

COMPACTCITIES: Analyzing the Urban Spatial Structure in Cities with Growth Restrictions
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COMPACTCITIES: Analyzing the Urban Spatial Structure in Cities with Growth Restrictions

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Abstract

A *compact city* form is one that espouses high intensity development within a restrictive geographic area. Its perceived benefits include (a) saving agricultural land (b) inducing shorter commute trips, thus less consumption of fuel and lower emission of harmful gases (c) bringing about a better quality of life through greater social interaction and (d) causing economic benefits through economies of agglomeration.

In this thesis I analyze these claims based on literature review, economic models, statistical tools, and by generating hypothetical transport scenarios. Based on this analysis, I conclude that high-density development by itself has little significant association with the benefits claimed above. Further growth control mechanisms have negative externalities such as increasing land rents and causing an immense strain on congestible amenities.

The thesis is divided into three parts. The first section is treated as an introduction to the concept of a “compact city”. In the second section I analyze whether a compact city can deliver the benefits that its proponents claim. I look at issues such as, (i) the effect of density on urban travel behavior factors like commute distances and public transit usage; (ii) the economics at the urban edge; (iii) the claim that sprawl is inevitable, (iv) effect of growth restrictions on land rent and (v) the relevance of compaction in developing countries (most of which are already highly dense). The third section analyzes the growth management regulations and policies being implemented in Delhi. I use the conclusions drawn from the second part to comment on the appropriateness of these policies, and suggest ways in which the city could better enforce these regulations.

I chose Delhi as the case study, in part due to my familiarity with the city, but also because it offers a unique urban laboratory. Delhi’s urban form could be described as the antithesis of the compact city form. Unlike most other cities, Delhi displays a positive (upward sloping) density gradient. The city is characterized by low-density development in the center and high-rise high-density at the periphery. The city owes this as much to its past as it does to its present political circumstances and planning policies.

The city faces massive strains on its infrastructure due to the high in-migration rates. To accommodate the

growing population, the city in the past five decades has quadrupled in area. I evaluate the urban growth management tools such as taxation policy, land use policy, development of satellite towns and imposition of physical restrictions, used by the city to deal with its problem.

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PROLOGUE

CHAPTER OUTLINE

- 1.1 THE AGE OF MEGACITIES
- 1.2 WHAT MAKES CITIES ATTRACTIVE
 - Centripetal Forces
 - Centrifugal Forces
- 1.3 THE COMPACT CITY CONCEPT
- 1.4 AIM OF THE THESIS
- 1.5 METHODOLOGY

1.1 AGE OF MEGA CITIES

In 1800, only 3% of the world's population resided in urban areas. This figure rose to 14% by 1900 with only 12 cities having a population greater than 1 million. By 1950, urban inhabitants comprised 30% of the world's population and now there were 83 cities with 1 million or more people. The last few decades has seen an unprecedented growth in urban population. According to a report published by the United Nations¹ in the year 2000, 47% of the world's population lived in urban areas and there were 411 cities that had a million or more people. Developed countries had 76% of the population in cities, while the similar figure in less developed nations was 40%. In 1994, there were 14 "mega-cities," defined as cities with at least 10 million inhabitants. Their number is expected to double by 2015. Bulk of these mega-cities will be in developing countries - or in economies that are least capable of sustaining giant cities.

1.2 WHAT MAKES CITIES ATTRACTIVE

Urban Agglomerations are an outcome of the trade off between centralizing [centripetal forces such as economies of scale, positive] and decentralizing pulls [centrifugal forces such as cheaper and more efficient transportation systems]. Some of

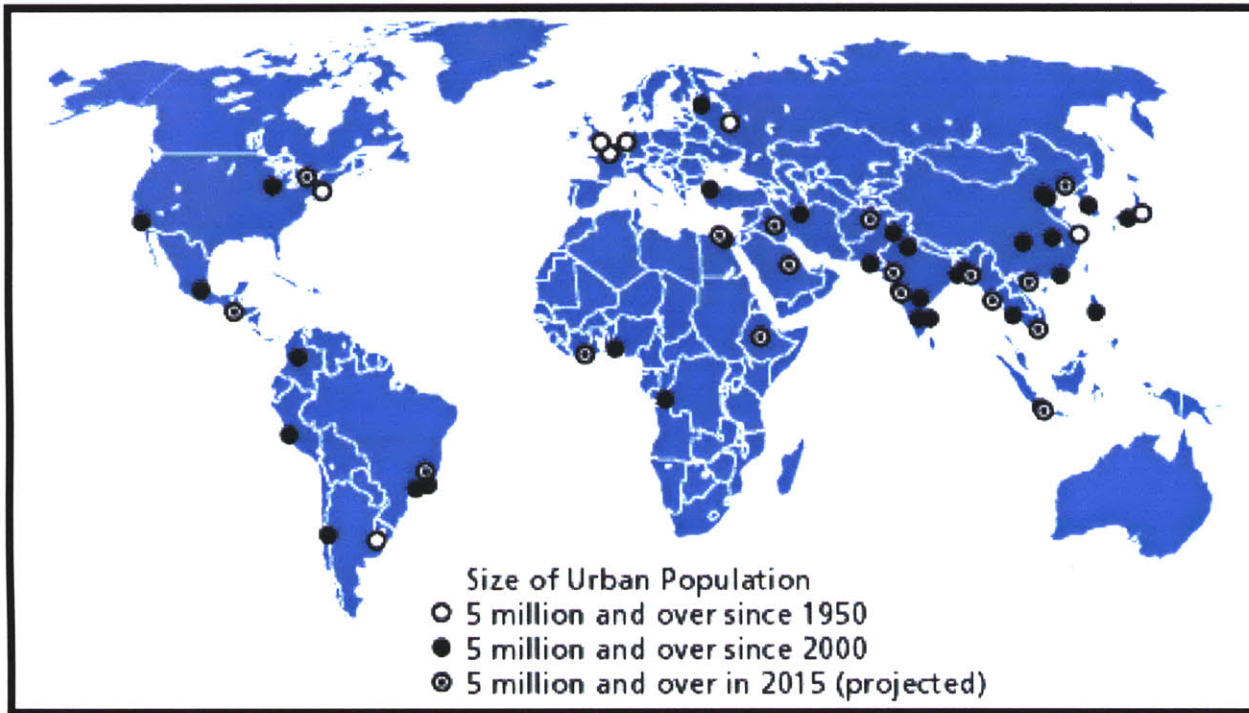
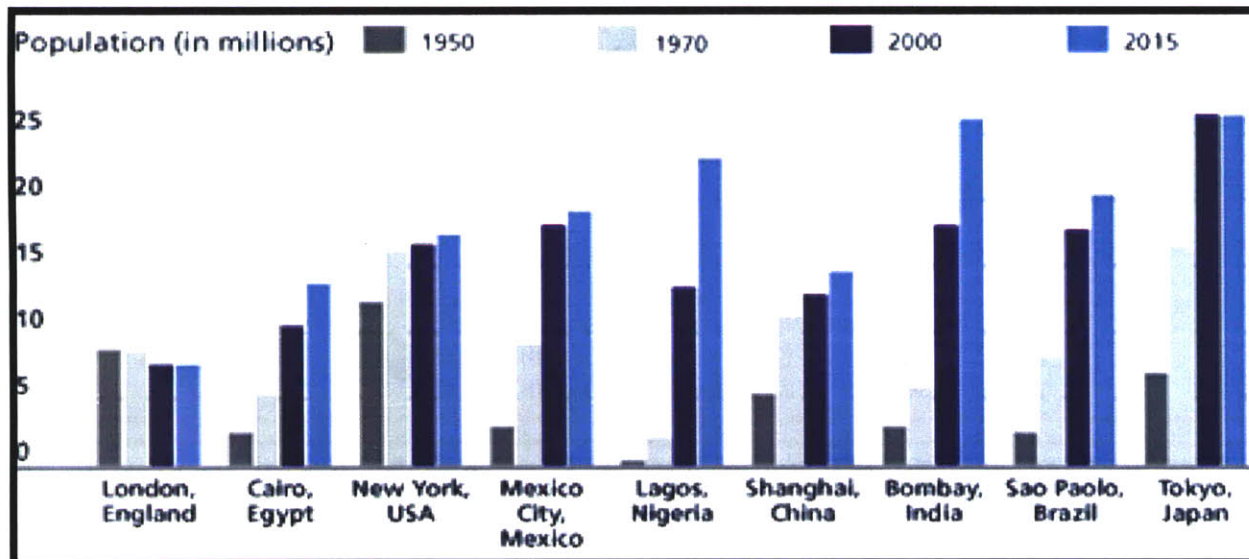


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 Source: Population Reference Bureau, "Patterns of World Urbanization"



the pull and push theories are summarized below.

CENTRIPETAL FORCES:

ECONOMIES OF SCALE

The high concentration in cities provides firms with a greater effective aggregate demand for industrial products as compared to a sparsely populated area. Firms thus prefer to locate in and around cities to produce cheaper and more efficiently, goods and services in larger but fewer sites (economies of scale). Further, firms are encouraged to congregate close to each other to deriving the benefits of sharing - costs for common infrastructure, - a pool of specialized labor - and to exchange ideas. This helps increase productivity and stimulates innovation. The labor benefits in locating close to industry for better job prospects while not having to change home locations.

POLITICAL FORCES

Ades and Glazer in their paper "Trade and Circuses" argue "political forces, even more than economic factors drive urban centralization." According to them political instability and dictatorship cause greater concentration in a single metropolis. They reason that increased distance lessens influence on the government because (i) threat of violence appears less direct when distance increases (ii) illegal political actions are difficult to conceal with distance (iii) access to information to political agents in the hinterland is less and (iv) distance hurts communication between political agents and government. Their

hypothesis is that the political power of the capital's population induces the government to transfer greater resources (e.g. tax benefits, better education facilities) to the city, and these benefits in-turn attract migrants.

INNOVATION AND LIFESTYLE

Recently developed models of urban economics, indicate an increasing evidence of urban agglomeration based on "innovation" and "lifestyle". Indeed the 'global city' growth paradigm is strong enough to have allowed cities like London and New York to thrive despite the decline of their traditional industrial and transportation sectors. Sanyal³ argues that successful cities are multi-cultural; they have a high concentration of human capital; are consumer oriented; and have a lively cultural/social life. He further claims, "The role played by the cities as innovation/life style hubs compensate for the costs of congestion because the process of agglomeration and human interaction itself generates externalities that have tangible economic benefits."³

TRADE POLICY

Krugman and Livas claim that protectionism generates larger central cities. While international firms serve both the city and hinterland equally well, domestic firms pay lower transport costs when serving their own locations. Hence it makes more sense for them to locate close to their market base (the cities). With protectionist trade policies in place, domestic suppliers take over the market. Since firms are located in the city, prices

net of transport costs are lower here and hence workers are attracted to the city to pay lower prices for the domestic goods.

CENTRIFUGAL FORCES:

CHEAPER AND MORE EFFICIENT TRANSPORTATION

Urbanists argue that concentration in cities will be higher when transportation is expensive. Cheaper and more efficient transportation and communication offer people/firms an opportunity to move to a farther location and yet still have the same access to jobs/market. Increasingly people in the developed world are moving to larger plots of land in the suburbs.

Urbanization usually accompanies social and economic development. However rapid urban growth on today's scale strains the capacity of local and national governments to provide even the most basic of services such as water, electricity and sewerage. Squatter settlements and over-crowded slums are home to tens of millions, like the favelas that cling to the hillsides of Rio de Janeiro and the tombs used as homes by tens of thousands in Cairo's "City of the Dead".

Urban growth management has become a vital part in the planning of mega-cities. In this age of mega-cities, planners are seeking more sustainable - denser urban forms, with policies such as the creation of poly-nucleated cities (cities with 4-5 satellite towns acting as magnets to attract some of the growth, e.g. Delhi); creation of physical boundaries such as greenbelts (e.g. London); guiding high density growth around

multiple district centers (e.g. Tokyo); by issuing ordinances that restrict development beyond a delineated boundary (e.g. Portland); and creating linear corridors of high density transport zones leading to the CBD.

1.3 THE CONCEPT OF THE COMPACT CITY

The genesis of the compact city lies in the sustainability imperatives of resource conservation (e.g. fossil fuel energy) and waste-minimization (e.g. carbon emissions) as embodied in the Brundtland Commission report and the UNCED Agenda 21 proposals published in the late eighties and early nineties.

Following the publication of the Brundtland Commission report in 1987, a fundamental question is being asked amongst the planning community, how do we use planning systems and tools to develop a sustainable urban development. A possible solution being offered is that of "compact city" development.

Containment policy has two fundamental tenets, (i) preservation of open space and thus protection of agricultural output through the practice of delineating a firm urban edge and (ii) maximizing efficiency in resource consumption by increasing the density within the urban contiguous area.

The moot idea as described by Ewing was that "higher densities mean less space consumed per capita, and more land for

agriculture and for open space; bus and rail would better serve denser settlements, and there would be less reliance on the automobile; and higher densities reduce society's environmental footprint and slow the consumption of non-renewable resources."⁵ Proponents of the compact city ideas also point to the economic, social and cultural benefits.

The perceived benefits of a compacted city can be summarized as -

(a) Protect agricultural output - By containing the urban size, compact cities preserve open spaces on the urban periphery and increase agricultural productivity. "Protecting agriculture on peripheral lands in turn, increases the capacity to generate food and forest products for export, while increasing agricultural output for domestic consumption."⁵

(b) Transport Benefits - Low urban density tend to go together with a high level of reliance on private cars, low use of public transport, and low levels of walking and cycling. In contrast, Newman and Kenworthy⁶, claim that compact city forms offer the opportunity for shorter work trip commute; more efficient and economically viable public transport; promotes a high level of accessibility for non motorized modes of transport and due to all the three above mentioned factors produce low levels of energy use per person in transport. This they hope to achieve because (i) compaction would draw home and work spaces closer together, (ii) concentrated development would provide a

large market for public transit.

(c) Infrastructure Benefits - Proponents call for the slowing or stopping of urban sprawl by confining growth in contiguous areas adjoining built up spaces or by directing the growth to similarly constraint areas. In such a scenario public services will be more efficiently delivered at less cost. Sprawl causes unnecessary extension of public infrastructure to serve outlying areas.

(d) Economic Benefits - Considerable evidence exists that agglomeration or clustering economies created in densely- settled areas lead to higher per capita incomes and faster economic growth rates (Ciccone and Hall 1996, Glaeser 2000, Ihlanfeldt 1995, Rupasingha et al. 2000). The conventional explanation is that (i) proximity facilitates exchange (spillovers) among workers, thereby raising productivity and stimulating innovation; (ii) cities are productive as they move ideas. An example of this is the remarkable geographic localization of patent citations; (iii) firms and people come to the city to reap benefits of the creative milieu; and (iv) cities lead to higher aspirations to improve standards of living. (With the increasing requirement of higher skill levels in cities, people are being encouraged to gain those skills to secure better jobs.)

(e) More vibrancy - As income levels rise cities are remaking themselves as consumer cities. While people earlier preferred

to live in suburbs and work in the cities, a reverse trend is now evident, where-in people prefer to work in the suburbs and live in the cities. This indicates the renewed desirability of living in cities. Higher density fuels a greater supply of restaurants and stores.

(f) Better Quality of Life - Cities in order to sell themselves better, are being repackaged as places that are safer to live. An example pointed out is the reduced crime rates in New York.

A legitimate question being asked is whether the compact city will deliver the gains mentioned above or not. The debate has brought forth a number of reactions. These views can be classified into three categories.

- De-centrists - those that favor urban decentralization and reject the gains made through containment as being either 'modest at best' or 'unpractical to achieve'. Many amongst them espouse the cause of free markets to shape urban spatial structures.
- Centrists - those that believe in the virtues of high-density cities and decry urban sprawl. They favor cities with high density and a firm-restrictive edge that controls the city's footprint.
- Compromisers - those that advocate middle line between the policies advocated by the centrists and the de-centrists.

The four main arguments pointed out against the 'compact city' by the de-centrists are

1. The compact city will not deliver environment benefits being

claimed,

2. Urban decentralization is inevitable,

3. Stopping decentralization has negative consequences with regards to congestion, land prices and infrastructure provision, and

4. It is unlikely that compaction will improve the quality of life.

1.4 THESIS AIM

The aim of this thesis is two fold –

A. Analyze the claims that containment policies (high intensity development within a restrictive geographic area) leads to the following gains - (1) saves farm land beyond the city edge and thus increases agricultural output (2) induces shorter commute trips, thus more pedestrian and public transit usage, which in-turn cause less consumption of fuel and lower emission of harmful gases (3) brings about a better quality of life through greater social interaction and (4) causes economic benefits through economies of agglomeration.

B. Evaluate and suggest improvements to growth management regulations and policies being implemented by a city like Delhi, based on the conclusions from the primary aim.

1.5 STRUCTURE OF THE THESIS

The thesis is divided into three parts. The first section is treated as an introduction to the “compact city” concept and is used to set up the analysis of the merits that follow. In the second section I analyze whether a compact city will deliver the benefits that its proponents claim. It looks into the effect of density on urban travel behavior factors such as commute distances and public transit usage; the economics of the edge condition; the claim that sprawl is inevitable and the relevance of compaction in developing countries (most of which are already highly dense). The third section uses conclusions drawn from the second part to comment on the growth management policies of a city in the developing world.

I chose Delhi as this city to be my case study, in part due to my familiarity with the city, but also because it offers a unique urban laboratory. Delhi’s urban form could be described as the antithesis of the compact city form. Atypically, the city has a sparse low-density development in the center and high-rise high-density at the periphery. The city owes this as much to its past as it does to its present political circumstances and planning policies. The city faces massive strains on its infrastructure due to the high in-migration rates. To accommodate the growing population, the city in the past five decades has quadrupled in area. I evaluate the urban growth management tools such as such as taxation policy, land use policy, development of satellite towns and imposition of

physical restrictions, used by the city to deal with its problem

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2

ANALYSIS - I

URBAN FORM AND TRAVEL BEHAVIOR - I

CHAPTER OUTLINE

Arguments FOR Compaction

- 2.1 Brings work-home closer-more walk/bike trips - ELKIN
- 2.2 Reduces gasoline usage - NEWMAN/KENWORTHY
- 2.3 Positive correlation b/w city size and auto use - ECOTEC

Counter Arguments

- 2.4 Difficult to mould density. - Urban Spatial Structure is the result of the interaction between land markets and regulation.
- 2.5 Influence of multi-family households and unpredictable future jobs on the dispersion of home and job locations.
- 2.6 Increased "family & personal" trips
- 2.7 More suburb to suburb trips.
- 2.8 Influence on income levels
- 2.9 Personal idiosyncracies and cultural preferences.
- 2.10 Hypothetical Model

(A) DENSITY AND TRAVEL BEHAVIOR

ARGUMENTS FOR COMPACTION

Prominent amongst the centrists have been Newman and Kenworthy. They claim that a compact city causes shorter work-trip commutes; fosters economically viable public transport; promotes a high level of accessibility for non motorized modes of transport. And due to all the three mentioned factors consume less fuel and hence lower the emission of harmful gasses.

2.1 ELKIN, McLAREN and HELLMAN

Elkin, McLaren and Hillman espouse the cause of a compact city that leads to lower automobile dependence. They aim to achieve shorter commute trips (for all essential daily requirements) by creating compact self-contained mixed use urban settlements. In their book *Reviving the City: Towards Sustainable Urban Development*, they point out that "even a 4 mile radius would put one in touch with most day to day requirements. School catchment areas are generally much smaller than that and in employment, a wide range of job opportunities are available within that distance."¹ They further argue that nearly three quarters of all commuting journeys in the UK are five miles or less in distance and the bicycle could be used to cover distances that cannot be met by foot.

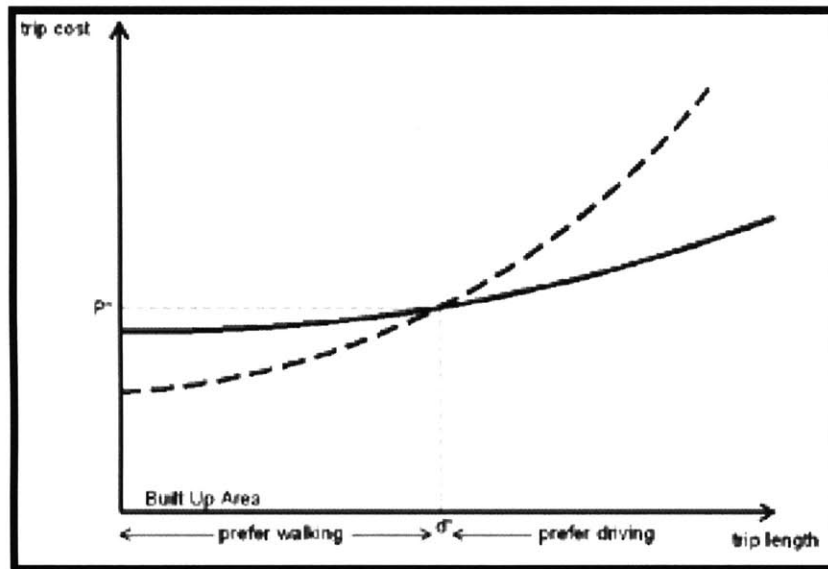


Fig. 2.01: Utility curves of walk and automobile trips.

Source: Boarnet, Marlon G., and Crane, Randall, (2001) "Travel By Design: The Influence of Urban Form on Travel"

Beyond a certain length " d^* " the cost of a car trip becomes less than that of a walk trip. By adopting compaction policies, centrists hope to reduce work-home trip lengths to less than d^* ; or by policies such as raising fuel and parking expenses they hope to shift " d^* " to the right.

2.2 NEWMAN and KENWORTHY

In 1989, Newman and Kenworthy published their book *Cities and Automobile Dependence*; in which they claim that metropolitan density is the primary factor that determines auto dependence, and that auto use declines swiftly where overall densities exceed 30-40 persons per hectare. [Refer Fig. 2.02] They suggest that planners should redensify cities by means of infill development to reach the above mentioned density levels. Their findings were based on cluster and fractal analysis undertaken on a sample set of 32 global cities.

"Average gasoline consumption in U.S. cities was nearly twice as high as in Australian cities, four times higher than in European cities and ten times higher than in Asian cities. Allowing for variations in gasoline price, income, and vehicle efficiency explains only half of these differences."² They conclude that land use intensity has the most significant correlation with gasoline consumption. Newman and Kenworthy argue for more compact and more monocentric urban land use patterns and investment in urban rail transit systems.

2.3 ECOTEC REPORT

The 1993 study conducted by ECOTEC Research and Consulting Ltd. stated

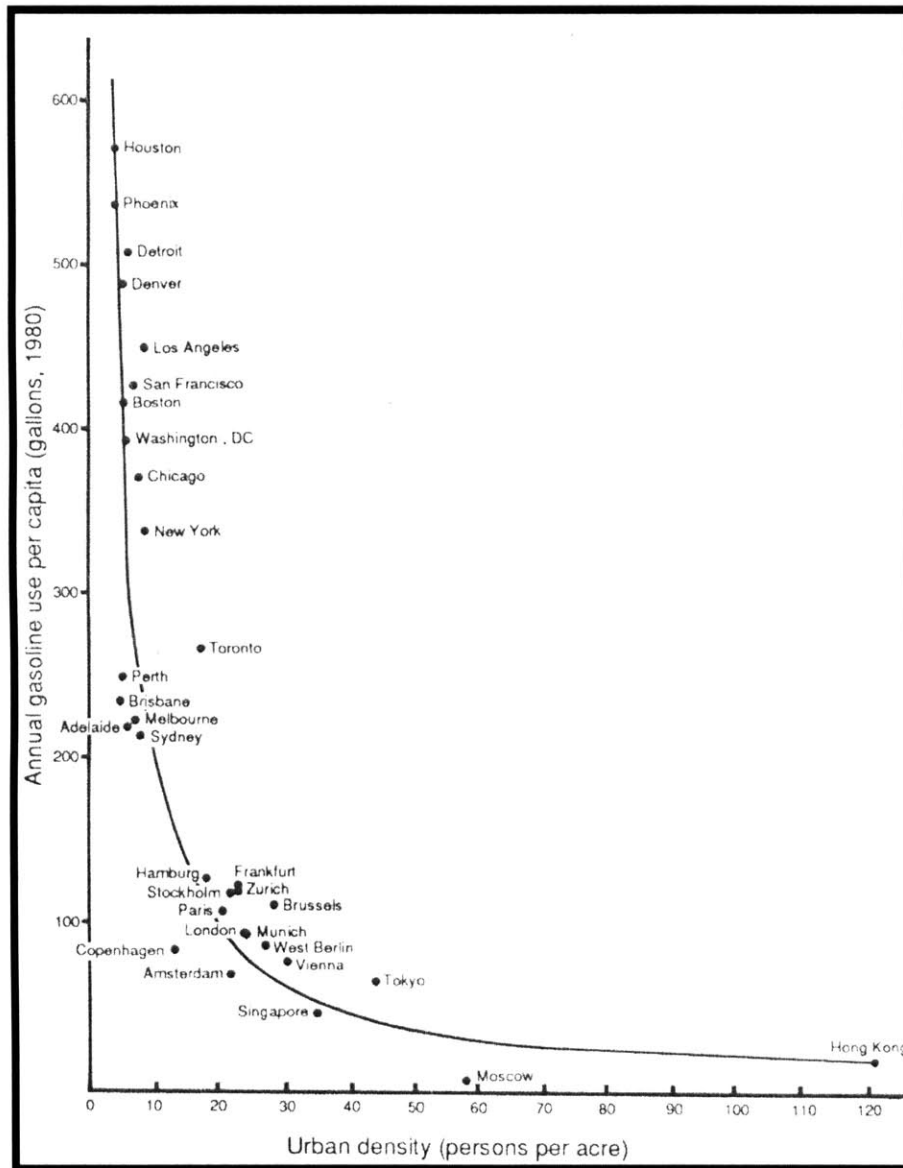


Fig. 2.02: Population Density versus Annual Gasolene Consumption per capita.
Source: Newman, Peter and Jeffrey Kenworthy (1989) "Cities and Automobile Dependence: An International Sourcebook."

