. Haliyur, and G. Page, Getting around a traditional city, a suburban planned unit development (PUD), and everything in between. Transportation Research Record, 1994(1466): p. 53-62.

15. Barnes, G., Population and Employment Density and Travel Behavior in Large U.S. Cities, 2001, Minnesota Depart of Transportation, Report: Minnesota.
16. Cervero, R. and K. Kockelman, Travel Demand and 3D's:Density, Diversity, and Design. Transport Research Digest, 1997. 2(3): p. 199 - 219.
17. Kockelman, K., Travel Behavior as a Function of Accessibility, Land use Mixing, and Land Balance: Evidence from San Francisco Bay Area, in City and Regional Planning1991, University of California: Berkeley. p. 50.
18. Kockelman, K., Travel Behavior as a Function of Accessibility. Transportation Research Record, 1997. 1607: p. 116-125.
19. Menon-Sen, K. and K. Prabhu, The Budget: A Quick Look through a'Gender Lens'. Economic and Political Weekly, 2001: p. 1164-1169.
20. Ewing, R. and R. Cervero, Travel and the built environment: A synthesis. Transportation research record, 2001(1780): p. 87-113.