1. Higher residential densities within settlements were associated with reduction in travel demand and encouraged emission efficient modes of travel. Although it was difficult to reveal precisely the threshold density levels beyond which travel demand is reduced.

2. City size was positively correlated with travel demand. Hence the trip lengths in widely spread out rural areas was much higher than those in cities. However cities in UK with less than 50,000 inhabitants were less transport emission efficient as compared to larger settlements.

3. Urban structures with centralized employment and other high travel generating activities significantly increased the use of public transport.

COUNTER ARGUMENTS

A number of researchers such as Gordon and Richardson, Gomez-Ibanez and David Hall to mention a few, argue that density by itself explains little for the amount of car usage, public transit usage and pedestrian trips.

2.4 ROLE OF URBAN FORM ON TRANSPORT BEHAVIOR

A primary flaw in the centrist's argument lies in the notion of density they portray. They look at density as the constant average density over a city, while much research shows that density in cities generally follows a negative downward sloping curve when graphed with the CBD as the origin. [Refer Plates xx, yy, zz]. Secondly, density cannot be molded as desired. It is an outcome of the interaction of land markets and regulations.

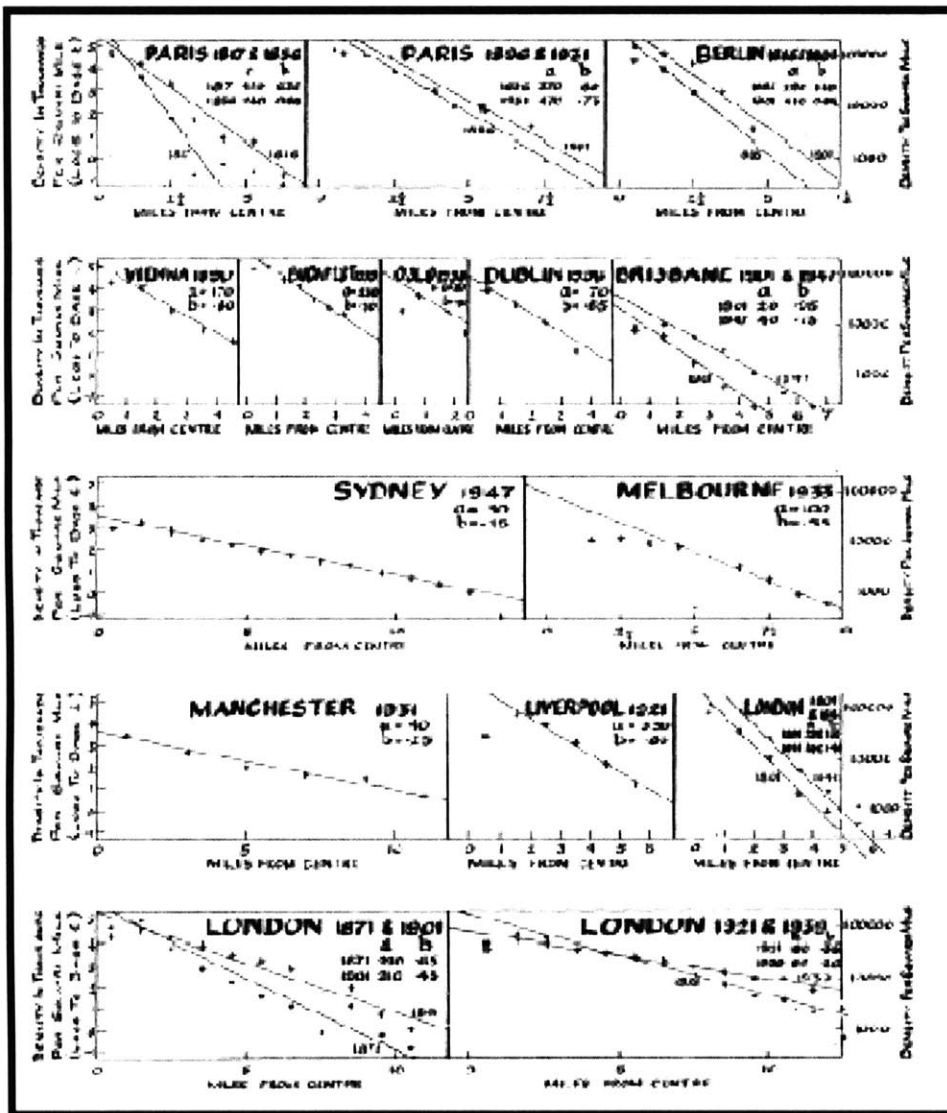
According to literature on urban economics the downward sloping curve can be explained thus:-

Choosing a home location is a trade-off between commute times and space requirements. Proximity is defined in terms of time and money required for transportation. The demand is thus greatest at the center of the city, since in the traditional monocentric city model, work locations exist in the Central Business Districts. Now since the determination of the price of land is based on the demand, the land in the center is most expensive. The more expensive the land is, the more likely that it shall be

densely developed, as builders trade-off construction costs against unit land costs. This explains the high land cost and density in the center and their progressive fall as one moves to the suburbs. As time passes, densities in the inner populous zones tends to fall, due to the flight of people to the suburbs. The city as a whole tends to spread out. The movement of people to the suburbs can be attributed to (a) reduction in prices and greater efficiency of transportation systems, (b) greater affinity for larger plot of land, (c) desire to co-locate next to business and labor market which might have moved out because of inner city congestion making it more expensive to transport goods and (d) cheaper land in the suburbs.

Density maps drawn by French scientist Meurot (1898) and Mark Jefferson (1909) and studies conducted by Colin Clark, (1951) [refer Fig. 2.03] and Alain Bertaud & Stephen Malpezzi (2003) [refer Fig. 2.04] corroborate this trend over a period of time.

Compact City proponents assume that the city forms can be molded to desired shapes. However this is highly unlikely. Cities display a certain inherent inertia to change. They are resilient and are not easily altered. The Urban Spatial Structure are created by the interaction of land markets and regulations. Very few cities have displayed a change in urban form. Curitiba can be cited as an exception and even in this case it took 15-20 years for the city to develop along linear transport corridors.



In his paper, Colin Clark plots the average density in each tract against its distance from the centre of the city. Using this method for different cities, he shows that the falling off of densities follows an exponential decline, given by the formula

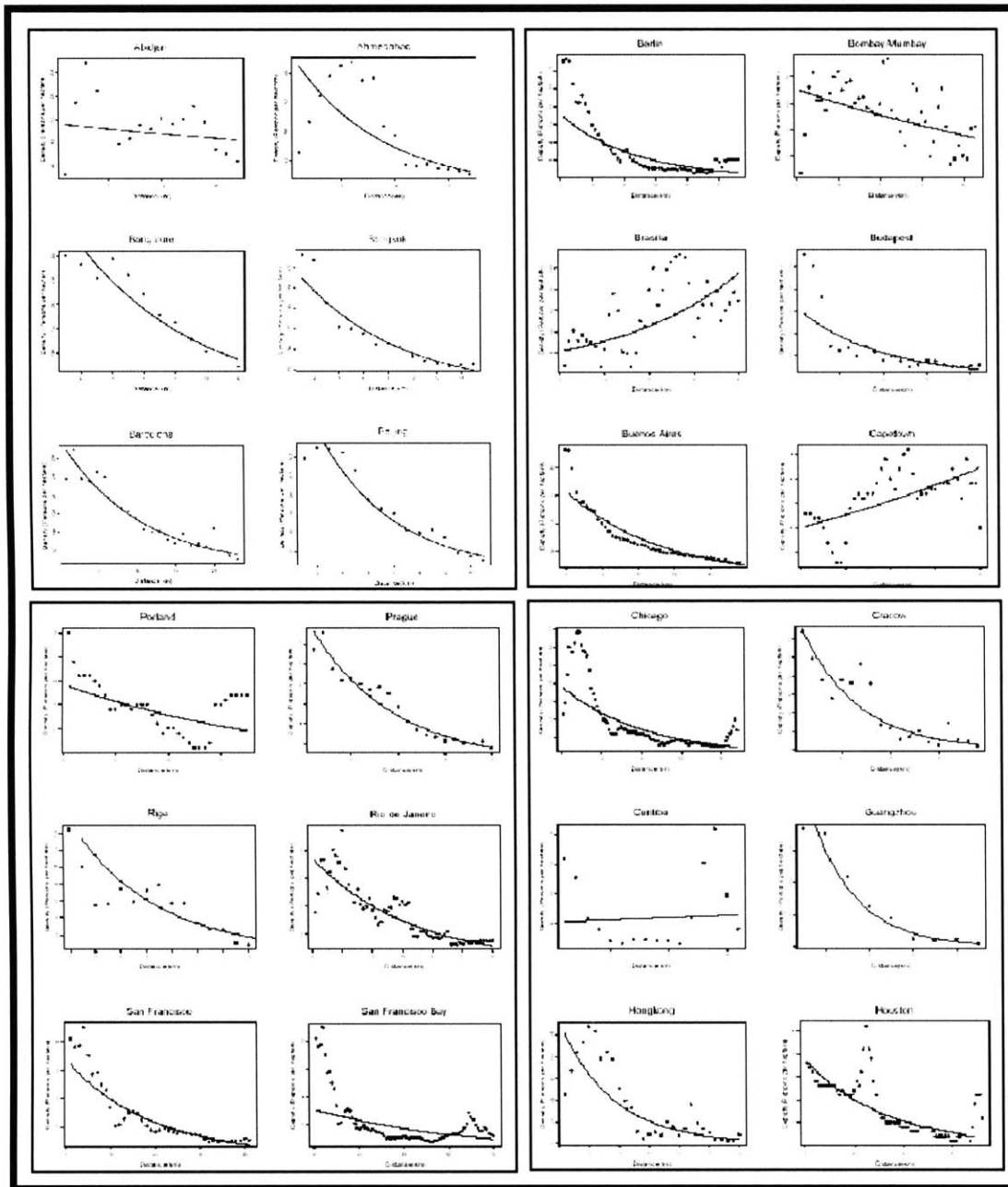
$$y = Ae^{-bx}$$

where x is the distance from the center of the city and y is the residential density.

Through a series of graphs he shows that the negatively sloped curve of density was a phenomenon seen in most cities. [Refer Fig. 2.03]. However the slope of the curve varied widely between cities. A high value of b representing a sharp decline in densities. The value of b was largely dependent on the cost of travel. The coefficient A represents the degree of overcrowding that the citizens were willing to accept in the center of the city (at $x=0$).

Fig. 2.03: Graphs showing historical density profile in cities around the world.

Source: Clark, Colin (1951) "Urban Population Densities" *Journal of Royal Statistical Society. Series A (General)* Vol. 114 Nos. 4 (pp. 490-496)



Stephen Malpezzi and Alain Bertaud formulated the 'compactness index' - "rho" - the ratio between the average distance per person to the CBD, and the average distance to the center of gravity of a cylindrical city whose circular base would be equal to the built-up area, and whose height will be the average population density,

$$\rho = (S_i d_i w_i) / C$$

The ρ is used as a measure of sprawl in monocentric cities and those polycentric cities where the CBD and the center of the city coincide.

Fig. 2.04: Density gradients in various cities around the world

Source: Bertaud, Alain and Malpezzi, Stephen (1999) "The Spatial Distribution Of Population in 35 World Cities: The Role of Markets, Planning and Topography", Wisconsin-Madison CULER Working Papers, The Center for Urban Land Economics Research – University of Wisconsin.

The effect of Urban Form on Travel has intrigued urbanists. Alain Bertaud finds that “dense contiguously urbanized and dominantly monocentric cities are favorable to transit and may significantly reduce trip length and as a consequence the total amount of harmful gasses emitted.” The reason being, that a geometrically central location will provide trips of a shorter length to all other locations in the city. In a polycentric city each sub center generates trips from all over the built up area of the city. Trips show a wide dispersion of origin and destination and tend to appear random. [Refer Fig. 2.04]

Even though the density gradient of polycentric cities is negative, their slope is much flatter as the proximity to center confers less of an advantage as compared to the monocentric city.

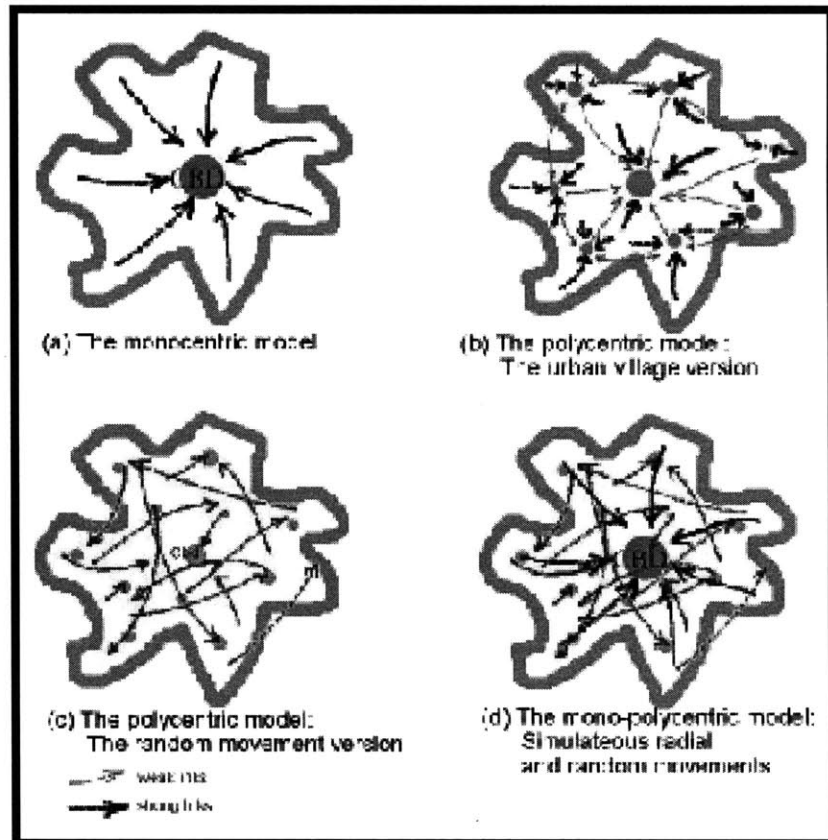
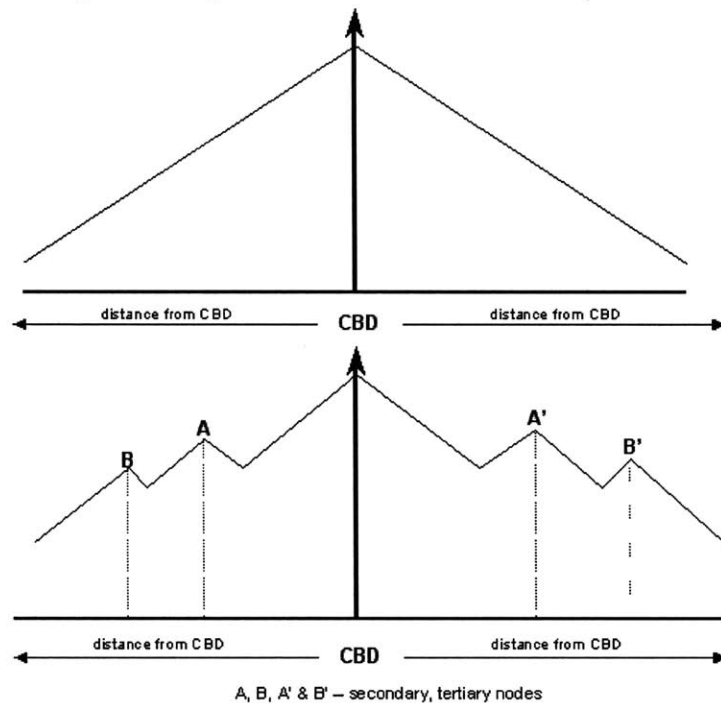


Fig. 2.04: (top- right) Schematic representation of trip patterns within a metropolitan area.
Source: Bertaud, Alain (2002) “Note on Transportation and Urban Spatial Structure”

Fig. 2.05: (below - left) Conceptualised density gradients of polycentric and monocentric cities.
Source: Author

2.5 INFLUENCE OF MULTI -WORKER HOUSEHOLDS AND UNCERTAIN FUTURE JOB LOCATIONS

Compaction policies work on the premise that when choosing a home location, each household will consider a trade-off between the value of access to their job against the cost of housing. This standard model is based on a mono-centric city, i.e. a city with a single site for employment and declining equilibrium rents and densities with increasing length of the commute.

However with increasing incidence of multi-worker households and multiple job locations, the task of choosing home locations has become more complicated. In the US, 60% of married households have both spouses working. Today most cities have employment sources in many centers and sub centers, changing the traditional single centered urban structure into a variety of multi-nucleated urban forms. Gordon and Richardson (1989) state, "By 1980, only 7.5% of jobs in the largest US urbanized areas remained in the Central Business District (CBD)."³

Urban economists such as Curran (1982) and White (1977) hold that a two-worker household would potentially prefer to locate at a place accessible to both job markets. Thus leading to possible home locations which are in-between job centers and not necessarily adjacent to either of them.

Complicating the matter further, Crane (1996) argues that in

an environment where job location may change and where it is costly to move, people will consider future job options rather than focus on minimizing current commute distances. He thus predicts, "shorter commutes for people with relatively small job change costs and relatively low home move costs" and "higher commuting costs per mile, and less job turnover."⁴

On a similar line of thought, Brueckner (1981)⁵ points out the relevance of local amenities (malls) and multiple employment

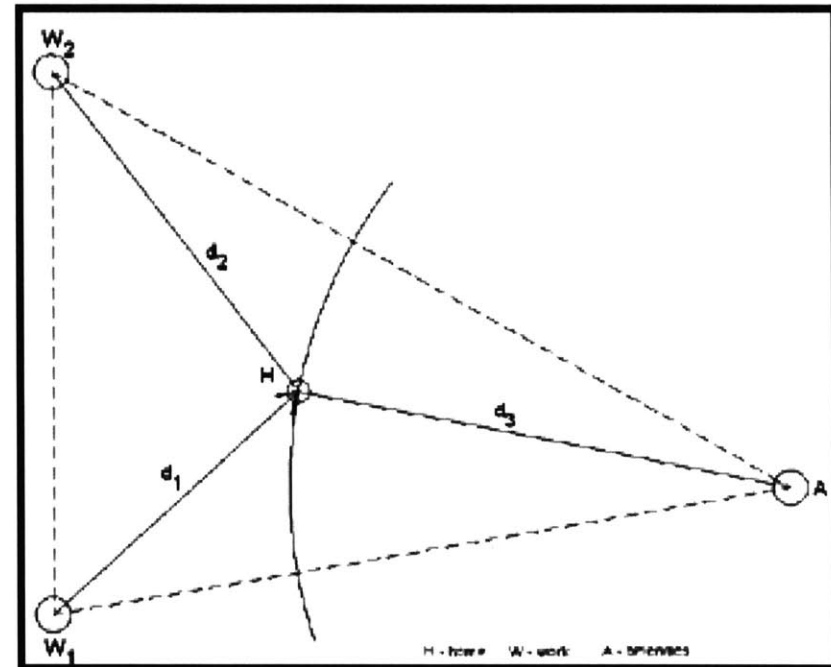


Fig. 2.06: Affect of multi-worker household and amenities in choosing home locations. [W1 & W2 - Work locations and A - Location of Amenities]

Source: Author

d1, d2 and d3 represent the utility of factors W1, W2 and A when deciding on a place to live.

centers when deciding between housing sites.

More trips today are made primarily for 'family', 'personal', 'social' and recreational'. The journey to work trip is no longer the defining travel experience. In the US considerably fewer than half the automobile trips are work-home trips.

Factors such as these lend credence to the idea of "wasteful" or "excessive commute". A number of research papers mention that aggregate commuting far exceeds the amount necessary to minimize the equilibrium work-home trips.

Piraski (1987) shows that most commuting in the US is suburb to suburb. The co-location of firms and households at decentralized locations has reduced and not lengthened commute times.

2.6 AUTO-DEPENDENCE and INCOME

Gomez-Ibanez⁷ writes that auto dependence is partly caused by low land density; but also by other factors such as income levels, gasoline prices and public policies to subsidize public transport and highway use. As income grows there is a greater demand for land-extensive housing and commercial building types. Rising incomes also encourage businesses to substitute capital and labor; for example - more office space per worker or single story manufacturing plants instead of a vertical ex-

pansion.

Many research papers have indicated that while high density neighborhoods do show low VMT's, at the same time these neighborhoods were also associated with low income levels. Kulkarni (1996)⁸ finds that the statistically significant association between neighborhoods and car trip rates are more an association between household incomes and car trip rates.

Building stock tends to reflect the incomes and transportation price levels that prevailed when it was built. Even when income and price levels change it is seldom economical to tear down older buildings and rebuild new densities. For example, London and Los Angeles were built at different time periods. The later was built in an auto era and for a wealthier population.

2.7 TRAVEL PREFERENCES

It is difficult to account for personal preferences. For example, shortening trip distances may promote walking, but they might also increase the number of trips taken by car. People may decide to shop more often and they may well continue using their cars to do so.

Further exploration needs to be done on how a change in

trip distance influences the individual desire and ability to take trips by various modes.

2.8 HYPOTHETICAL MODEL

I created a hypothetical model to study

- the influence of (or lack of) urban form on travel
- the effect of work-home location on distance commuted.

The model is based on an 11x11 grid [refer fig. 2.xx] with an average density of 2 blocks per grid (i.e. a total of 242 blocks). Each grid has been arbitrarily assigned as being 2 units in length and width. Each grid has a 1 unit wide street running on all four sides. To simplify calculations, each block is assumed to house one person. Hence by default it represents a single worker household.

To simulate the first part of the stated goal, i randomly assign blocks to the grid. The blocks are juxtaposed bearing in mind that the average density of 2 blocks per grid is maintained. Also, to simulate a realistic spread, further caveats are added - that the minimum coverage be more than 75% of the grids and that no grid can have more than 25 blocks on it.

To resolve the second aim of the model, three different work-home location scenarios are created.

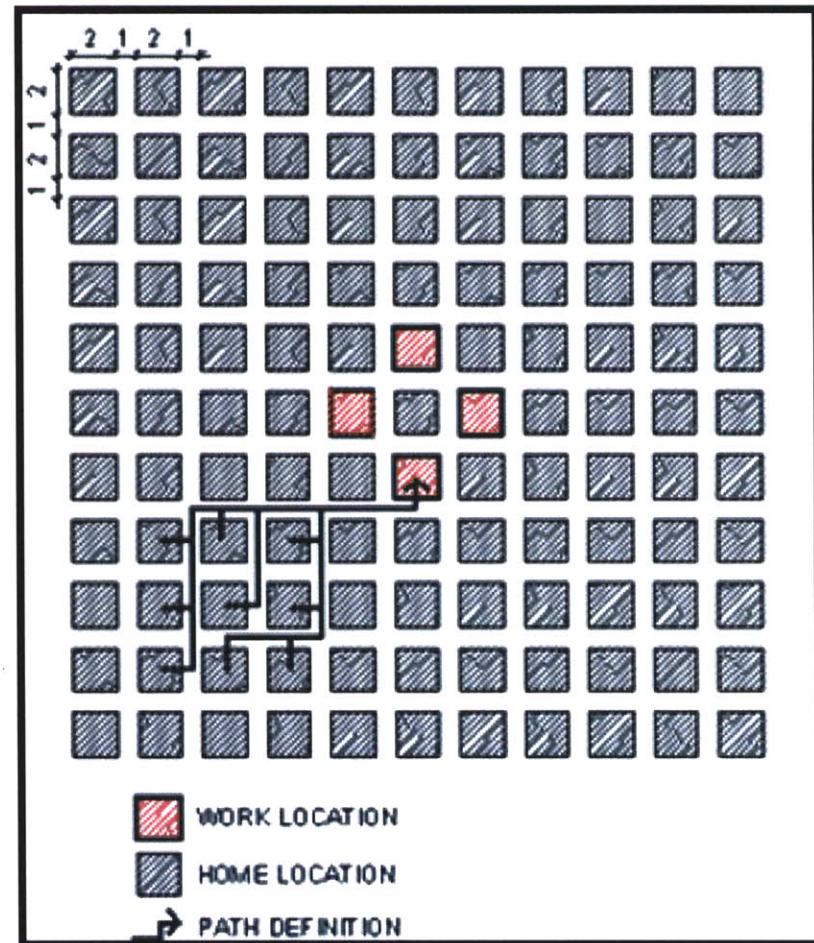


Fig 2.07: Grid - Scenario I: Monocentric city model
Source: Author.

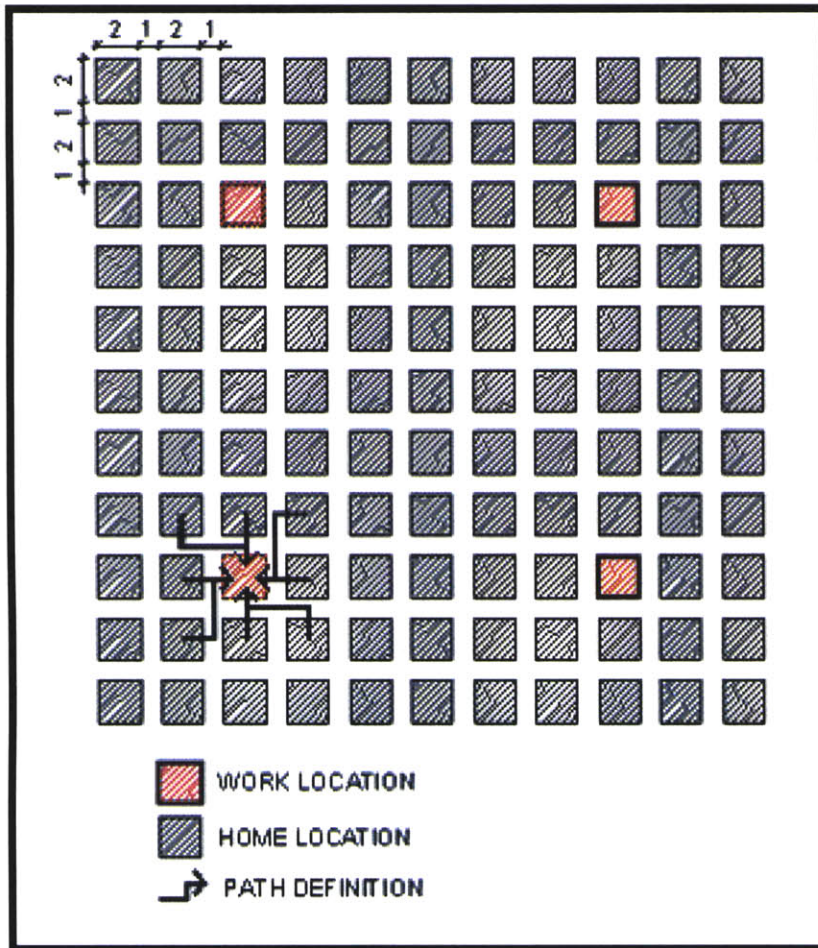


Fig 2.08: Scenario 2: Polycentric 'ideal' model.
Source: Author



Fig 2.09: Scenario 3: Polycentric 'worst case' model
Source: Author

1. Recreating the monocentric city model, four blocks adjoining the central grid are demarcated as work blocks, and all residents work in these central blocks. [Refer fig 2.07]

2. Representing the polycentric city model (or multiple employment centers), four blocks in each of the four corners grids are demarcated as work grids. Everyone is then assumed to work in one of the blocks nearest to his or her assigned home location. This is an ideal case situation for the multi-centric city. [Refer fig 2.08]

3. The third scenario is similar in set up to the second. It differs only in the fact that each resident is assumed to work in a block furthest to their home location. This represents the worst-case scenario for the polycentric city model. [Refer fig 2.09]

A thousand randomly assigned block permutations were then selected in each of the three scenarios. The work trip distances were then computed and results are shown in Table 2.01 and Fig. 2.10

| | Scenario 1 Monocentric Model | Scenario 2 Polycentric Model (Ideal) | Scenario 3 Polycentric Model (worst) | Mean of Case 2 and Case 3 |
|---------------|---------------------------------|---|---|---------------------------|
| Mean | 12.27 | 5.95 | 24.57 | 15.26 |
| Median | 12.28 | 5.95 | 24.58 | 15.26 |
| Maximum | 10.96 | 5.32 | 23.15 | 14.23 |
| Minimum | 13.59 | 6.47 | 25.93 | 16.20 |
| St. Deviation | 0.39 | 0.19 | 0.38 | 0.29 |
| N | 1000.00 | 1000.00 | 1000.00 | 1000.00 |

Table: 2.01 Tabulated results of the Hypothetical Model.

RESULTS OF THE MODEL

- the manner in which blocks are placed on the grids has a significant effect on total commute distances. The standard deviations are substantial, considering the fact that this is a miniature model dealing with a grid of 11 x 11. These will be magnified manifold on a true scale.

- As was expected the 'Ideal' scenario (Case 2) performs the best. Distance commuted is half of case 1 and a quarter of case 3. Which brings to focus the question, how realistic is the notion of self-contained neighborhoods? Or is it a utopian concept?

- For the polycentric models, a realistic situation would be somewhere between case 2 and case 3. Assuming that to be the average of the two, gives us an average of the mean values as 25.26 units. This value is far greater than the monocentric model. In such a stylized situation the monocentric city out-performs. However, such a statement would be fallacious, since the range for the mean of the total commute distance is between 5.95 and 24.57. The randomness of the dispersion of work and home locations in a polycentric city adds a lot of ambiguity to any comparison between the monocentric and polycentric city models.

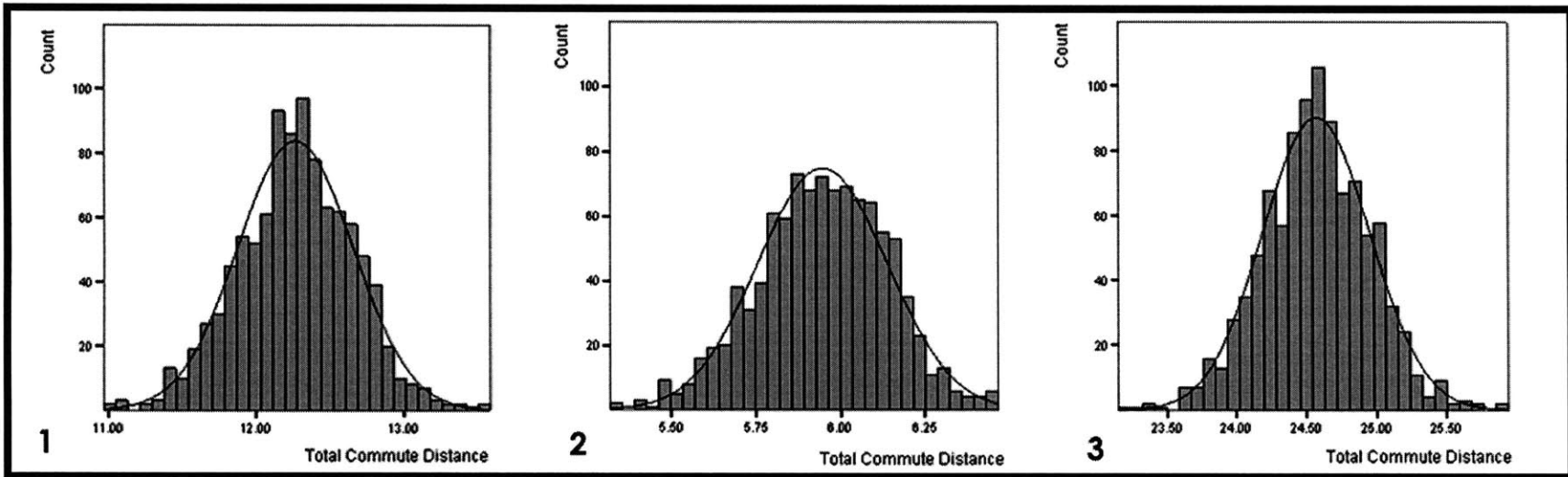


Fig 2.10: Result Hypothetical Model [1. Monocentric Model; 2. Polycentric Model (Ideal situation); 3. Polycentric Model (Worst case situation)]

Source: Author

LIMITATIONS OF THE MODEL

The model represents hypothetical scenarios, hence has obvious limitations due to the many assumptions built into it.

- For starters, it isn't able to account for individual idiosyncrasies or cultural preferences in travel behavior.
- It assumes all trips made will be work trips and that even these shall be one stop - starting from home and culminating at work (and vice versa) with no other destinations in between. Multiple trips and other trips such as "personal" & "family" trips are not taken into consideration.
- Even though I did consider the fact that below a certain threshold distance many of the work trips would be made on foot or bikes. These should be accounted for. However it was

difficult to come up with a figure that could precisely represent this "threshold distance." As mentioned before this threshold distance [Refer Fig. 2.01] could depend on a number of factors such as price of parking and fuel costs.

The model has the potential of becoming more elaborate with some other factors (such as multi-worker households) being introduced to it. However, this would also lead to more assumptions being made, hence diluting the efficacy of the model.

1. Elkin, McLaren and Hillman, "Reviving the City: Towards Sustainable Urban Development."

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1. Elkin, McLaren and Hillman, "Reviving the City: Towards Sustainable Urban Development."
 2. Newman, Peter and Jeffrey Kenworthy (1989) "Cities and Automobile Dependence: An International Sourcebook."
 3. Gordon, P. and Richardson, H.W. (1997) "*Are Compact Cities a Desirable Planning Goal?*" *Journal of the American Planning Association*, 63.
 4. Crane, Randall (1996) "The Influence of Uncertain Job Location on Urban Form and the Journey to Work" *The Journal of Urban Economics*, 39
 5. Brueckner, J.K. (1981) "A Dynamic Model of Housing Production." *Journal of Urban Economics*, 10.
 6. Boarnet, Marlon G. and Crane, Randall (2001) "Travel By Design: The Influence of Urban Form on Travel."
 7. Gomez-Ibanez - *Journal of American Planning Association* 57(3).

3

ANALYSIS - II

URBAN FORM AND TRAVEL BEHAVIOR- II

CHAPTER OUTLINE

- 3.1 AIM OF THE EXERCISE
 - 3.2 THE DATA SET
 - 3.3 LIMITATIONS OF THE EXERCISE
 - 3.4 OVERALL TRENDS
 - 3.5 TRANSPORTATION and DENSITY
 - Correlation Analysis
 - Density vs. Median Travel Time for Work Trips
 - Density vs. Modal Share of Public Transit
 - Density vs. Private Motorized Vehicle Ownership
 - Multivariate Regression Models
 - Public Transit Model Split regressed with City Product per capita, gasoline price, city size and travel time.
 - 3.8 CONCLUSION
-

3.1 AIM OF THE EXERCISE

The primary goal of this exercise is to ascertain whether there exists a correlation between urban density and transportation behavior factors such as 'median travel time (for work trips)', 'percent modal split by public transit, pedestrian and bike modes' and 'private motorized vehicle ownership'. To accomplish these objectives, statistical tools - univariate and multivariate regression, cluster and fractal analysis are undertaken on a global city data set.

3.2 THE DATA SET

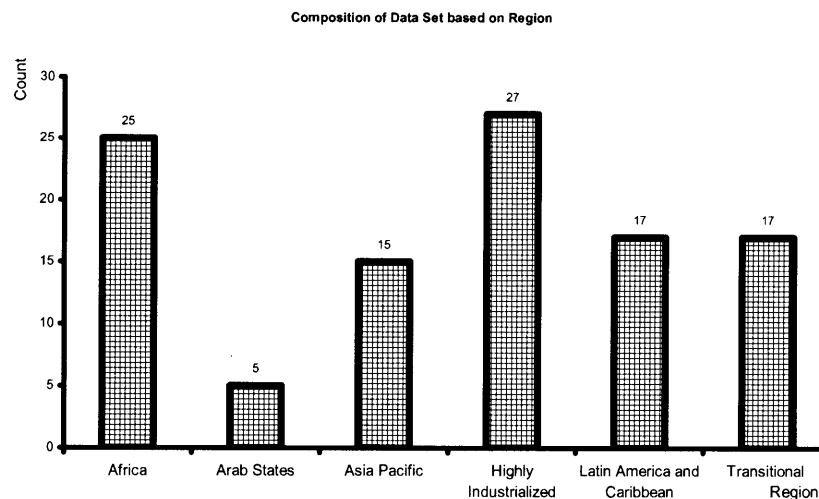
The data set has been drawn primarily from the UN Habitat's GOU (Global Urban Observatory) database, which contains data for more than 200 cities. The data was collected by local and national bodies in each city and represents a time period from 1993 to 1998. Other sources used in compiling the data include, the US Census data, World Bank – World Development Indicators, CEROI (City Environmental Indicators Encyclopedia), London Census Data and Hong Kong Census Data.

The data corresponds to 'urban agglomeration', which is defined by the UN GOU as the "built-up or densely populated area containing the city proper; suburbs, and contiguously settled commuter areas". This is different from the definition of a metropolitan area, which in turn corresponds to the administrative area delineated by the local city governments.

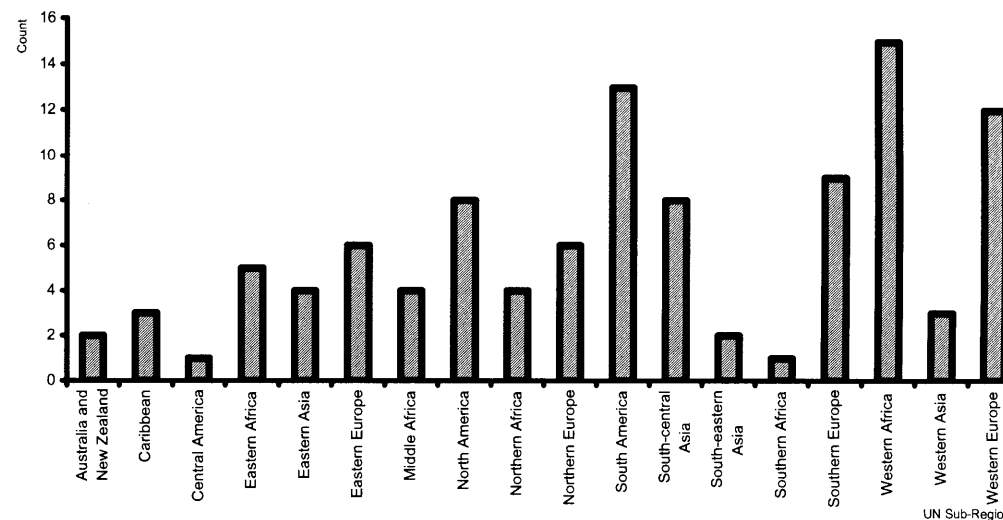
These might contain non-urban areas or as in the case of Indian cities be much smaller than the actual urban agglomeration area. [Refer Fig. 3.04] A single large urban agglomeration may comprise several cities or towns and their suburban fringes.

In the US (other than in New England) the urbanized area is much smaller than the MSA area or the metropolitan area as those are defined by the county areas.

For those indicators, which involve monetary values, these were converted to 1993 US dollars, using IMF exchange rates and conversion factors. Stock data (e.g. unemployment, housing stock) were estimated as the average value during the year, but in some cities this has been taken as the value at the middle of the year. To normalize for



COMPOSITION OF DATA SET BY UN SUB-REGION

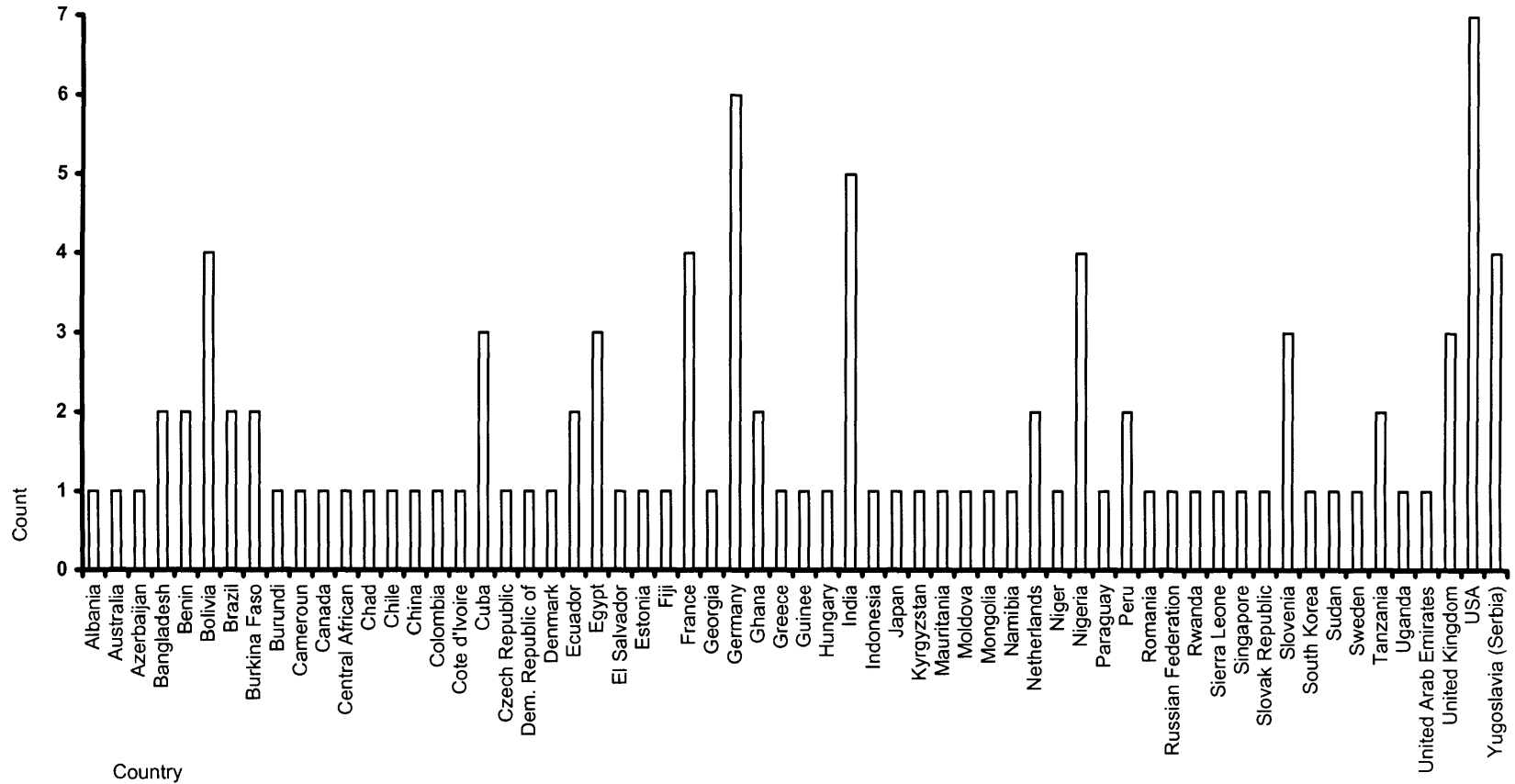


income levels, the data set has been divided into four

Fig. 3.01: Composition of data by UN classified Region

Fig. 3.02: Composition of data by UN classified Sub Regions

COMPOSITION OF DATA SET BASED ON COUNTRY



Source: (both above) Compiled by author.

Fig. 3.03: Composition of the data set by country. Source: Author
 categories (Lower Income, Lower-Middle Income, Upper-Middle Income and Upper Income Level) based on the World Bank definitions. Density analysis has been conducted

independently on each of the four income levels. Since data for only 5 cities in the Upper-Middle income category was available, these were deemed insufficient and hence the results obtained on this sample set has been ignored.

[The list is appended as Appendix - B, C & D]. For details on the data profile refer Figures 1, 2, 3 and 4. It contains an even spread of cities representing the various geographic areas. The density ranges from 6 persons per hectare in Salt Lake City to 603 persons per hectare in Mumbai. There are 26 cities in Africa, 34 from Europe (15 of which are transitional economies), 8 cities from North America, 19 from Asia, 18 from Latin American Countries and 1 from Australia. A look at the city product per capita reveals that of the cities for which data is available, about 60% of the cities are in the range of \$0 to \$5000. While the remaining 40% are in the range between \$5001-\$40,000, with as many as 10% in the top bracket of \$35,000 - \$40,000. (This justifies my decision to normalize for income levels.) It comes as no surprise cities in the US and Western Europe are in the higher income levels while those in Africa and South Asia make up the lower rungs.

3.3 LIMITATIONS OF THE EXERCISE

There have been very few exercises that involve global comparisons amongst cities. One of the main reasons has been the difficulty in obtaining data at the city level. UN Habitat's GOU is one of the few organizations that provides such a data. Due to the involvement of a large number of agencies in undertaking such an exercise, it is difficult to ensure that all criteria have been meticulously followed. A fact acknowledged by the UN, which calls for using rough estimates when secondary sources of data are not available. "A high level of accuracy was not required for this first survey. It was recommended that data be accurate enough for policy purposes. An approximate result is considered better than no result at all, since this provides a benchmark for future, more accurate estimates."¹

A major problem is the lack of consistency in the definition of

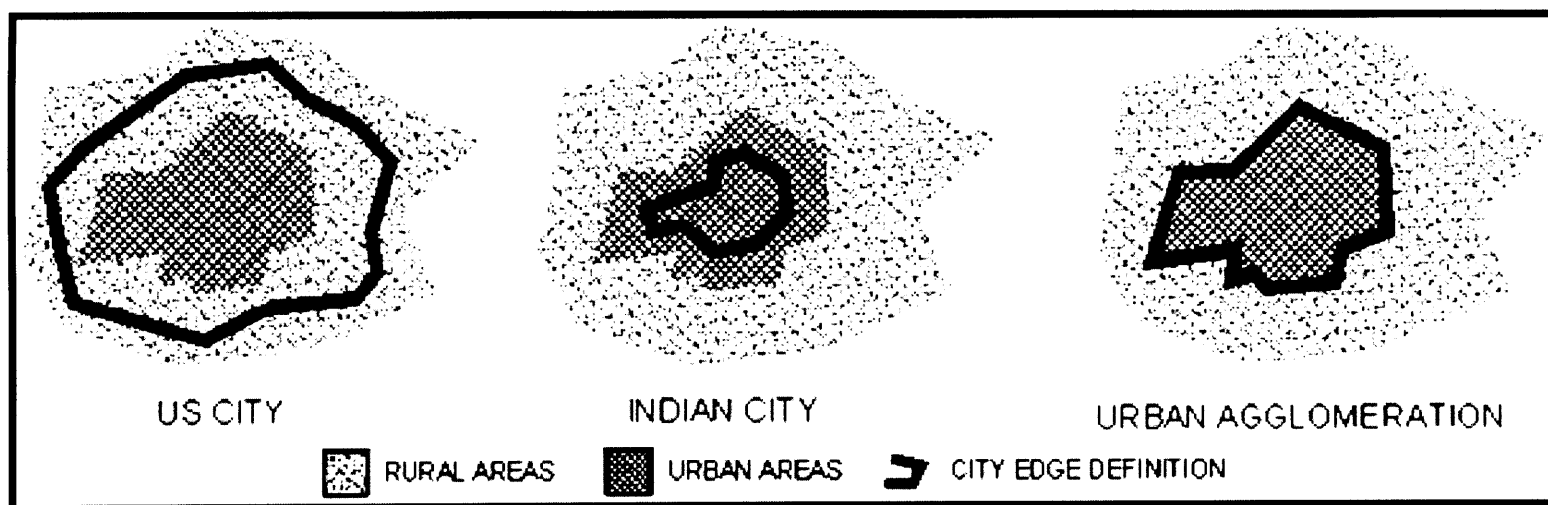


Fig 3.4 Metro(US); Metro (India) and urbanized area
Source: Author

the term “urbanized area” itself. Different parts of the world have different criteria. There is much debate about what should be acknowledged as an urban area. While most census information defines a city as that demarcated by the local government jurisdiction. For example, the US Census, defines an urbanized area as “a densely populated area (built up area) with a population density of more than 1,000 per square mile with a population of more than 50,000”. This is not a globally recognized standard and the criterion varies from country to country.

A more widespread definition popular amongst urbanists and geographers is the concept of contiguous urban space that defines any area with a population density of greater than 500 people per hectare. A process developed by Ulam and modified by White and Engelen (1993), called Cellular Automata, has been used by some researchers to demarcate urban areas. The process involves dividing images into cells of 3 by 3 or 5 by 5. These cells are then colored based on the density gradient to see contiguousness.

Even if one is able to demarcate the contiguous urbanized area, the next problem that arises is of finding data that corresponds to this geographic region.

An oft-mentioned drawback of such a research involving global comparisons is that these do not account for regional or cultural preferences and variations in lifestyle and behavior

patterns. It has been argued that due to the above reason, such exercises have little policy implications. Thus what works in one city may not be applicable in another. It is imperative to point out that the purpose of this particular document is not to compare cities, nor outline policy for any city. The moot idea is to understand the overriding factors that affect travel behavior.

3.4 OVERALL TREND

BASED ON REGIONS OF THE WORLD: Urban Densities are highest in Asia; high in Europe, North Africa and the Middle East; low in Latin America and sub-Saharan Africa; and lowest in North America and Australia. However within each region there is considerable variation. Hence the notion that cultural acceptance of density levels can solely explain this variation is found to be untrue. Besides acceptable levels of space consumption and proximity has changed historically in all cultures.

BASED ON WORLD BANK INCOME CLASSIFICATIONS: The World Bank divides nations into 4 categories namely - Lower, Lower Middle, Upper Middle and Upper Income level. In general, urban densities are high in nations falling under the lower and Lower-Middle income levels. They are low in the Upper Income group, with a number of cities such as Hong Kong, Tokyo, New York and Seoul being the exception to the norm.

There appears to be an overlap in the two categories mentioned. Cities in the Lower income group are mostly located in Asia and Africa; those in Lower-Middle group are found in Latin America and North Africa and those in the Upper income group are located in North America, Australia and Europe. Which brings me to question whether income overrides cultural preference to density levels.

3.5 TRANSPORTATION and DENSITY

(A) Density vs. Median Travel Time for a Work Trip

[Refer Appendix B for the Data Set Used]

Travel time is one of the key performance measurements of a transportation system. A long transport time to work is an obvious sign of urban dysfunction, associated with severe traffic congestion, uncontrolled mixes of traffic types, poorly operating public transport networks, lack of adequate local traffic management, accidents and general dissatisfaction of the commuter population. It is closely related to transport density.

“Median travel time to work is defined as the average time in minutes for a one-way work trip; this is an average of all modes of transport. Train and bus times should include average walking and waiting times. Car times should include parking or walking to the workplace.”²

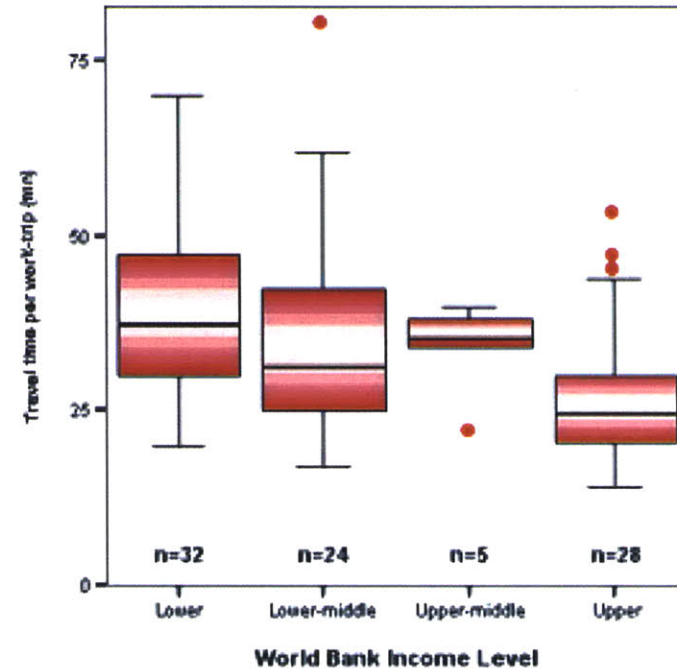


Figure 3.07: Boxplot showing Median Travel Times to work in cities classified by the World Bank Income Levels. There appears a trend of median travel times decreasing as we move from Lower to Upper Income level. However the presence of outliers and substantial overlaps make it difficult to draw such a conclusion.

Source: Author

Here we test the argument that increased density would reduce median travel time to work as it would induce work and home to be closely located. This is done by seeing whether there is any association between an increase in density causing a decrease in travel time.

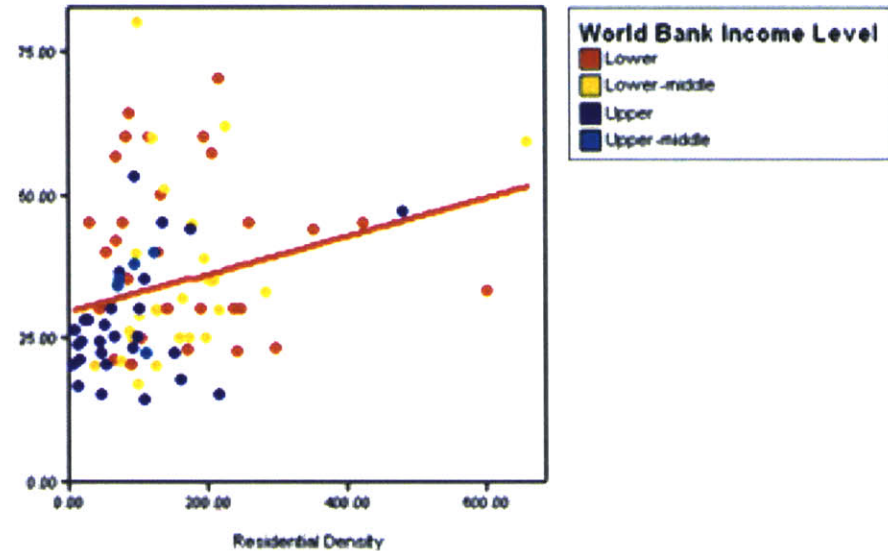
The scatter plot and the results of the regression analysis [Table 3.yy], reveal that while the correlation between urban density and median travel time for a work trip is weak ($r^2 = 0.064$), it still is statistically significant. In other words only 6.4% of the change in median travel time can be attributed to the change in urban density. Density in itself only marginally accounts for differences in median travel time.

In an attempt to normalize for income levels, I have performed OLS regressions on three sample sets representing cities in Lower, Lower Middle and Upper Income groups. These results too corroborate with the earlier test. Income does not appear to significantly change median travel times.

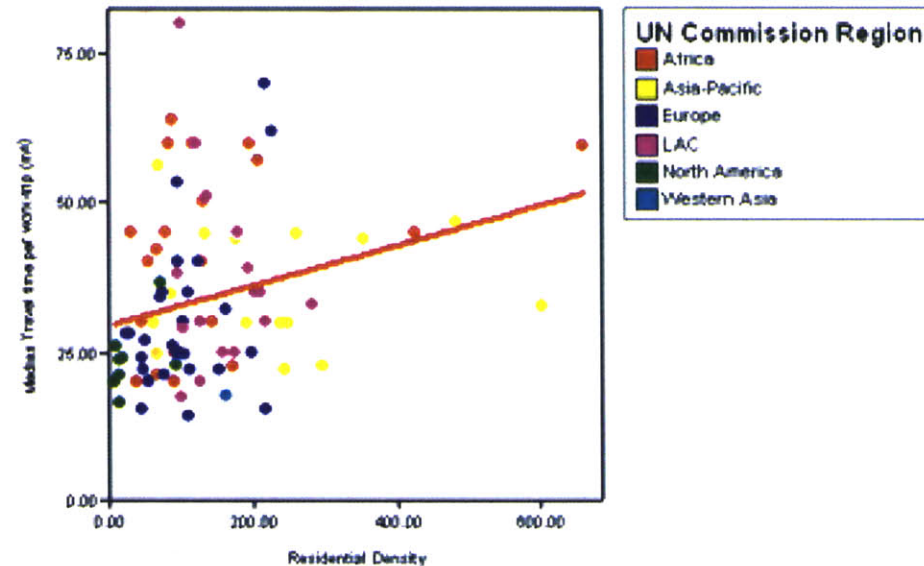
Plate 3.08 (above right): Scatter plot, with residential density on the x axis and median travel time to work on the y axis. The cities are color coded based on the World Bank Income Level. Median travel time appears to be dispersed and shows no pattern based on income levels.

Plate 3.09 (bottom right): Scatter plot, with residential density plotted against median travel time to work. The cities are color coded based on their location (UN Commission Region). As in the plate above, median travel time appears to be dispersed and shows little or no pattern based on regional location.

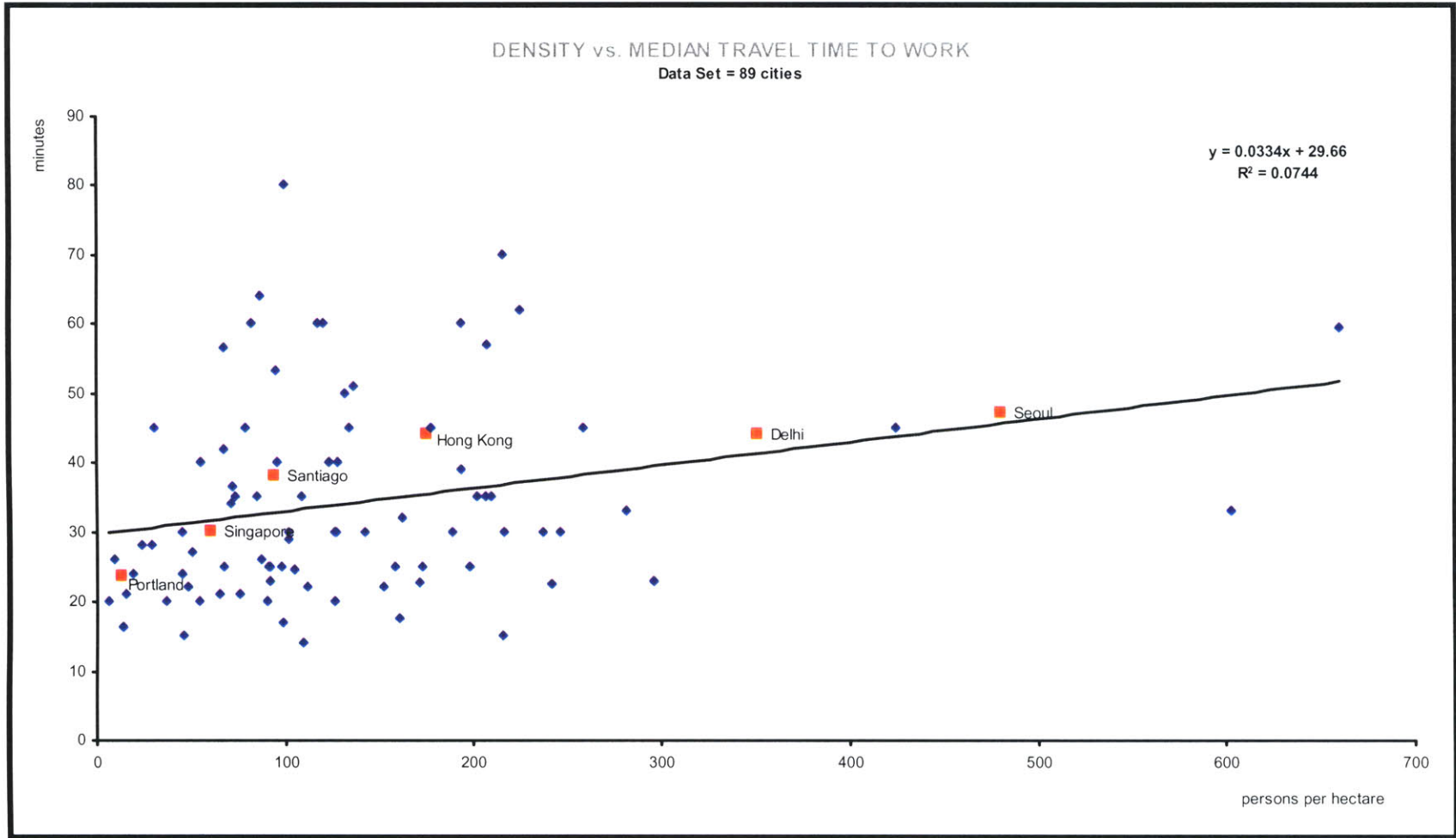
Source: Compiled by the Author (both)



Linear Regression
 Travel time per work-trip (min) = 29.66 + 0.03 * resident
 R-Square = 0.07



Linear Regression
 Travel time per work-trip (min) = 29.66 + 0.03 * resident
 R-Square = 0.07

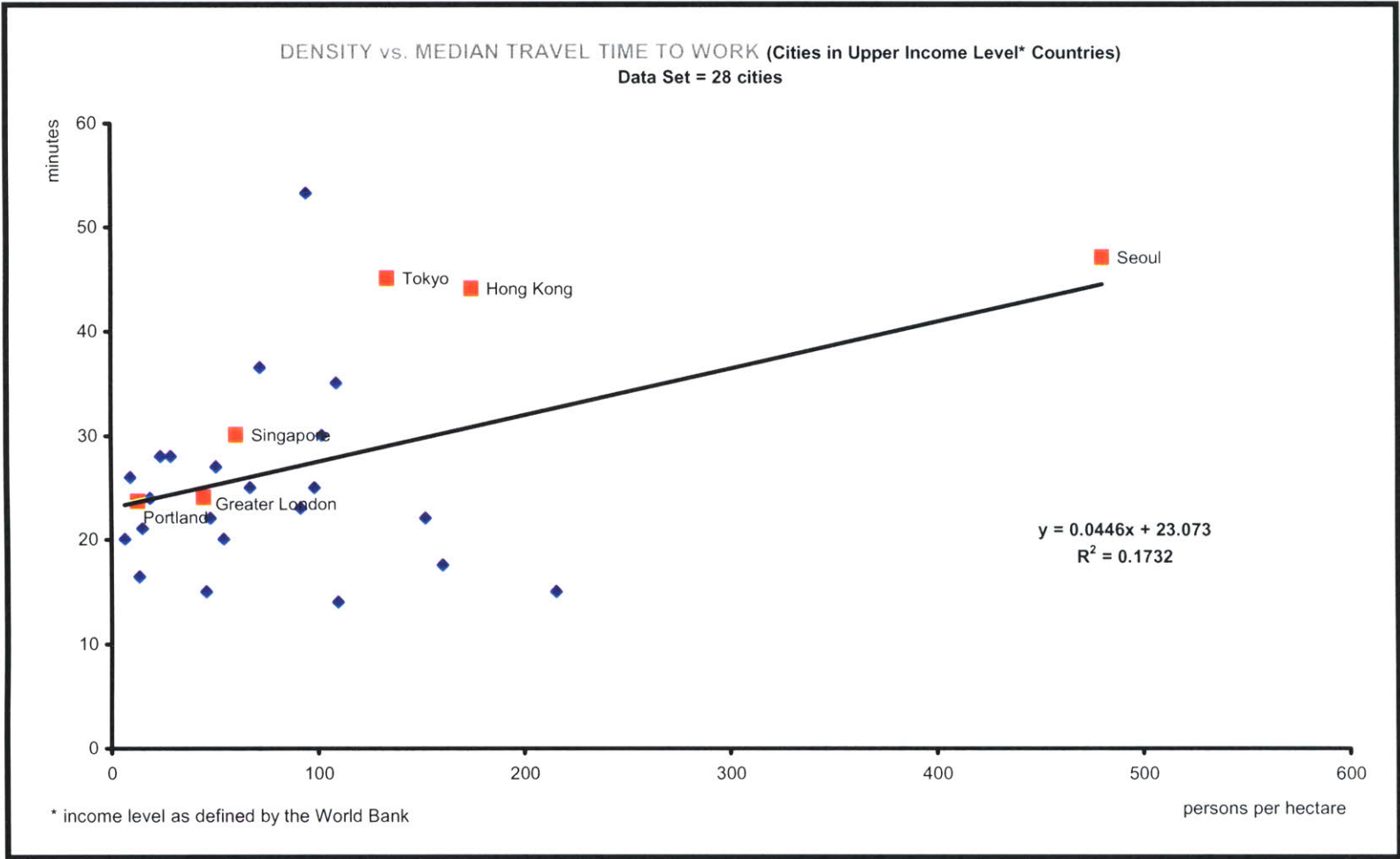


| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|---------|----------|-------------------|----------------------------|
| 1 | .273(a) | 0.074 | 0.064 | 13.67127 |

a Predictors: (Constant), Residential Density

Fig:3.10: Scatterplot and linear regression between residential density and median travel time for work trips (All Income Level)

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|-------|---------------------|-----------------------------|------------|---------------------------|--------|-------|
| | | B | Std. Error | Beta | | |
| | (Constant) | 29.66 | 2.287 | | 12.972 | 0.000 |
| | Residential Density | 0.033 | 0.013 | 0.273 | 2.644 | 0.010 |

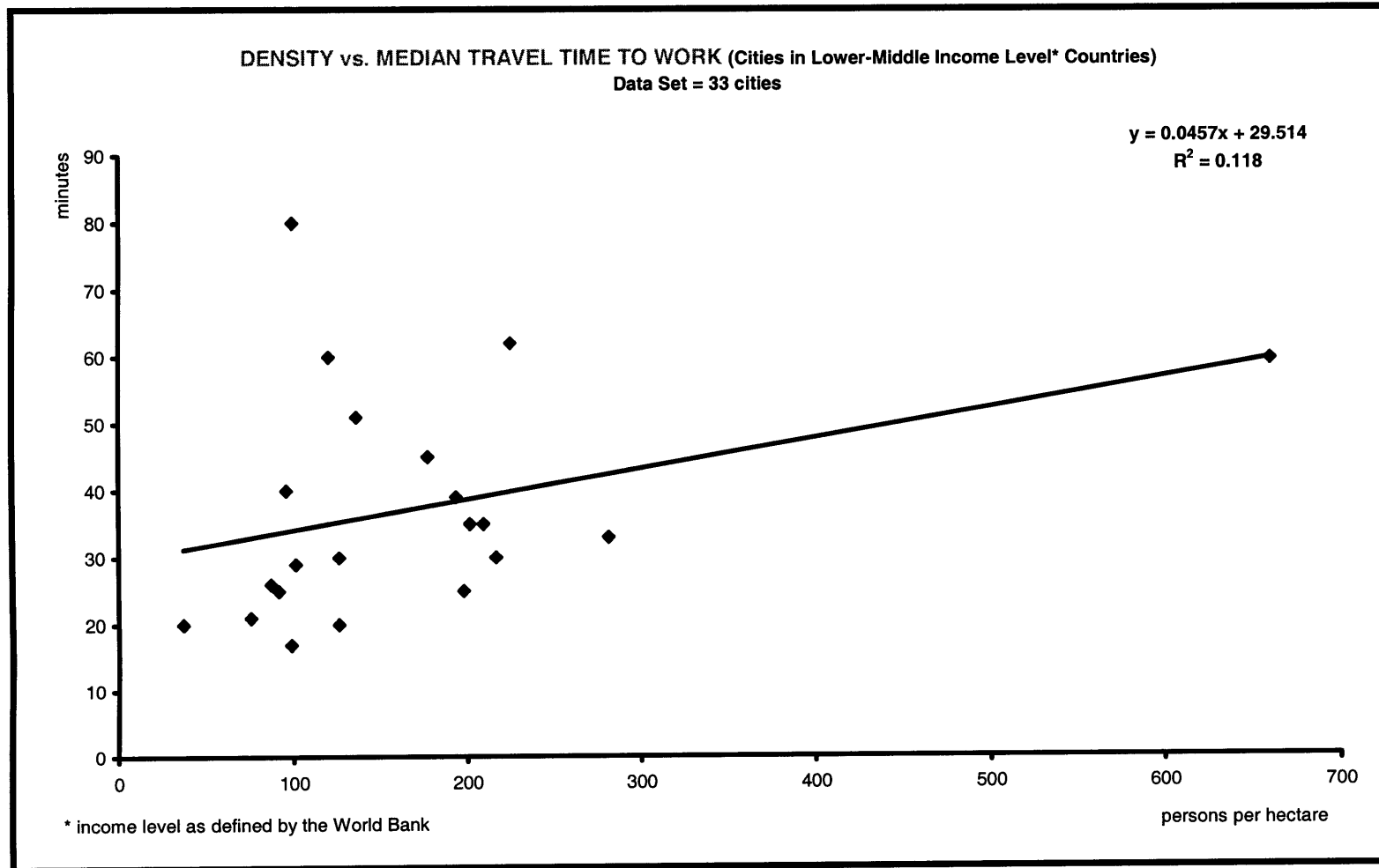


| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|---------|----------|-------------------|----------------------------|
| 1 | .416(a) | 0.173 | 0.141 | 9.39276 |

a Predictors: (Constant), Residential Density

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|-------|---------------------|-----------------------------|------------|---------------------------|-------|-------|
| | | B | Std. Error | Beta | | |
| | (Constant) | 23.07 | 2.459 | | 9.383 | 0.000 |
| | Residential Density | 0.045 | 0.019 | 0.416 | 2.334 | 0.028 |

Fig. 3.11: Scatter plot and linear regression between residential density and median travel time for work trips (Upper Income Lvl.)

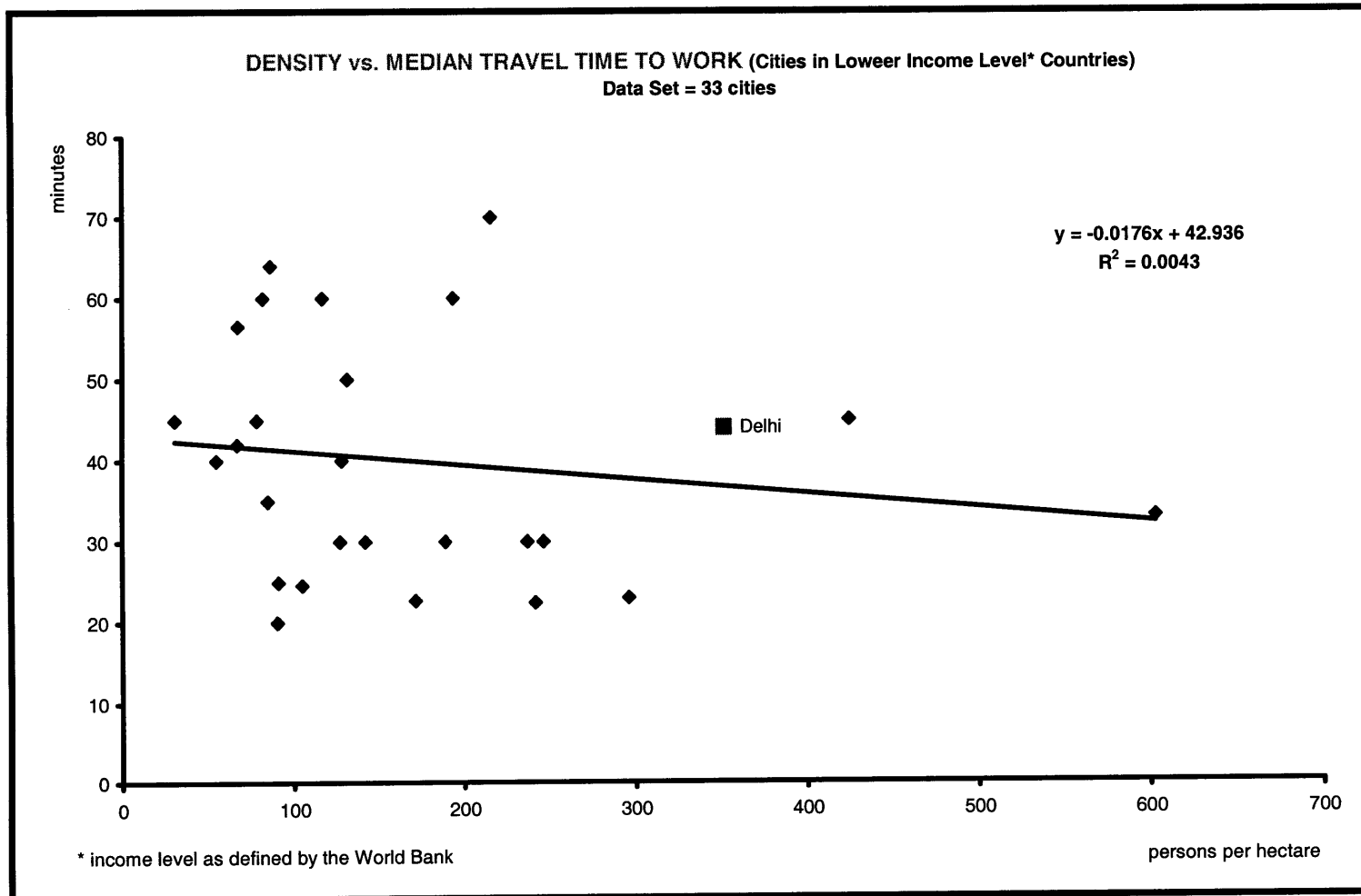


| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|---------|----------|-------------------|----------------------------|
| 1 | .344(a) | 0.118 | 0.078 | 15.37991 |

a Predictors: (Constant), Residential Density

Fig. 3.12: Scatterplot and linear regression between residential density and median travel time for work trips (Lower Middle Income Level.)

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|-------|---------------------|-----------------------------|------------|---------------------------|-------|-------|
| | | B | Std. Error | Beta | | |
| | (Constant) | 28.25 | 5.510 | | 5.126 | 0.000 |
| | Residential Density | 0.046 | 0.027 | 0.344 | 1.717 | 0.100 |



| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|---------|----------|-------------------|----------------------------|
| 1 | .063(a) | 0.004 | -0.029 | 14.42838 |

a Predictors: (Constant), Residential Density

Fig. 3.12: Scatterplot and linear regression between residential density and median travel time for work trips (Upper-Middle Income Lvl.)

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|-------|---------------------|-----------------------------|------------|---------------------------|-------|-------|
| | | B | Std. Error | Beta | | |
| | (Constant) | 40.79 | 4.405 | | 9.260 | 0.000 |
| | Residential Density | -0.007 | 0.021 | -0.063 | -.348 | 0.730 |

3.5 TRANSPORTATION and DENSITY

(B) Density vs. Modal Share of Public Transit

[Refer Appendix C for the Data Set Used]

Different transport modes place pressures on the environment. However, Public transport saves valuable space and energy compared to private transport. Transport congestion is associated with air pollution, accidents, reduced productivity, and general frustration for the population.

Transport modes are measured as a proportion of trips undertaken by private cars, train or tram, bus or minibus, motorcycle, bicycle, walking or others. Public Transit Mode here is used to describe the total percentage of modal share of bus, train, bicycle and pedestrian modes of commute.

The following series of tests are done to verify the hypothesis that an increase in urban density induces greater usage of public transit. This has been assumed to be true because (i) greater concentration making public transit more competitive and efficient as more people can be served using shorter transit lines and (ii) shorter work-home distances converting many auto trips into walk trips.

The correlation and regression results are similar to the test conducted in the previous section. There is a small positive correlation (adjusted $r^2 = 0.163$) between residential density and public transit modal share and this is statistically significant.

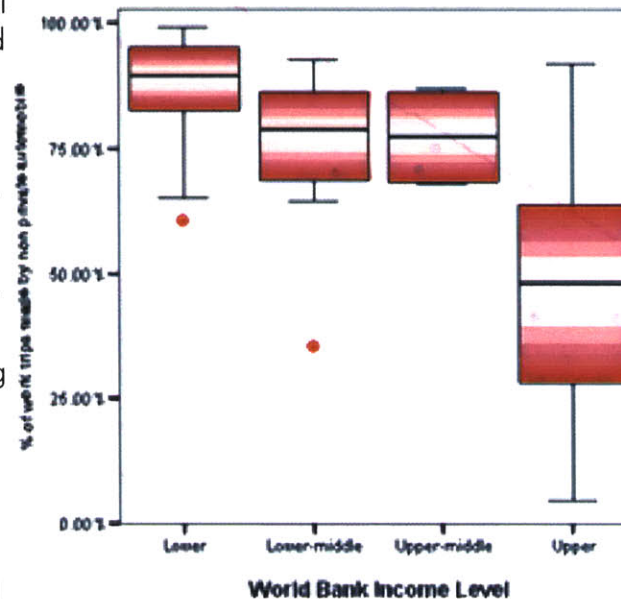
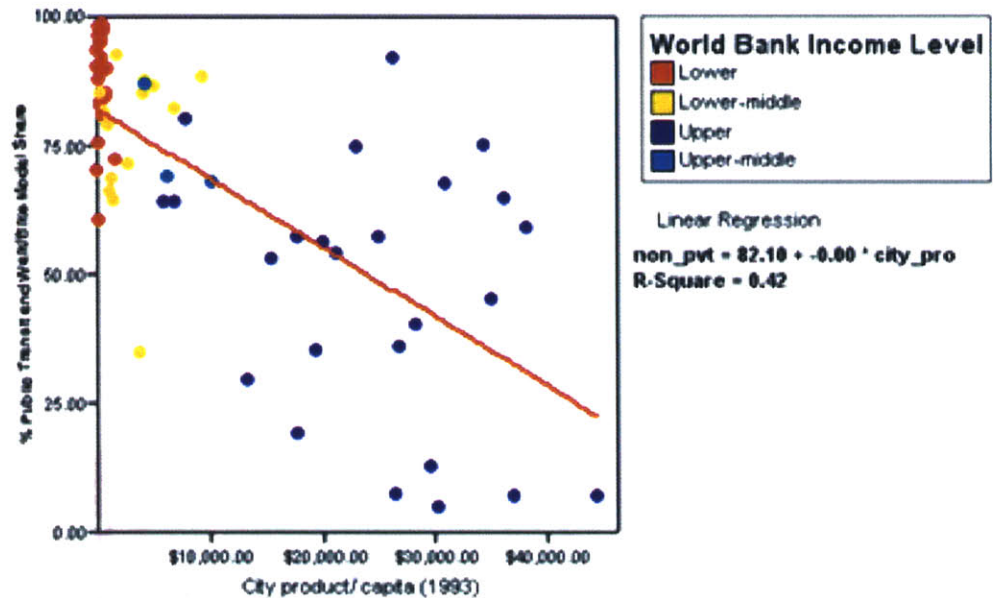


Fig 3.14 (above): Scatterplot of Public transit mode percentage to city product per capita. Color code for income level provided.

Fig 3.15 (below): Boxplot of percentage public transit modes accounting for income level categorization. Mean level of public transit appears to decrease from lower to upper income levels. The wide range displayed by the upper income group, precludes the confirmation of any such trend.

Further tests which normalizing for Income levels reveal a similar result. However density in cities in the upper income classification reveal a slightly greater positive correlation ($r^2=0.2479$). Indicating perhaps that density plays a greater role in explaining usage of public transit in higher income cities.

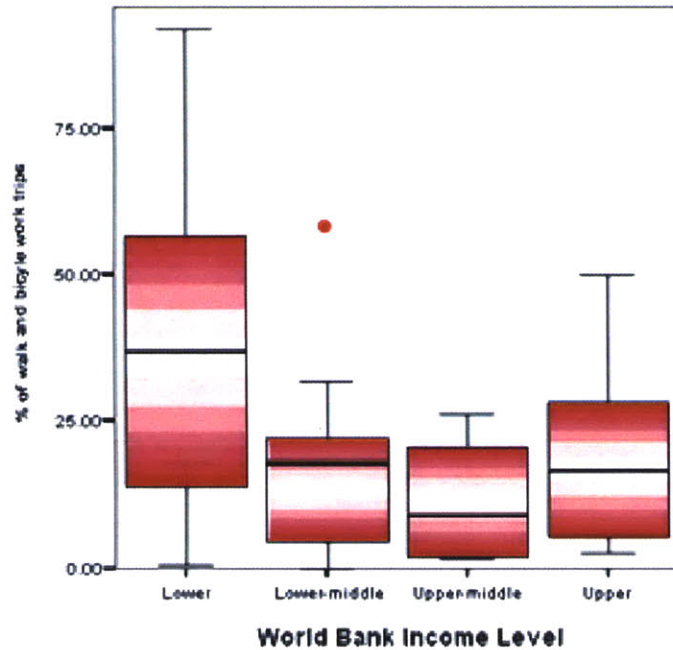


Plate 3.16: Boxplot showing pedestrian work trip percentage in different Income Level cities. Walking is a preferred mode of transit in lower income groups.

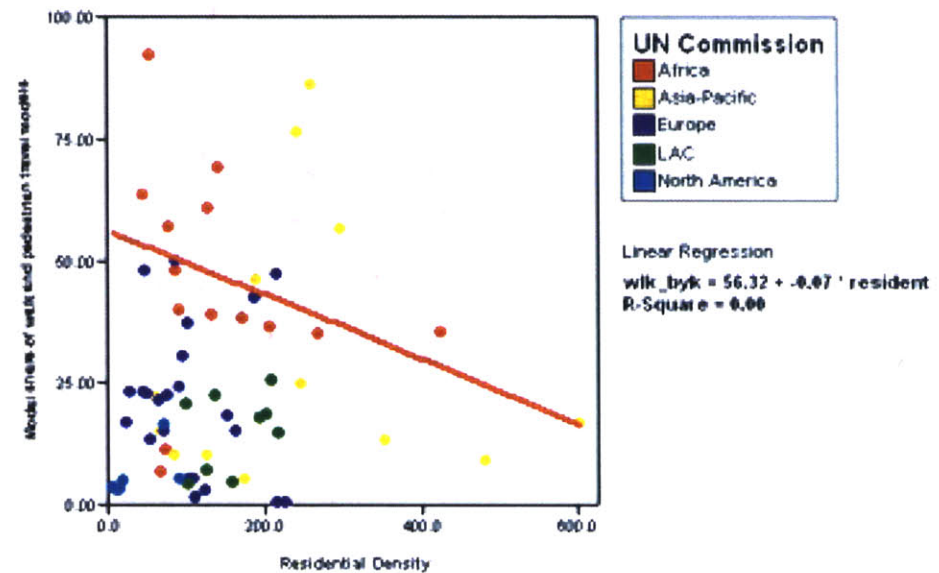
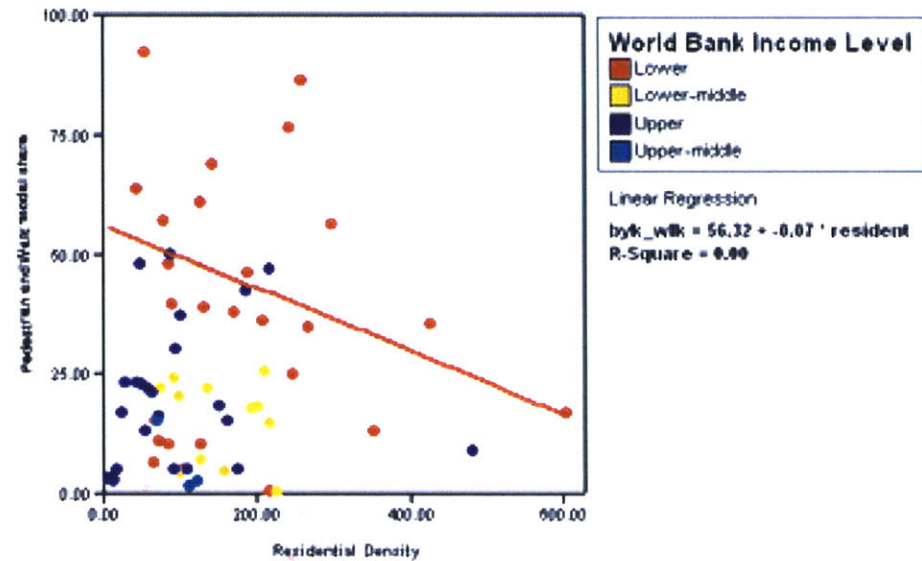
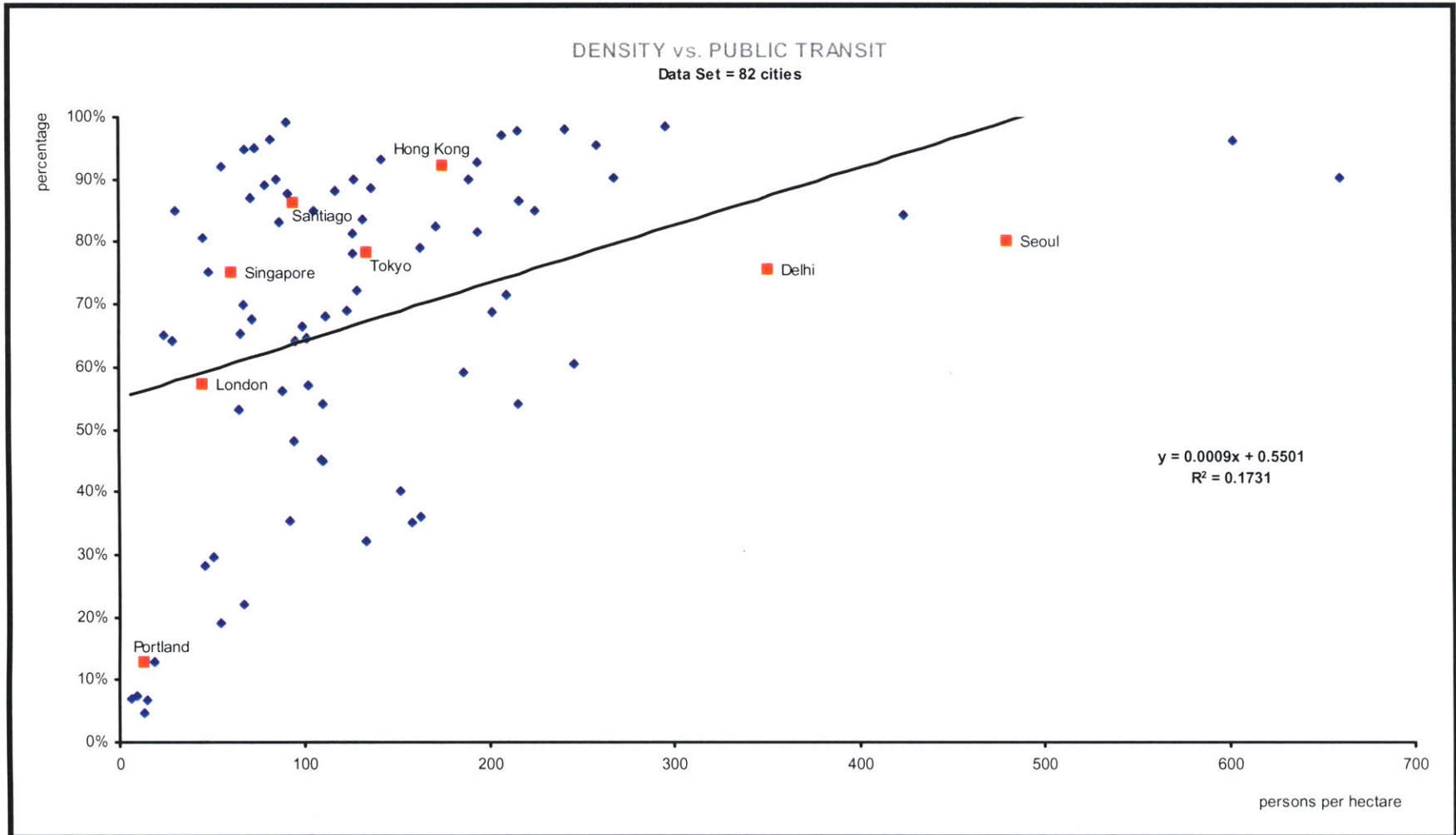


Plate 3.17: (above) Scatterplot of pedestrian mode of work trip vs. urban density with income level classification.

Plate 3.18 (below) Walk trip against residential density. Color code based on regions. More people in African cities walk to work than elsewhere.

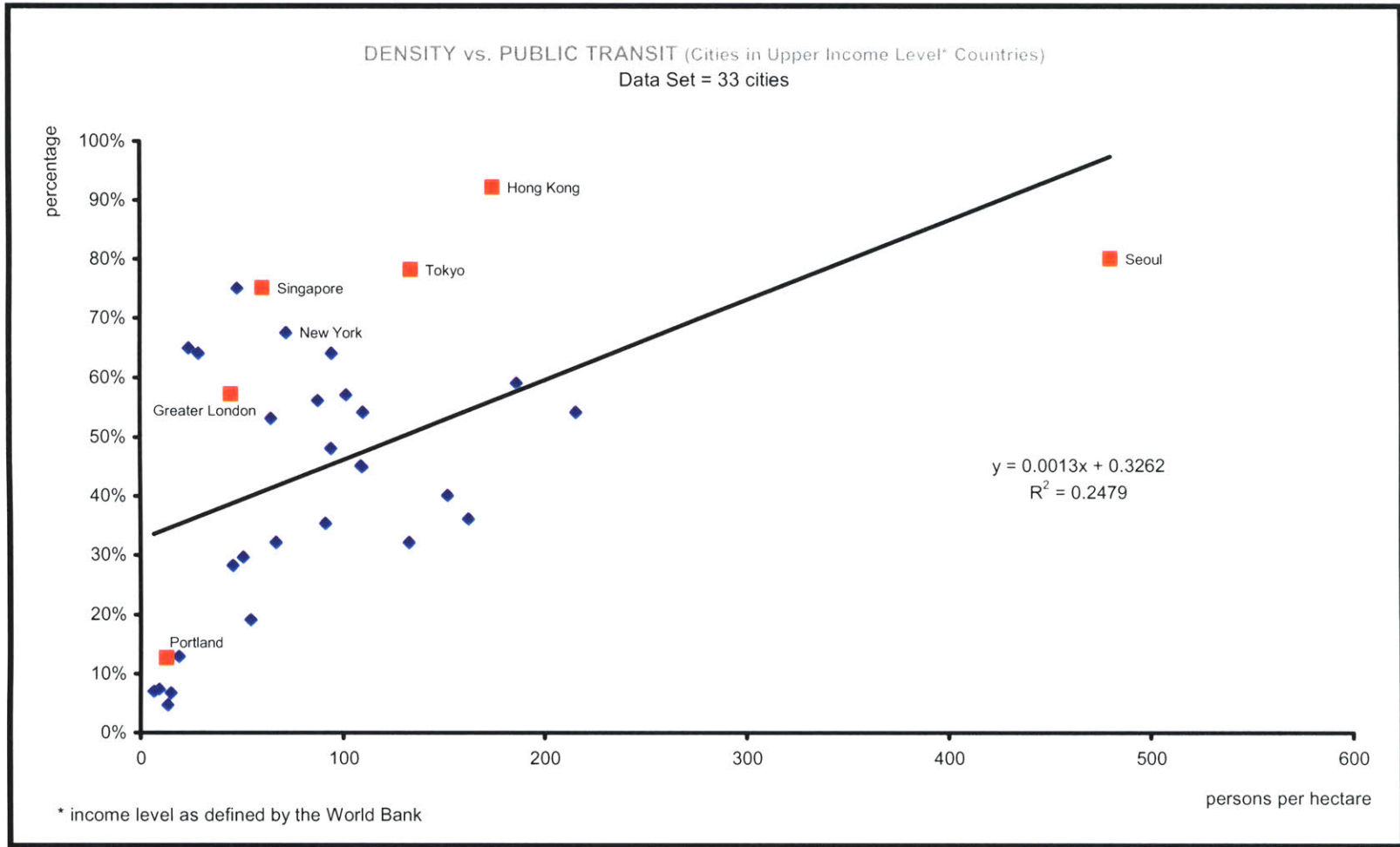


| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|---------|----------|-------------------|----------------------------|
| 1 | .416(a) | 0.173 | 0.163 | 23.97282 |

a Predictors: (Constant), Residential Density

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|-------|---------------------|-----------------------------|------------|---------------------------|--------|-------|
| | | B | Std. Error | Beta | | |
| | (Constant) | 55.01 | 4.103 | | 13.409 | 0.000 |
| | Residential Density | 0.092 | 0.022 | 0.416 | 4.092 | 0.000 |

Fig:3.19: Scatterplot and linear regression between residential density and public transit mode for work trips (All Income Level).

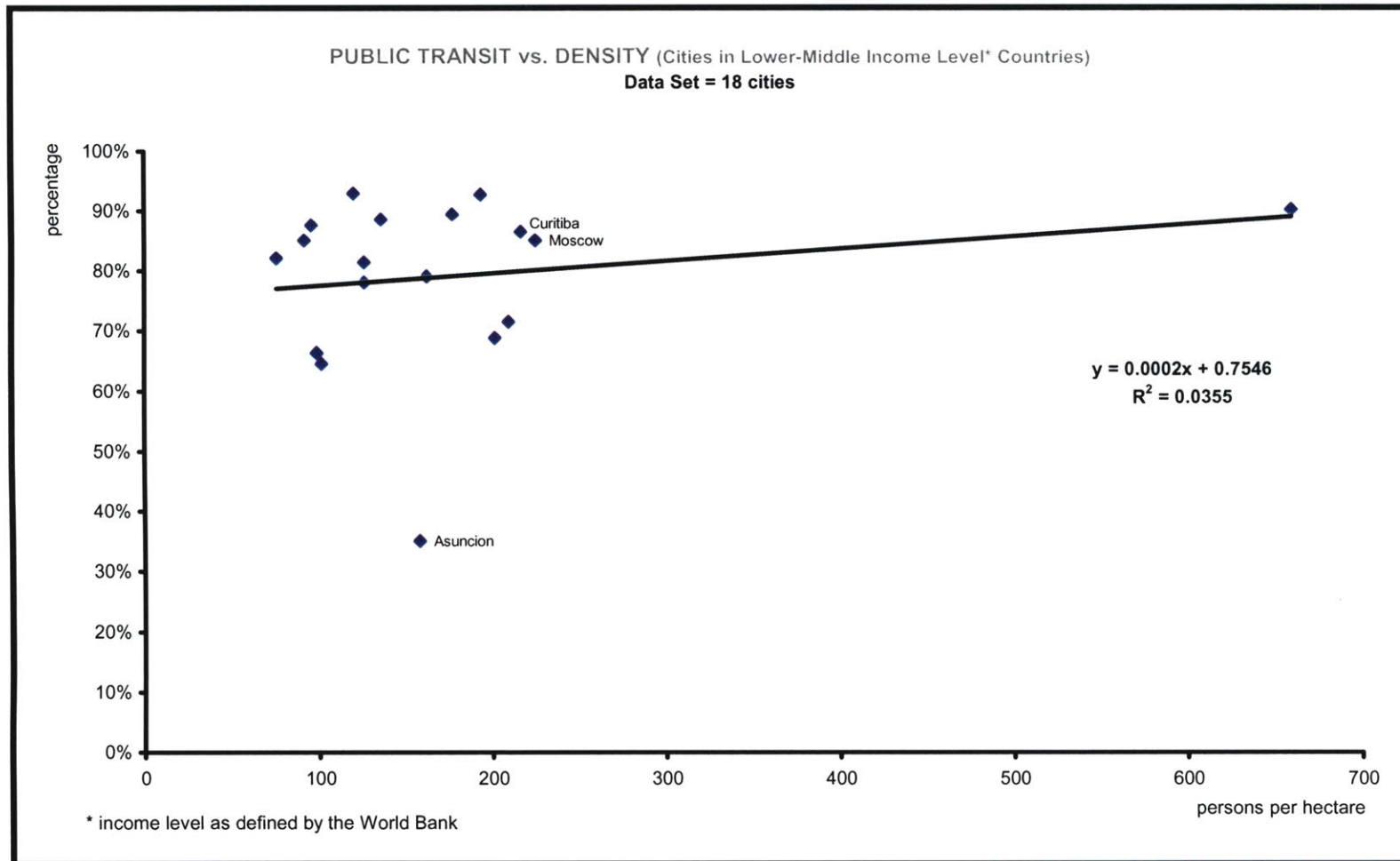


| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|---------|----------|-------------------|----------------------------|
| 1 | .497(a) | 0.247 | 0.223 | 21.44966 |

a Predictors: (Constant), Residential Density

Fig. 3.20: Scatterplot and linear regression between residential density and median travel time for work trips (Upper Income Lvl.)

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|-------|---------------------|-----------------------------|------------|---------------------------|-------|-------|
| | | B | Std. Error | Beta | | |
| | (Constant) | 32.23 | 5.446 | | 5.917 | 0.000 |
| | Residential Density | 0.136 | 0.043 | 0.497 | 3.188 | 0.003 |

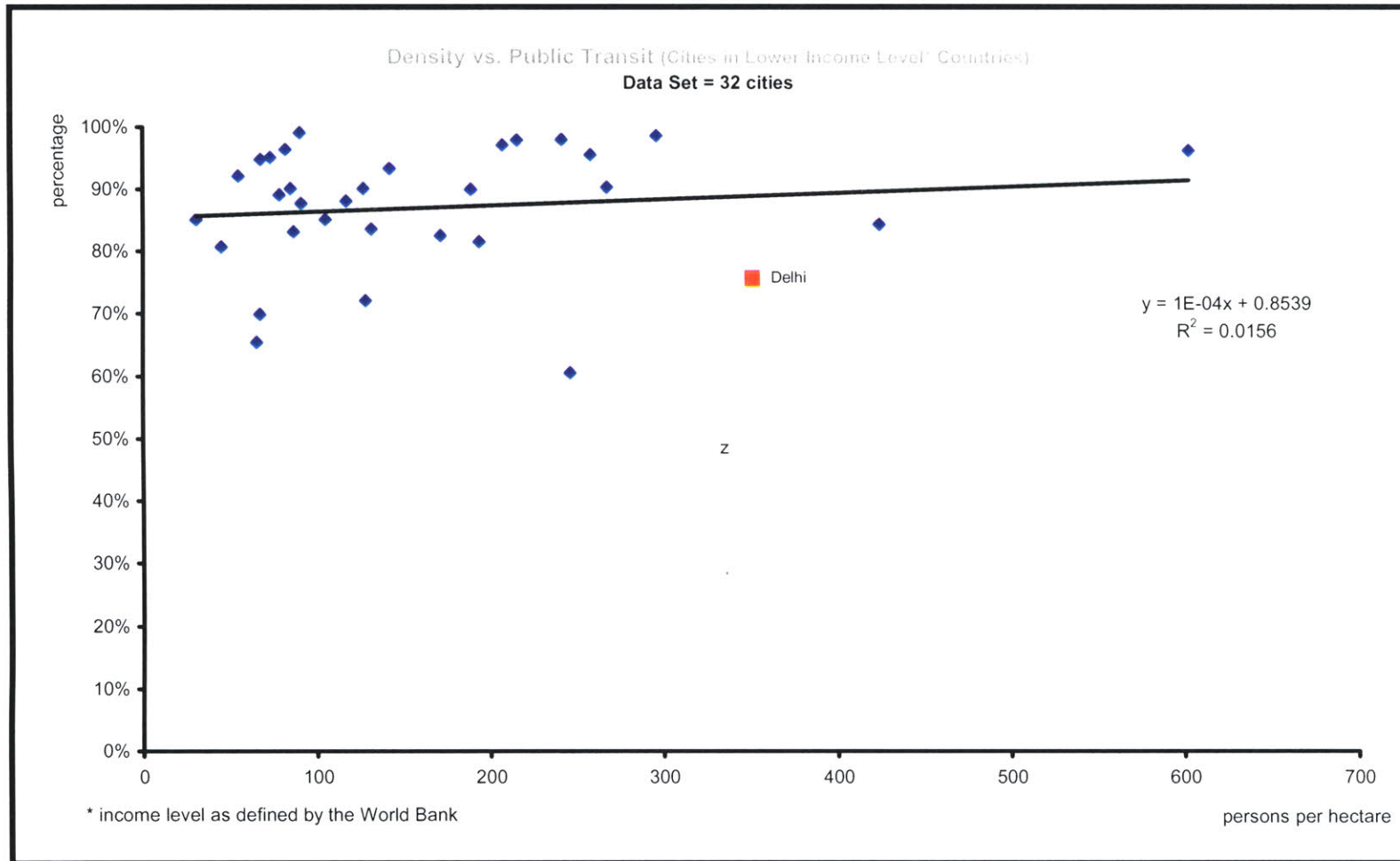


| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|---------|----------|-------------------|----------------------------|
| 1 | .341(a) | 0.117 | 0.036 | 15.10911 |

a Predictors: (Constant), Residential Density

Fig. 3.21: Scatterplot and linear regression between residential density and median travel time for work trips (Lower Middle Income Lvl.)

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|-------|---------------------|-----------------------------|------------|---------------------------|-------|-------|
| | | B | Std. Error | Beta | | |
| | (Constant) | 68.59 | 7.379 | | 9.296 | 0.000 |
| | Residential Density | 0.036 | 0.030 | 0.341 | 1.205 | 0.254 |



| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|---------|----------|-------------------|----------------------------|
| 1 | .341(a) | 0.117 | 0.036 | 15.10911 |

a Predictors: (Constant), Residential Density

Fig. 3.22: Scatterplot and linear regression between residential density and median travel time for work trips (Lower Income Lvl.)

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|-------|---------------------|-----------------------------|------------|---------------------------|-------|-------|
| | | B | Std. Error | Beta | | |
| | (Constant) | 68.59 | 7.379 | | 9.296 | 0.000 |
| | Residential Density | 0.036 | 0.030 | 0.341 | 1.205 | 0.254 |

3.5 TRANSPORTATION and DENSITY

(C) Density vs. Private Auto Ownership
[Refer Appendix C for the Data Set Used]

Private auto ownership is referred to as number of private automobiles owned per 1000 population.

Statistical tests conducted to test the correlation between private ownership and density reveals that only a slight negative correlation exists between the two. This result is statistically significant and cannot be rejected as coincidence. The result is predictable, as one would assume income levels would affect car ownership rates. Fig. 3.26 Box plot indicates that this is more likely. Cities that buck this trend are Singapore, Hong Kong and New York. These cities have low car ownership rates even though they fall into the higher income bracket. One could argue that the existence of an extensive public transit network can explain this phenomenon.

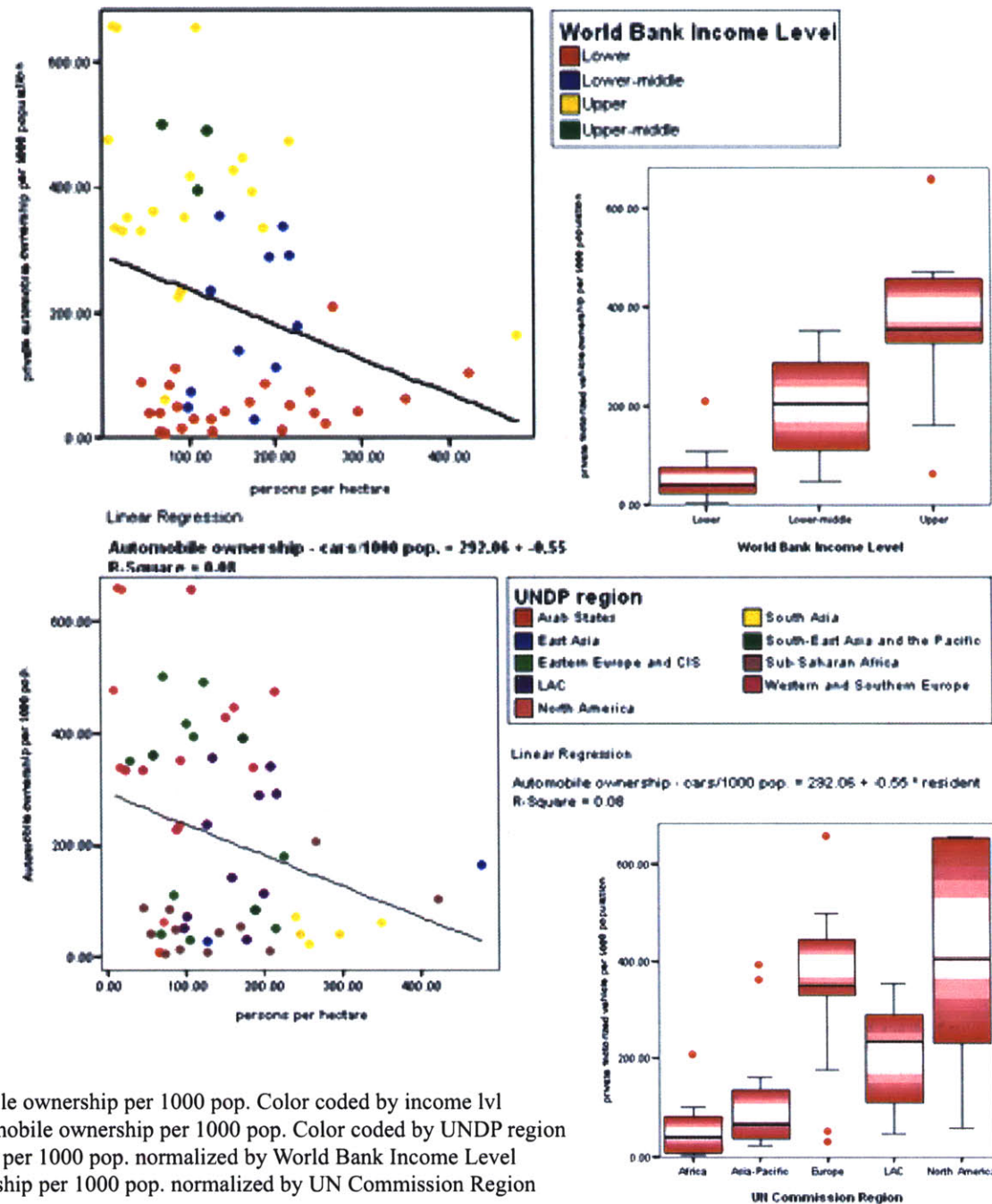


Fig. 3.23 (left top): Scatterplot: Density vs. Automobile ownership per 1000 pop. Color coded by income lvl
 Fig. 3.24 (left bottom): Scatterplot: Density vs. Automobile ownership per 1000 pop. Color coded by UNDP region
 Fig. 3.25 (right top): Boxplot: Automobile ownership per 1000 pop. normalized by World Bank Income Level
 Fig. 3.26 (right bottom): Boxplot: Automobile ownership per 1000 pop. normalized by UN Commission Region

3.5 TRANSPORT AND DENSITY

(D) Multivariate Regression Models

[Refer Appendix D to see the dataset]

Dependent Variable

% Modal Split – Walk + Public transit

Independent Variable

Density

Pump Price of Super Gasoline

City Product per capita

Total Urbanized Area

Median Travel Time for Work Trips

INDEPENDENT VARIABLES

Residential Density (units = persons per hectare): According to the tenets of the Compact City Policy, increased density should induce greater number of walk trips (replacing auto trips) and more people would use bus and rail, which better serve dense areas.

City Product per capita - normalized based on Purchasing Power Parity (unit = 1998 US \$ per capita): Growth in income induces greater usage of private automobiles.

A city product is essentially the gross national product (GNP) of a city, an estimate of economic output. The city product is the total product of a city as defined in national accounts procedures (USD\$). This may be interpreted as either total income or value-added (wages plus business surpluses plus taxes plus imports), or total final demand (consumption plus investment plus exports). 2

Pump Price of Super Gasoline - normalized based on Purchasing Power Parity (unit = 1998 US \$ per gallon): High price of gasoline should add as a deterrent to the usage of automobiles.

Total Urbanized Area (unit = square kilometers): The 19xx Ecotec report mentions that city size is positively correlated to usage of public transit.

Median Travel Time for Work Trips (units = minutes): Transport planners and urbanists argue that beyond a certain distance, people prefer using public transit.

Automobile Ownership: For obvious reasons greater the automobile ownership less the percentage of public transit modal splits. One can argue that auto ownership is related to city product per capita. We use the first step to see whether we can eliminate this, based on the evidence of a high correlation between automobile ownership and city product per capita. This appears to be the case, thus we preclude automobile ownership rates from the multivariate model.

Dependent Variable = % Modal Split of Public transit (Walk+Bicycle+Bus+Train)

Independent Variable = Residential Density, Pump Price of Super Gasoline, Automobile Ownership, Total Urbanized Area and Median Travel Time for Work Trips

Independent Correlations

| Variable | | Residential Density | Pump Price of Super Gasoline (normalized by PPP) | City product per capita (normalized by PPP) | Total Urbanized Area (hectares) | Median Travel Time for Work Trips |
|---|-------------------|---------------------|--|---|---------------------------------|-----------------------------------|
| % Modal Split – (Pedestrian + Bicycle + Public Transit) | Adjusted R square | 0.081 | 0.35 | 0.322 | 0.069 | 0.177 |
| | T statistic | 2.110 | -4.688 | -4.149 | 1.975 | 3.066 |
| | Significance | 0.042 | 0.000 | 0.000 | 0.056 | 0.004 |
| | N | 40 | 40 | 40 | 40 | 40 |

Table 1: Shows individual correlations between % Modal split of Pedestrian + Bicycle + Public Transit work trips with the individual variables.

Model Summary

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|---------|----------|-------------------|----------------------------|
| 1 | .756(a) | .572 | .509 | 19.81192 |

a Predictors: (Constant), Travel time per work-trip (min), Total Urbanized Areas (km2), Pump Price for super gasoline (US \$ per liter - 1998) - PPP, Residential Density, City Product / capita (PPP)

Coefficients(a)

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|-------|--|-----------------------------|------------|---------------------------|--------|------|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | 32.845 | 13.944 | | 2.356 | .024 |
| | Residential Density | -.007 | .038 | -.023 | -.179 | .859 |
| | Pump Price for super gasoline (US \$ per liter - 1998) - PPP | 15.281 | 4.097 | .460 | 3.730 | .001 |
| | City Product / capita (PPP) | -.691 | .359 | -.301 | -1.923 | .063 |
| | Total Urbanized Areas (km2) | .000 | .005 | -.009 | -.066 | .948 |
| | Travel time per work-trip (min) | .609 | .277 | .275 | 2.200 | .035 |

a Dependent Variable: % Non-pvt Motorized Transit

Table 3.01: Result of the Multiple Regression Model

Coefficient Correlations(a)

| Model | | | Travel time per work-trip (min) | Total Urbanized Areas (km2) | Pump Price for super gasoline (US \$ per liter - 1998) - PPP | Residential Density | City Product / capita (PPP) |
|-------|--------------|--|---------------------------------|-----------------------------|--|---------------------|-----------------------------|
| 1 | Correlations | Travel time per work-trip (min) | 1.000 | -.148 | .050 | -.133 | .352 |
| | | Total Urbanized Areas (km2) | -.148 | 1.000 | .040 | .074 | -.464 |
| | | Pump Price for super gasoline (US \$ per liter - 1998) - PPP | .050 | .040 | 1.000 | -.152 | .247 |
| | | Residential Density | -.133 | .074 | -.152 | 1.000 | .240 |
| | | City Product / capita (PPP) | .352 | -.464 | .247 | .240 | 1.000 |
| | Covariances | Travel time per work-trip (min) | .077 | .000 | .056 | -.001 | .035 |
| | | Total Urbanized Areas (km2) | .000 | 2.124E-05 | .001 | 1.283E-05 | -.001 |
| | | Pump Price for super gasoline (US \$ per liter - 1998) - PPP | .056 | .001 | 16.782 | -.024 | .363 |
| | | Residential Density | -.001 | 1.283E-05 | -.024 | .001 | .003 |
| | | City Product / capita (PPP) | .035 | -.001 | .363 | .003 | .129 |

a Dependent Variable: % Non-pvt Motorized Transit

Table 3.02: Coefficient Correlations of Independent Variables

Correlation and multiple regression analyses were conducted to examine the relationship between percentage work trips by the following means of transit - pedestrian, bicycle and public transit (incl. bus, train and metro) and the various potential predictors. Table 1 summarizes the individual correlations and their significance levels. It indicates that city product per capita and pump price of super gasoline (adjusted to purchasing parity power) are negatively correlated to the dependant variable while total urbanized area, median travel time for a work trip

and residential density are positively correlated, but their relationship is quite weak.

The multiple regression model with all four predictors produced $R^2 = .572$. As can be seen in Table 3, PPP adjusted pump price and city product per capita have significant regression weights and that they are negatively related to the percentage modal splits by walk, bike and public transit modes. Other predictors do not contribute to the multiple regression model.

3.9 CONCLUSION

The result of the statistical analysis show that urban density in itself has very slight bearing on transportation behavior factors such as “median travel time to work” and “non private automobile modal split percentage”. At the same time this association cannot be discarded, as it is statistically significant, implying the numbers are not due to coincidence. What this implies is that containment benefits that the proponents of the compact city desire will not be attained simply by a change in density levels. A number of other factors would have to be taken into consideration. Simply modifying urban forms is not the solution. As Alan Bertaud points out cities are shaped by the interaction of transportation, labor, land and housing markets. For example, auto dependence is caused by factors such as incomes, gasoline prices and public policies to subsidize public transport. A fact that is corroborated by the results in the multi-variate analysis - use of public transport has

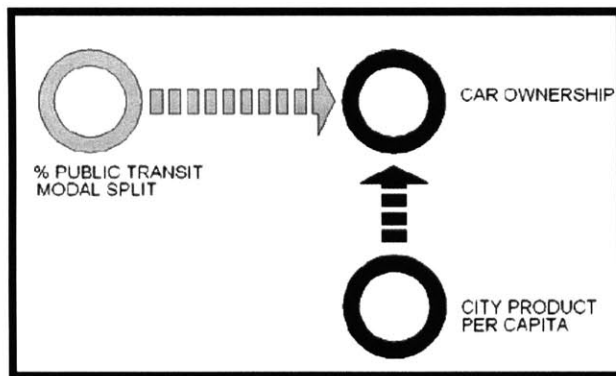


Fig 3.27: Relationship Matrix between car ownership, city product per capita and % non private car modal split.

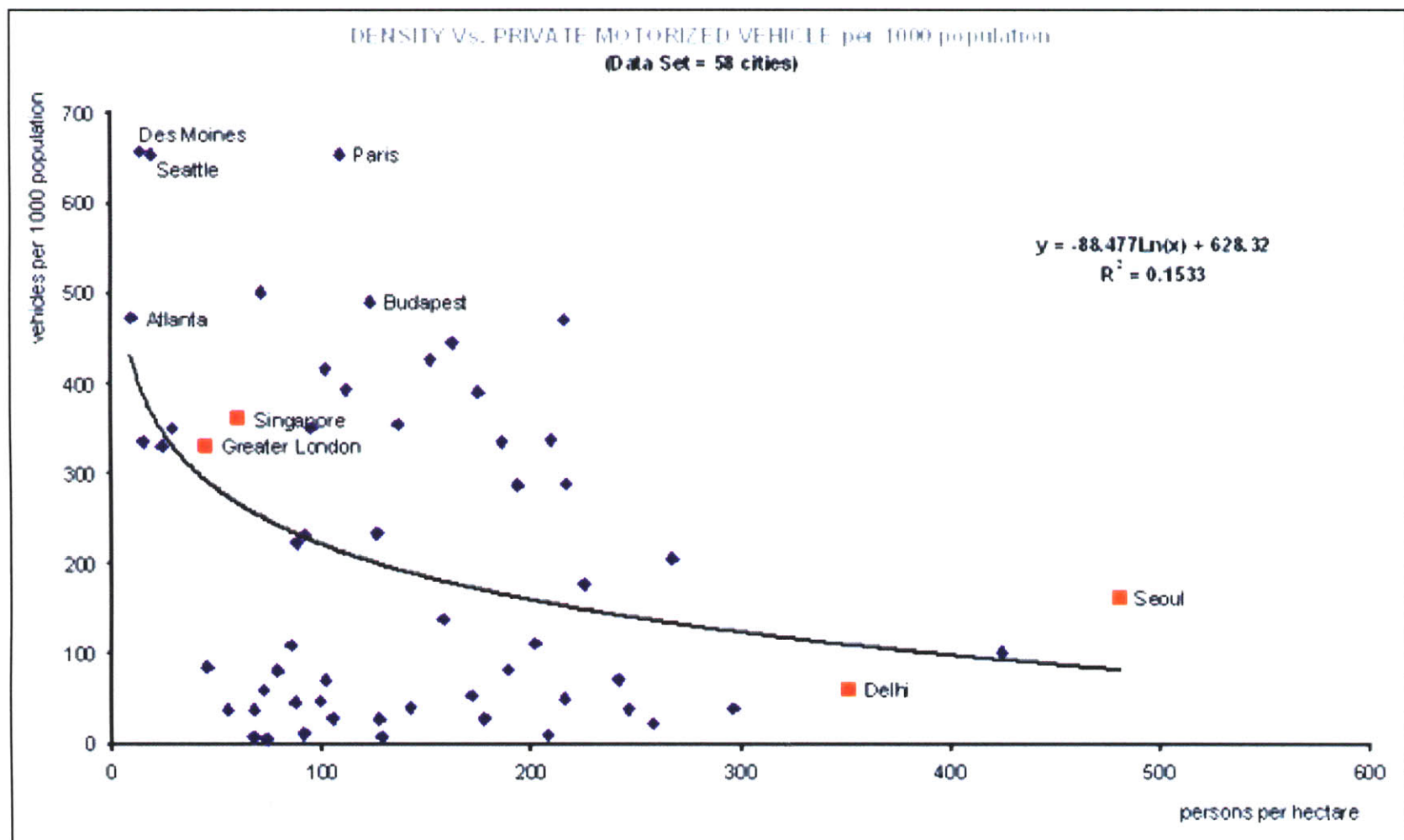
a significant correlation with pump price of gasoline.

My results also show that City Product per capita has a significant and strong correlation with automobile ownership rates. [Refer Table 3.03] This is in contrast to the weak association between density and automobile ownership rates. [Refer Fig. 3.28].

The problem with a study of global comparisons such as this is that it does not reveal much about policy implications. What one could decipher from the results is that policy decisions can perhaps be more effective in bringing about a more sustainable solution.

Four examples of such types of regulations are as below.

- (i) Price Regulation – Ideally, this is an attempt to raise the cost of driving to an amount that would exactly equal the external harm from the air pollution and traffic congestion.
- (ii) Quantity Regulation of Externality - These set maximum limits for the concentration of harmful pollutants within the air basins. Thus mandating that quantities don't exceed the maximum.
- (iii) Mandated Innovations - Laws that call for innovations that make the production or consumption of the product cleaner.
- & (iv) Changing Travel Behavior - These regulations affect the consumption side. They affect the travel behavior rather than the technology of travel. (e.g. No drive days in Mexico City, that bans 20% of the city's cars from the streets on each day of the week.)



| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|---------|----------|-------------------|----------------------------|
| 1 | .284(a) | 0.081 | 0.064 | 183.00031 |

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|-------|---------------------|-----------------------------|------------|---------------------------|--------|-------|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | 292.061 | 43.035 | | 6.787 | 0.000 |
| | Residential Density | -0.551 | 0.249 | -0.284 | -2.214 | 0.031 |

Fig 3.28: Scatterplot and linear regression between residential density and private motorized vehicle per 1000 population (All Income Level)

Model Summary

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|---------|----------|-------------------|----------------------------|
| 1 | .842(a) | .709 | .702 | 96.6616876 |

a Predictors: (Constant), City Product / capita (PPP)

Coefficients(a)

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|-------|-----------------------------|-----------------------------|------------|---------------------------|-------|------|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | 54.124 | 20.239 | | 2.674 | .011 |
| | City Product / capita (PPP) | 12.104 | 1.257 | .842 | 9.631 | .000 |

a Dependent Variable: Automobile ownership - cars/1000 pop.

Table: 3.03 - Tabulated results of the linear regression between Automobile Ownership and city product per capita normalized by purchasing power parity.

4

ANALYSIS - III

ECONOMICS OF THE EDGE CONDITION & RELEVANCE OF CONTAINMENT IN DEVELOPING COUNTRIES

CHAPTER OUTLINE

(A) ECONOMICS OF THE EDGE CONDITION

4.1 EFFECT OF SPRAWL ON AGRICULTURAL OUTPUT

4.2 ECONOMIC THEORY OF SPRAWL

Rodriguez-Bachiller Model

4.3 CONTAINMENT AND LAND PRICES

Man-Cho Model

Seoul example

(B) RELEVANCE OF CONTAINMENT IN DEVELOPING COUNTRIES

4.4 RELEVANCE OF COMPACTION IN DEVELOPING COUNTRIES

ECONOMICS OF THE EDGE CONDITION

4.1 EFFECT OF SPRAWL ON AGRICULTURAL OUTPUT

Higher density it is argued would lead to less space per capita being consumed. By limiting the city's footprint more land would be available for cultivation; in-turn helping in increase agricultural output.

Economists such as Mills, Gordon and Richardson refute the idea that urban encroachment is a threat to prime agricultural land and thus diminishes agricultural capacity. They base their argument on the productivity advances made in the agriculture sector, which result in less land being needed for agriculture. They content that even at today's average suburban densities only a small share of the land is consumed by urban growth.

I use the following equations to understand the pressures on the peripheral agriculture land. Say a farmer/landowner makes \$X per year through produce from his farm. Under a perfectly competitive market, the developer would have to pay him \$ X/r (using the perpetuity formula - where r is the interest rate) to acquire the land.

$$\text{Cost of land} \geq \$ (X/r)$$

The developer would then have to spend an additional cost (say) \$Y on construction to build on it. Hence a firm/person would

have to pay $\$ X/r + Y$ to occupy the space.

Development will take place when an activity has

$$\text{Utility} \geq \$ (X/r + Y)$$

This implies,

(i) If the land is unsuitable for agriculture then open space preservation holds no meaning. In this case, X is low and hence land price is cheap. The land is very likely to be acquired for development.

(ii) If there is a great demand for the agricultural output, then there will be a greater likelihood that all the land will be used for cultivation, unless other rival economic pursuits have a greater utility. By definition, peripheral land is near cities and has the advantage of lower transport, which is accentuated in the case of easily perishable goods. X in this case is high, thus development is unlikely.

(iii) "If parcels are fragmented, supporting infrastructure in short supply, or if the rights of the owner are not supported by government institutions, then farming activities will be marginalized."¹ In this case too, X would be lower if the above mentioned criteria are true.

(iv) Containment policies will place greater number of people and activities on the available land; thus increasing land prices

and development intensity on land adjacent to the urban edge. Urban farming would loose out under such a condition, as ground rents will become too expensive for agricultural uses.

(v) Clark and Tsai (2000) point out that in Asian cities, land management practices on the metropolitan periphery inhibit the use of adjoining lands for farming and ranching. At this rural and urban intersection, marginal and progressive economic enterprises vie for position. In case of a squeeze on the metropolitan regions, users of urban land may exercise both economic and political influence to secure footholds in the very rural areas that containment was meant to protect. This encroachment of rural land would deny the existing marginal non-farming enterprises access to the rural areas, thus "hindering their capacity to incubate, innovate, and increase market share and elevate their competitiveness."¹

4.2 ECONOMIC THEORY OF SPRAWL

De-centrists argue that sprawl is inevitable. The following paragraphs, adapted from Augustin Rodriguez-Bachiller's paper², explain the inevitability of sprawl.

Alonso, Muth and others in their versions of the bid-rent theory assume that the markets offer 'perfect competition'. However, in reality this is not the case, development markets are imperfect. At times there aren't enough consumers and producers to make

them all 'price takers'. In other words due to lack of competition, their behavior affects market prices.

Development markets can be divided into land markets and floor space market. In the first case, the landowner sells their land to the developers and in the latter case, the developer rents floor space to the consumers.

In a growing city the floor space market is a sellers market.³ There are relatively few developers, but many buyers. Thus the price paid for the floor space will tend to the maximum that the consumers can afford.

In the case of the land markets, two scenarios occur -

(i) In central built up areas, due to scarcity of developable land, the landowner is in a strong position. Thus this can be called a sellers market. The landowner can extract maximum price for the land and the developer can also charge maximum rents for the floor space. In such a scenario one notices a compact pattern of urban growth.

Fig. 4.01 shows a conceptual representation of the bid rent curve. This is based on the simplistic notion that the floor space bid-rent curve represents the developer's revenue, the land bid-rent curve represents his variable cost and the difference between the two is the profits.

(ii) At the urban edge, the floor space market will still be a

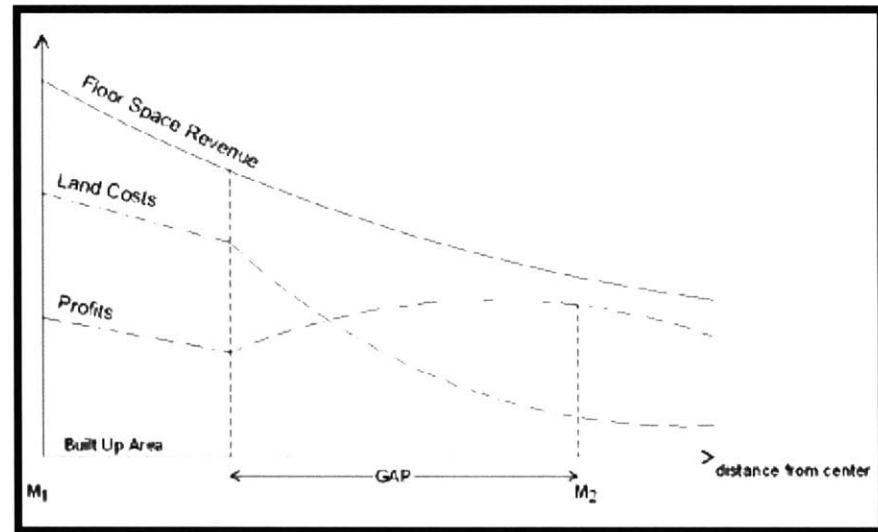


Fig. 4.01: Conceptual diagram explaining the Rodriguez-Bachiller concept. Source: Rodriguez-Bachiller, Augustine (2000) "Discontiguous Urban Growth" in Simmonds, Roger and Hack, Gary (eds) "Global City Regions"

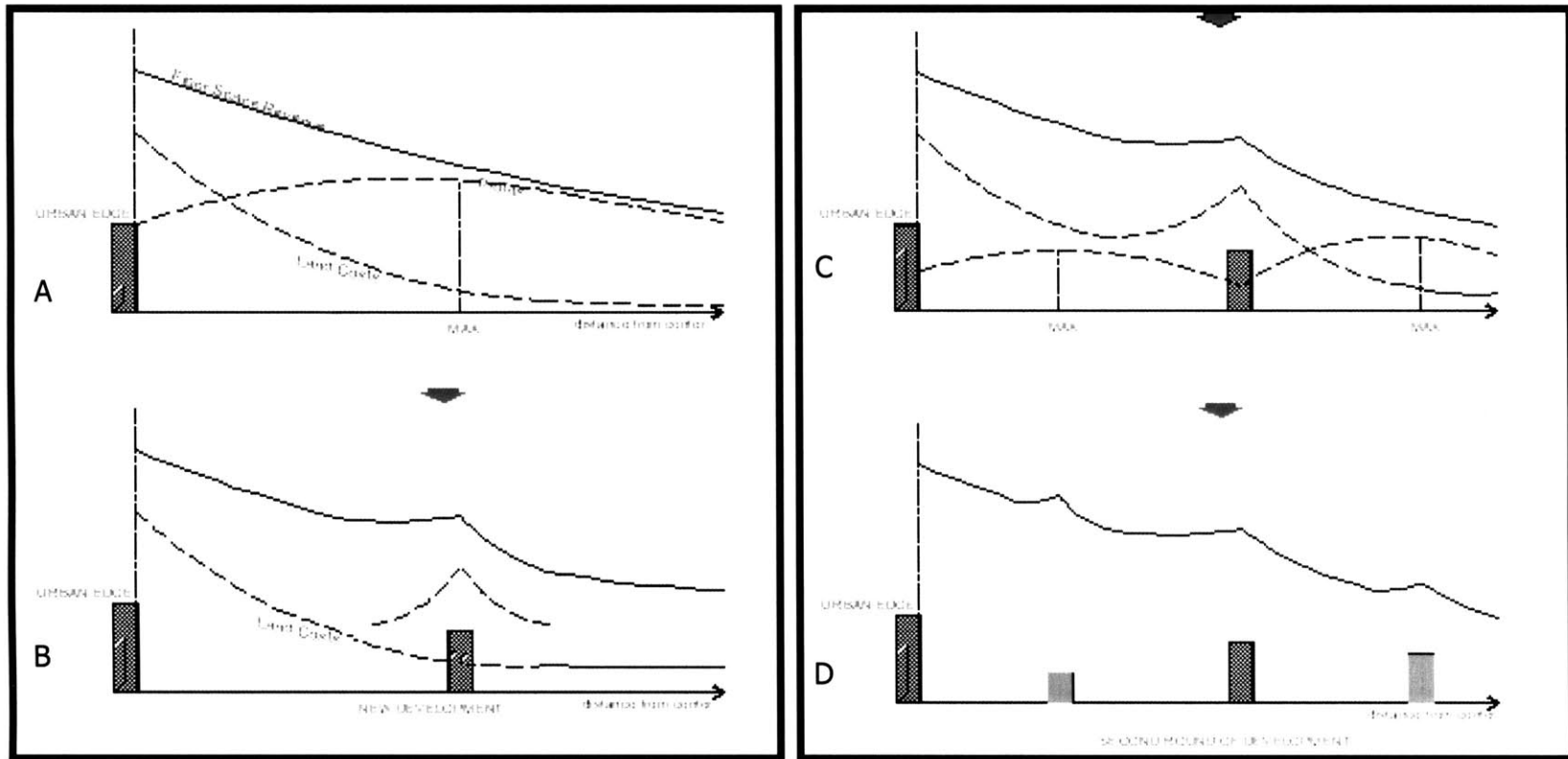


Fig. 4.02: Stages of Development beyond the urban edge.

seller's market. However as we move further out, the land market rapidly changes into a buyers market. The reason for this being that demand for land decreases, and the availability of land increases exponentially. The developer can thus pay lower land prices as he moves further beyond the edge. At a point x_2 , his profits will maximize. Self-sustaining development (ones that are not dependent on the adjacent urban area for its existence) will

take place at this point. This creates discontinuous urban development. Developments that are unable to detach themselves from the urban core, will continue to be built at the edge of the city, in the process accepting sub-optimal profits.

This process shall continue, with increased infill development. Land prices in the vicinity of this new development will ap-

preciate - the expectations of the landowners rise, while their numbers drop. With the depressed profit margins, a stage will be reached wherein the land here will not be able to compete with new land available further outside the city. Land speculation itself will prevent many landowners to sell their land as long as there is available land beyond the fringe.

(C) CONGESTION AND INCREASING LAND PRICES

To counter sprawl created by the above-mentioned economic reasons, many cities around the world try to restrict the availability of cheap land beyond the city's edge. This is done by designating a greenbelt or by regulations demarcating an urban growth boundary for the purposing of containing physical expansion of built up areas.

The first case of greenbelt regulation was observed in London in 1939. Seoul, Ottawa, Tianjin, Boulder and Portland followed suit with similar regulations. Such a policy has been linked with higher land prices. This is because they restrict land and housing supply, thus increasing demand.

The following effects are noticed on land prices [Refer Plate

- Land Rent in the non-restricted urban area (inside) can increase due to the rise in location demand caused by the scarcity of land and possible influx of demanders excluded from the

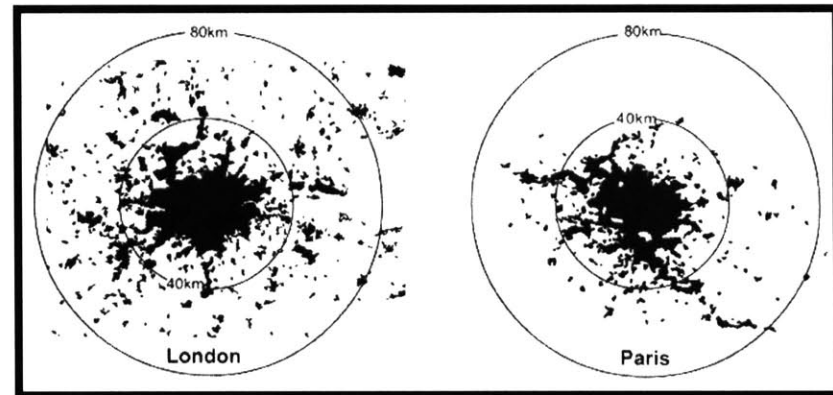


Fig. 4.03: Urban growth in London and Paris.
Source: Jenks, Mike and Burgess, Rod (2000) "Compact Cities: Sustainable Urban Forms for Developing Countries"

restricted area.

- The greenbelt can create positive amenity in regions next to the greenbelt and thus raise values on the fringes of the greenbelts.
- Since restriction can delay or totally prohibit development inside the greenbelt, land values would fall here.

Overall land prices are likely to rise throughout the restricted city and there would be tremendous pressure on the congestible public amenities.

Kim, K.H. (1987) based on simulations has shown that if Seoul were to release a 1 km band of land from the inner restricted greenbelt zone, it would lower land rent and housing prices by 7.7% and 2.7%.

Man Cho's (1997) ⁶ results on Seoul, Korea offer evidence of the gradient-flattening effect of greenbelt regulation.

(D) RELEVANCE OF COMPACT CITY IN THE DEVELOPING WORLD

Cities in developed countries and those in less developed share a contrasting experience with regards to growth rates (both in size and population). While population growth in

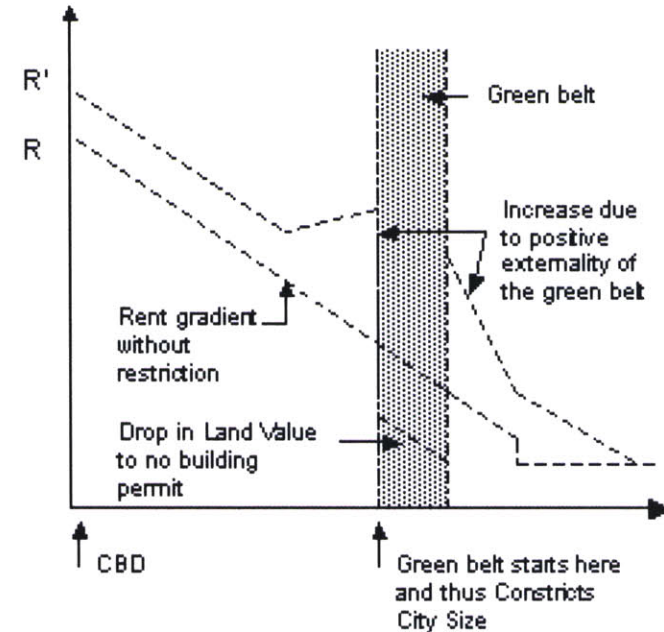


Fig. 4.04: Conceptual sketch of land price effect due to imposition of a greenbelt. **Source:** Cho, Man (1997) "Congestion Effects of Spatial Growth Restrictions: A Model and Empirical Analysis" Real Estate Economics Vol. 25.

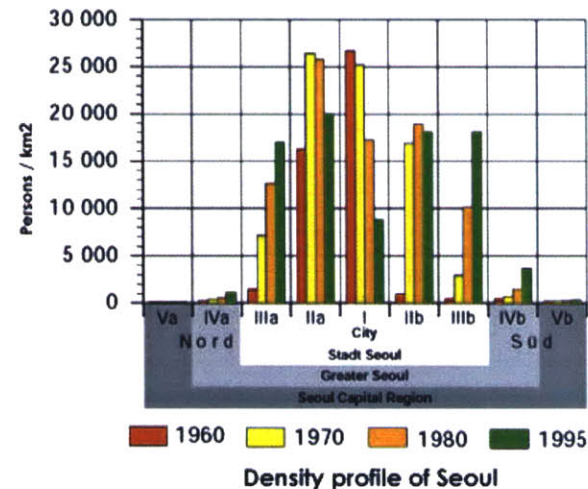


Fig. 4.05: Effect of the greenbelt on Seoul's density profile. **Source:** <http://www.megacities.uni-koeln.de/index.htm>

the former has stabilized, the later is in the midst of accelerated growth rates. This is can be explained by the following reasons.

Urban growth can be attributed to two factors, namely natural increase (increase of births over deaths) and in-migration (movement of people from the rural areas to the city).

$$\text{Increase in population} = \frac{[\text{Deaths} - \text{Births}]}{(i)} + \frac{[\text{In-migration} - \text{Emigration}]}{(ii)}$$

(i) In less developed countries, death rates have fallen due to the increased access to health care while birth rates remain high. [Refer Fig 4.06].

(ii) As cities become more and more industrialized, greater manufacturing output can be achieved with little labor input. While job sources become scarce in developed nations, the informal sector plays an important role in providing employment opportunities for the migrants in less developed countries. This provides a great incentive for people in the countryside to move to the cities. The advantages of the informal sector over the formal sector jobs are (a) higher real wages for the unskilled worker, (b) higher potential for absorbing migrant labor, (c) less sex discrimination and (d) better opportunities of upward mobility through entrepreneurship even with limited capital.

Cities in developed and less developed countries differ in their urban spatial patterns. The story of city development in devel-

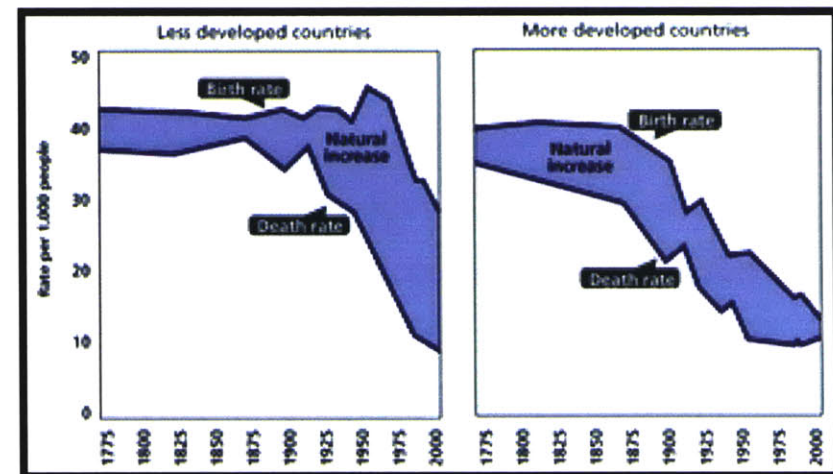


Fig. 4.05: Increasing gap between death and birth rates in developing countries
Source: <http://www.megacities.uni-koeln.de/index.htm>

oped countries follows the following pattern. The pre-industrial city is a compact city structured around some focal points of civic or religious significance. With industrializations cities start to grow in size, generally along transportation networks. With the advent of cars, the rich choose to reside in large plots in the low-density suburbs, away from the congestion and pollution of city centers. Thus in the developed countries the poor and the middle income live in the relatively dense urban core, while the rich have moved to the suburbs.

However in the less developed countries, the poor migrants initially move to the inner city receptor centers, living in high-density tenement blocks. Later these migrants with greater space requirements and higher incomes move to the periphery where

they commence illegal building process based on progressive building and self help. (Turner 1976). Thus the poor reside both in the center and in the periphery squatter settlements.

Given the fact that in developing countries, densities are already high and associated with a range of problems such as overcrowding, infrastructure overload, congestion, high income disparity, severe health hazards, lack of public and green spaces, high levels of air pollution and environmental degradation; does densification make sense in these cities?

“High demographic growth, low levels of economic development, high income inequalities, small urban budgets and shortages of environmental infrastructure, shelter and basic services have a critical effect on densification policies and the effectiveness of policy instruments.”⁸ Without significant improvements in infrastructure, further densification may have disastrous consequences.

The idea that densification will lead to cheaper infrastructure costs is contentious to say the least. In developing countries, the cost of infrastructure provision depends on environmental factors and technical complexities. This can be attributed to the disorganized layouts built on fragile environments (eg. steep slopes, tidal flats or land prone to flooding).

Research has shown that use of public transport is more a factor of income [Refer Section 3]. The increase of income is accom-

panied by an increase in auto usage. Most cities are characterized by low road capacity per capita and per hectare. Further, while there is low car use and emission rates per capita; the car use and emission rates per hectare are high. Under such a condition it is difficult to increase road capacity. Increasing the fuel efficiency of public and private transport might be of help. Immediate sustainability gains can be had by the construction of environment friendly mass rapid transport systems. However investment needed to start such projects is immense.

Achieving greater gains through the rational allocation of space within existing housing stock, may not apply to developing countries. These countries are at an early stage of the demographic transition process. Their high rates of household formation is explained by the high rates of natural increase and rural to urban migration, large family size, number of young people of child bearing age are high and low number of old. Even though some of the squatter settlements might appear to have low density, these are actually tuned to develop over time with increase in income and family size.

Greater use of mixes already exist in these cities in the form of local markets, small-scale workshops and other employment sources in the informal sector that are dispersed throughout the city.

What is of concern is the creation of new settlements in their vicinity. To attract potential investors and economic activities

(with the notion of creating a “global settlements / technology parks”), many cities have relaxed regulation norms. These settlements thus are characterized by low-density developments.

Urban restructuring has become a major strategy for growth management in developing countries. Some of the strategies being implemented in the developing world with varying degrees of success are -

(i) HIGH-RISE, HIGH-DENSITY REDEVELOPMENT: Popular in South-east Asia, this is thought to be associated with very high densities, short work trips, easy access to services, widespread mass transit, self contained new towns and settlements.

(ii) CONCENTRATED DECENTRALIZATION: This is an attempt to intensify activity usage and density in multiple sub centers throughout the city. These sub-centers are then connected through transport and development corridors.

(iv) TRANSIT ORIENTED DEVELOPMENT: An example of this is the city of Curitiba. Public transit systems are developed. Urban growth is then channeled along selective axes based on transit routes.

(iv) INFILL AND DENSIFICATION: This is the traditional method, where in the core is regenerated and derelict land such as dis-used industrial areas are used for densification.

This thesis analysis Delhi as a case study to understand growth management policies in developing nations. Delhi uses a combination of all these strategies. Through its policy of developing 16 sub centers, it is trying to create a more polycentric form where each sub-center is self-sufficient. On the peripheries, the city encourages high-rise, high-density development, shunning the traditional bungalow development typology. Within the core, many of the defunct mills are being redeveloped for mixed-use development. Future growth areas are to be channelized along the routes of the mass rapid transit system. Delhi is also developing satellite cities to act as counter magnets for the urban in-migration. The following chapters discuss the merits and demerits of Delhi’s growth management policies.

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1. Clark, Thomas and Tsai, Albert (2000) “Agricultural Consequences of Compact Development” in Jenks, Mike and Burgess, Rod (eds.)“Compact Cities: Sustainable Urban Forms in Developing Countries.”
 2. Rodriguez-Bachiller, Augustine (2000) “Discontiguous Urban Growth” in Simmonds, Roger and Hack, Gary (eds) “Global City Regions”
 3. The term seller’s market refers to a market condition wherein the seller due to their small numbers are able to influence the market prices (akin to monopoly condition). The seller is able to extract the maximum that the consumer can afford due to lack of choices for the consumer.
 4. The term buyer’s market refers to a market condition wherein the number of buyers is less and the number of people willing to sell a product are large. In this case the consumer can influence the market price, by extracting the lowest possible price.

6. Cho, Man (1997) "Congestion Effects of Spatial Growth Restrictions: A Model and Empirical Analysis" Real Estate Economics Vol. 25.

5

DELHI - INTRODUCTION

CHAPTER OUTLINE

- 5.1 MASSIVE IN-MIGRATION
- 5.2 DELHI'S URBAN SPATIAL STRUCTURE
- 5.3 LOCAL AGENCIES CONTROLLING DEVELOPMENT
- 5.4 HOUSING PROFILE
- 5.5 TRANSPORT PROFILE
- 5.6 CITIES RESPONSE TO GROWTH

5.1 MASSIVE RURAL-URBAN MIGRATION

On an average 1000 people migrate to Delhi every day in the last decade. The city today is home to around 14 million people [2001 Census]. This figure is projected to double by the year 2021. Delhi has been subject to massive rural-urban migration due to its political stature, availability of jobs and perception of a better lifestyle [Refer Table 5.01].

About 30% of the urban growth from 1981 to 1991 can be attributed to the accelerated rural-urban migration.¹ This rural-urban flight is more due to an escape from rural misery, hunger and disease rather than just being an economic pull. About 2/3 of the Indian labor force is in the agriculture sector. Constant fragmentation has led to the Indian farmer's average holding degenerating to less than .7 acre.²

This is not to say that jobs aren't a factor. In fact recent studies reveal that of the total number of jobs created in the 8 largest cities of India {4 mega cities - Delhi, Mumbai, Kolkatta and Chennai and 4 other major metropolitan cities -Pune, Bangalore, Ahmedabad and Hyderabad}, "Delhi is home to one fourth of all the jobs."³

Table 5.01 reveals that between 1941 and 1950, the city more than doubled in population. This can be attributed to the flood of refugees thronging the city in the aftermath of Partition of India. However, the decades thereafter have witnessed a "relentless

and chaotic agglomeration of people and property.”⁴ The rapid increase in population and the continuing inability of the city agencies to cope with has led to a severe scarcity of land, affordable housing, and shortage of basic infrastructure. This is clearly manifested by the increasing number of informal settlements sprouting throughout the city.

| Census Year | Population (in million) | Decennial Growth Rate (%) (of this about 22 per cent is due to natural increase) |
|-------------|-------------------------|--|
| 1901 | 0.21 | - |
| 1911 | 0.24 | 11.13 |
| 1921 | 0.30 | 20.94 |
| 1931 | 0.45 | 46.98 |
| 1941 | 0.70 | 55.48 |
| 1951 | 1.44 | 106.58 |
| 1961 | 2.36 | 64.17 |
| 1971 | 3.68 | 54.57 |
| 1981 | 5.77 | 58.16 |
| 1991 | 9.42 | 63.58 |
| 2001 | 13.78 | 46.31 |

Table 5.01: Decennial Population Growth Rate
Source: Delhi Statistical Handbook, N.C.T.D., 1994.

To compensate for such growth in population, the city acquired 93,233.92 acres (or 37, 746.5 ha) of land from 351 villages and 67 urban areas of Delhi for planned development [Refer Table 5.02 and Fig. 5.01]. “Perhaps no other city in the world has converted so much of rural land for urban expansion through Public Intervention in the Land Markets.”⁵ Numerous studies have been conducted about the change in demographics and occupational scenario of rural Delhi. The

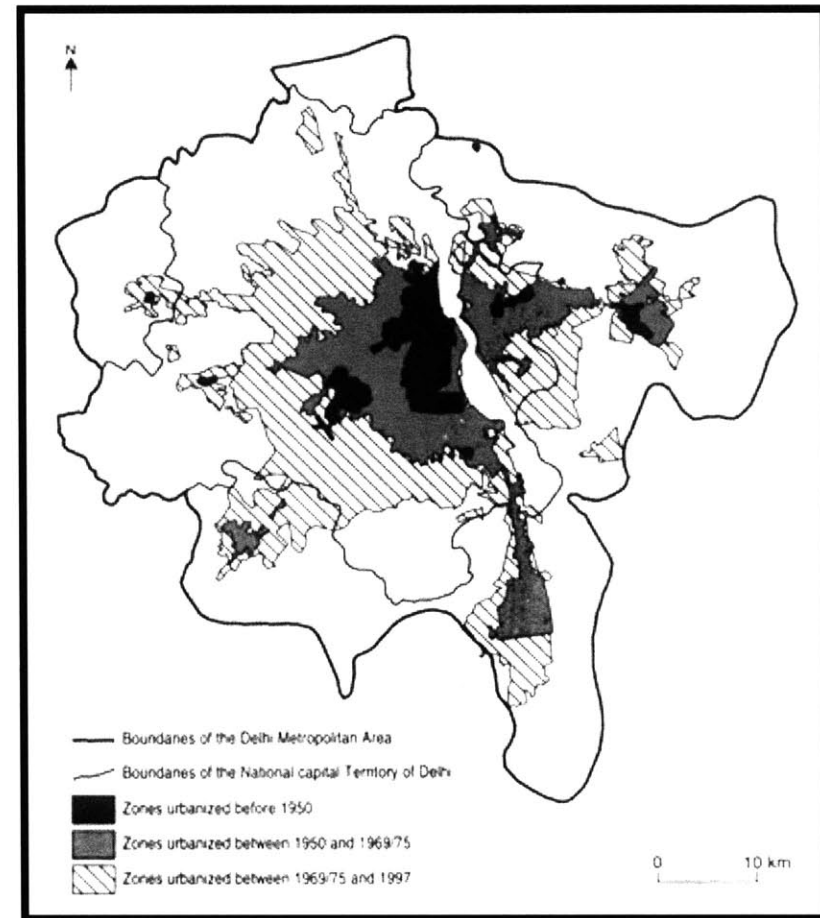


Fig. 5.01: Land Acquired by the city between 1947 & 1997
Source: unknown

millions paid as compensation has bred a new class, the neorich in rural Delhi.

| Growth of Urban Areas in Delhi (1901 to 1991) | | | |
|--|--------------|----------------------|----------|
| Decadal Year | Area (sq.km) | Net Addition (sq.km) | Growth % |
| 1901 | 43.3 | - | - |
| 1911 | 43.3 | 0 | 0 |
| 1921 | 168.1 | 124.8 | 288.22 |
| 1931 | 169.6 | 1.5 | 0.89 |
| 1941 | 170.1 | 0.5 | 0.29 |
| 1951 | 195.8 | 25.7 | 15.11 |
| 1961 | 326.3 | 130.5 | 66.65 |
| 1971 | 451.4 | 125.1 | 38.34 |
| 1981 | 591.9 | 140.5 | 31.13 |
| 1991 | 685.3 | 93.4 | 15.78 |

Table 5.02: Growth of Urban Areas in Delhi (1901-1991)
Source: India Stat.

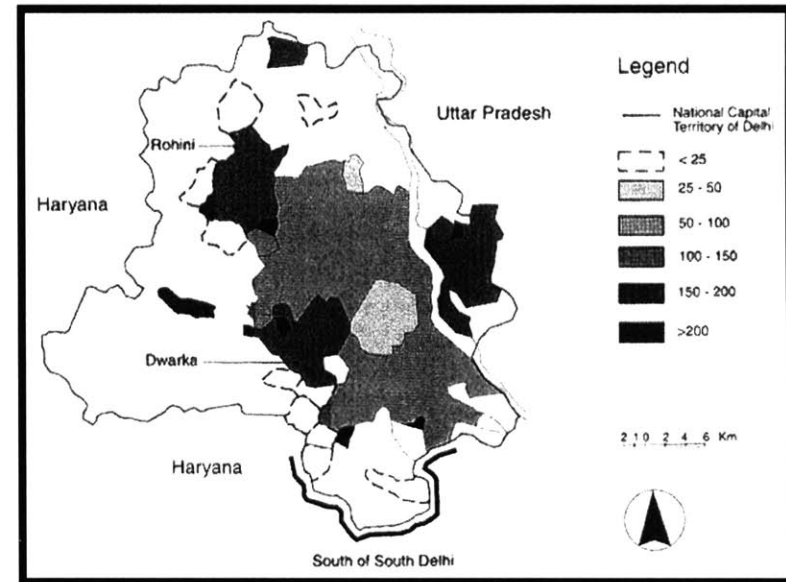


Fig. 5.02: Delhi density map.

Source: Kumar, Ashok (2003) "Inverted Compact City of Delhi" in Jenks, Mike and Burgess, Rod "Compact Cities"

5.2 THE CITY'S SPATIAL STRUCTURE

In general cities exhibit a negative rent gradient as seen in the works of Alonso, Muth, Colin Clark and Alain Bertaud. [Refer Plate 3]. However in the case of Delhi, the opposite is true - densities increase with increase in distance from the center of the city.

Densities in the city vary widely - 12 persons per hectare in the rural areas; 22 persons per hectare in the cantonment areas,

100 -150 persons per hectare in Old Delhi and Karol Bagh and 150 to 200 persons per hectare in the peripheral areas.

A number of political and historical reasons are behind this phenomenon of increasing densities with increase in distance from the CBD. The city is composed of the following typologies.

LUTYEN'S NEW DELHI: The center of the city constitutes Lutyen's New Delhi, which was planned by the British as a low-rise bungalow development (a garden city) in 1910. Lutyen's Delhi was supposed to house only 140 bungalows.⁶ Residences were to be single storied with maximum ground coverage of 25%. This region houses government offices, the parliament and the presidential palace. The center of the town also includes the cantonment - military barracks.

HIGH RISE HIGH DENSITY PERIPHERY: As mentioned earlier the city undertook policies of densely developing the peripheral areas. This high-rise, high-density development is taking place primarily in Dwarka, Rohini and Narela. [Refer Fig. 5.06]. "Dwarka is being built to accommodate 1 million people on 5,645 hectares of land at a gross density of 177 persons per hectare."⁷

BUNGALOW - PLOTTED DEVELOPMENT: Most of the inner core was developed as small residential plots (165 sq.mts and 420 sq.mts). As families extended, it became a common

practice to add some rooms or even an additional floor over the allowable limit. In many cases, private builders in collusion with the owners of the plot have even built 4-5 stories, when legal provision is for only 2 ½ stories. This phenomenon is being witnessed throughout Delhi.

UNPLANNED HIGH RISE URBAN VILLAGES: Of Delhi's 369 villages, 170 were incorporated into the urban areas. These urban villages with densities upto 400 persons per hectare have never had any planning controls. While most structures were planned as single story residences, over time they have become 4-5 stories high.

SQUATTER SETTLEMENT: These are evenly distributed throughout the city. Around

UNPLANNED RURAL AREAS: These have now been incorporated in the Delhi Municipal Corporation Area. Farmers in these parts have subdivided land into plotted areas and sold them off to poor people. These sites weren't serviced and hence fetched little money.

5.4 LOCAL AGENCIES CONTROLLING DEVELOPMENT IN DELHI

Planned development has been attempted in Delhi since 1874, when the Delhi Municipal Committee was formed. The problems of pollution and housing, immediately after India's

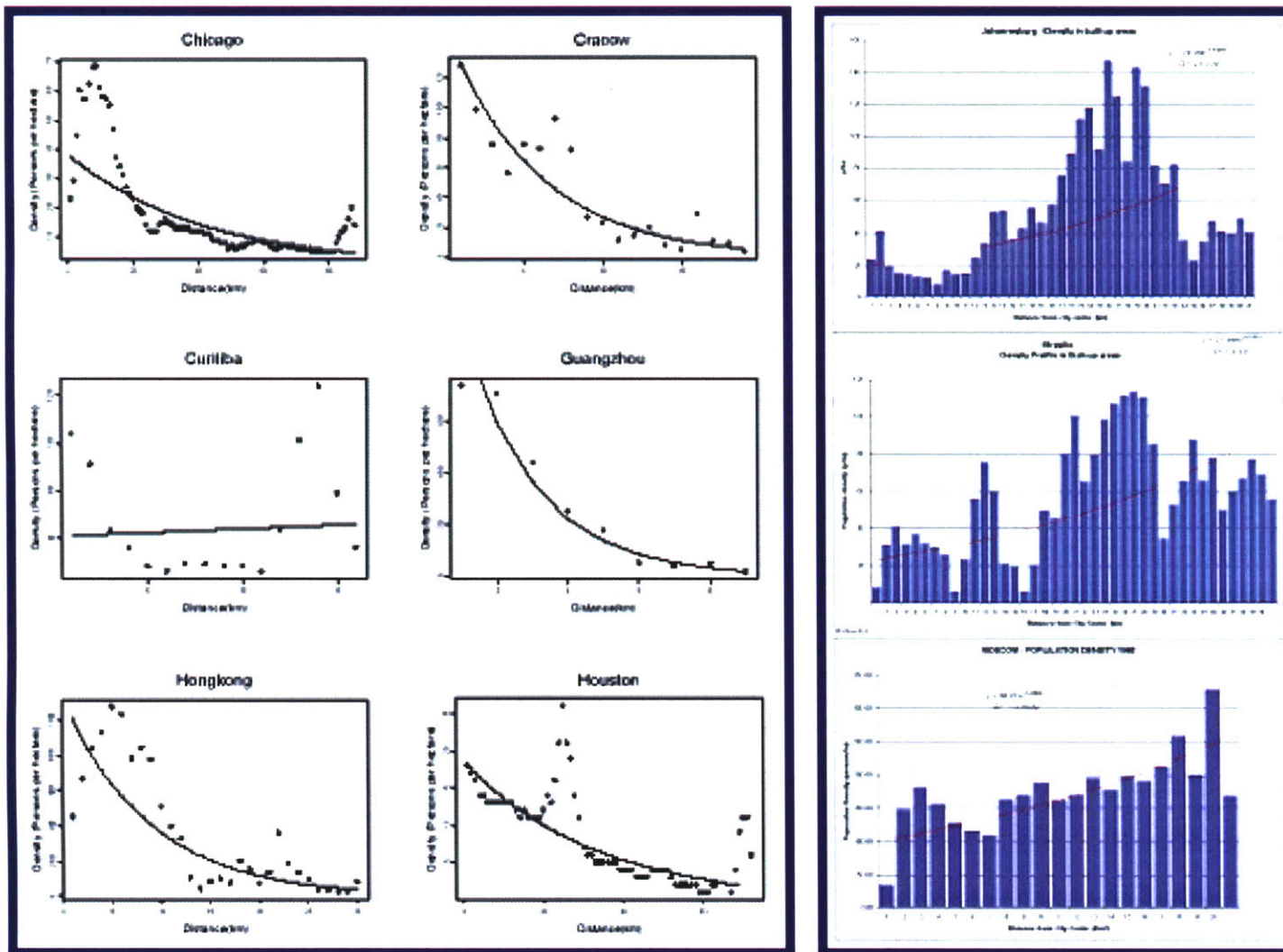


Fig. 5.03: shows typical cities with the negative exponential density slopes. Fig. 5.04: shows the density levels in relation with distance from the CBD in cities which are exceptions to the rule - akin to Delhi – Johannesburg, Brasilia and Moscow. Johannesburg due to its apartheid laws had low density white areas in the center, Brasilia like Delhi housed government functions in the center and transition cities like Moscow had industry in the middle - are some of the reasons provided for the positive slope seen in these cities.

Source: (both) Bertaud, Alain (2002) “The Spatial Organization of Cities: Deliberate Outcome or Unforseen Consequence?”

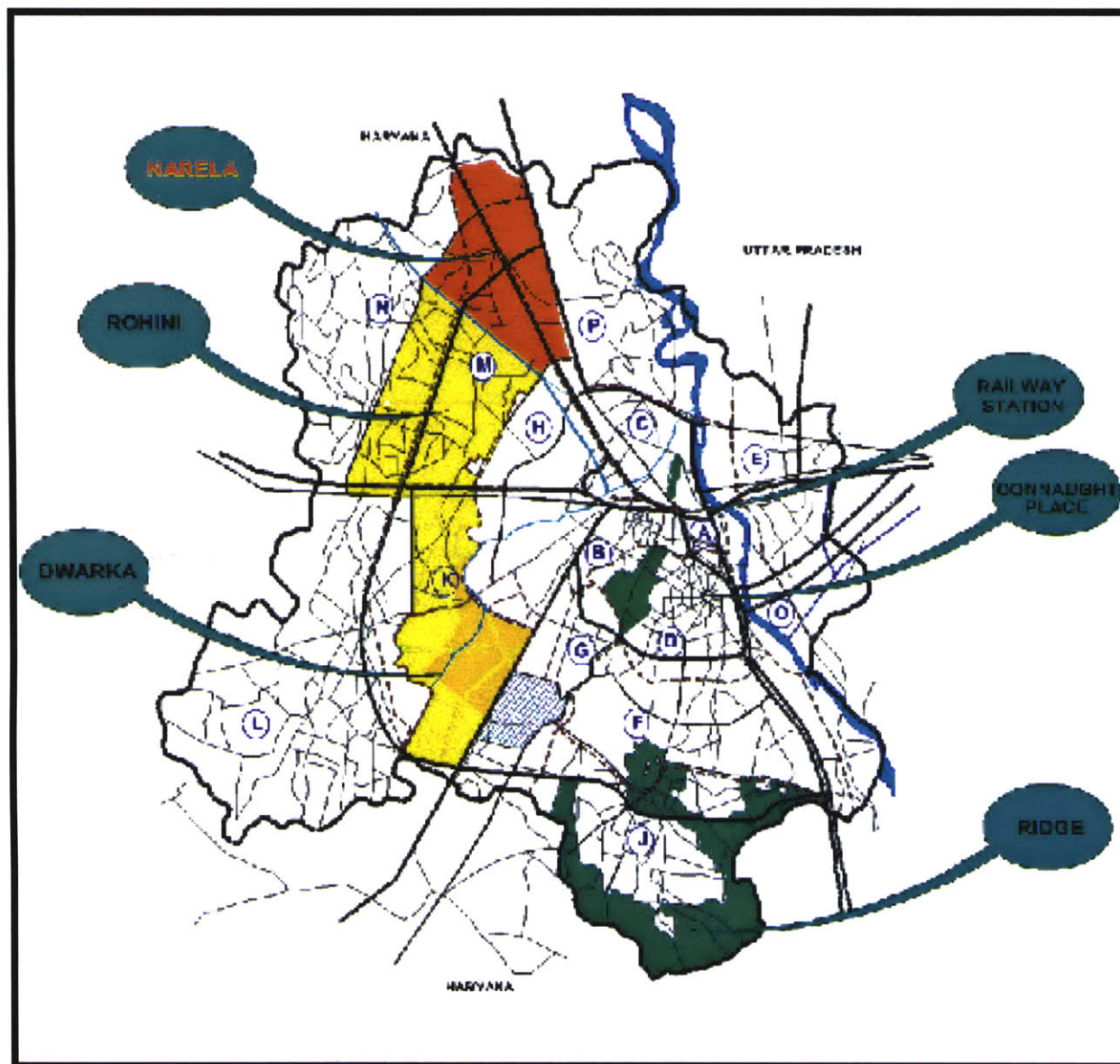


Fig. 5.06: Map showing location of peripheral sub cities.
 Source: Delhi Development Authority

independence led to the establishment of the Town Planning Organization (TPO) and the Delhi Development Authority (DDA) in 1955 and 1957 respectively. The first master plan was prepared in 1962 and earmarked spaces for the industrial units and other land uses.

Today there are four local bodies that control development, these are

The NEW DELHI MUNICIPAL COMMISSION (NDMC): This has jurisdiction over 46sq.km with areas included - downtown Cannaught Place, Lutyen's area which house the institutional buildings, Central government offices, the Parliament and President of India's residential compound.

DELHI CANTONMENT BOARD: It has about 44 sq.km under its jurisdiction. These areas are primarily military barracks.

MUNICIPAL CORPORATION OF DELHI (MCD): It has jurisdiction of about 370 sq.km of urban area and about 1003 sq. km of rural area.

DELHI DEVELOPMENT AUTHORITY (DDA): It is the agency responsible for preparing and updating the Master Plans. Its area of jurisdiction is over an area of 150 sq.kms declared as development areas.

The city agencies develop master plans, generally with a 20-

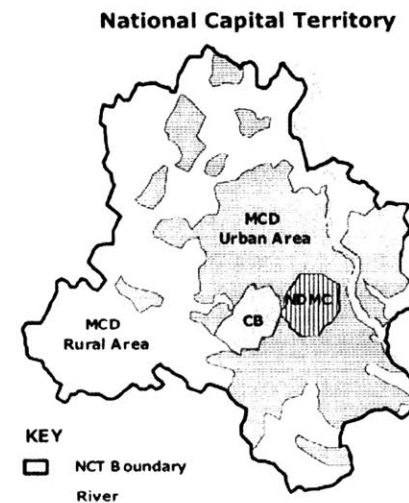


Fig. 5.07: Areas under various development agencies in Delhi.
Source: Tiwari, Geetam (2003) "Transport and Land Use Policies in Delhi"
Bulletin of the World Health Organization 81(5).

year perspective. The master plan is supposed to be the blueprint for the city's development.

HOUSING PROFILE

According to the 2001 Census Data, Delhi has a total housing stock of 3,379,956, of which 92.8% are in the urban areas. Surprisingly, in spite of the huge demand for housing, the city still has 11.2% vacant housing.⁸ International standards hold 5% vacancy rate as the norm, bearing in mind the rollover time needed for changes in tenants and for new housing to be occupied. Delhi requires 73,920 additional houses per year, leading to a continuing gap between supply and demand - a situation that has resulted in unauthorized colonies and slums. It is hardly surprising then that 14.49% of the city's population (in 1991) lives in slums. [Refer Appendix E, F & G]

In terms of tenure type 67.1% of the houses are owned, 25.6% are rented and the rest are classified as "Any Other".

The main housing typologies in Delhi are the DDA housing schemes (EWS/Janta Flats, LIG, MIG, and SFS units)⁹, private group housing schemes (apartments), private plotted residential colonies, urban villages, illegal apartments built on land meant for bungalows and slums.

A major problem plaguing the city authorities is the city's

inability to provide housing for the poor. Migrants are attracted to Delhi, due to the city's thriving informal sector. In 1999 - 1,136,000 jobs were being provided by small-scale industry that employed less than 10 people¹⁰. Along with this a large number of people are employed in the informal sector undertaking activities such as selling newspaper, house-helps, newspaper vendors. The acute scarcity of land forces the poor to build substandard housing and squat on public land. It is estimated that about 1500 unauthorized colonies are without civic amenities. Delhi has a history of illegal and forced eviction. Since the mid 1970's there has been a practice to evict people from their original location to resettlement colonies in the city's outskirts.

Acute shortage of housing for the poor is in contrast to the tremendous spurt in construction activity for upscale apartments and condominiums. This is because of the boom in the BPO (Business Process Outsourcing) and IT (Information Technology) sectors and the movement of expatriates and Non Resident Indians (NRI) to prime locations. Many landowners have got together with developers with the intention of building apartments on their plot of land. Several residences have been converted to small office spaces, an arrangement preferred by fledging IT start-ups. Many of the larger firms have shifted to Gurgaon (a suburb of Delhi) and Noida (one of the ring cities of Delhi) due to the lower rents and the ability to build on cheaper land that accords a larger floor plate accompanied with a higher Floor Area Ratio.

Over the past decade the median age of first time housing loan borrower has fallen from 44 years to 34 years. Omkar Goswami, chief economist for the Confederation of Indian Industries, attributes this to the “changing demographics, rapid growth of real income of the top 20% and the fall in interest rates - all of which point to an even more promising growth in the market for housing. Home loans have always been a very safe bet for banks and housing finance companies. A house is too precious an asset to an Indian, irrespective of culture, age or occupation; and every home loan borrower would rather scrimp than default on housing installments. Not surprisingly, all banks are bending backwards to offer such loans.”¹¹

The peripheral city of Gurgaon is increasingly becoming popular with mid and upper level executives working for the many multi-national firms located here. Its proximity to Delhi and its relatively low congestion rates has aided property prices (in 2001) here to increase by 35% as compared to 10-15% in prime localities in south Delhi areas such as Jor Bagh, Shanti Niketan, Westend, Chankyapuri and Golf Links.¹²

TRANSPORT PROFILE

Traffic in Delhi is composed predominantly of motorized vehicles. The proportion of motorized vehicles is fast increasing. Delhi accounts for more number of vehicles than the combined number of vehicles in Chennai, Mumbai and Calcutta (the three other metropolitan regions in India). The large number and variety of vehicles as well as narrow roads have caused extreme congestion.

| Mode | Share of transport mode (%) | | | | |
|-----------------------------|-----------------------------|--------|--------|-------|--------|
| | 1957 | 1969 | 1981 | 1994 | 1994* |
| Cycle | 36.00 | 28.01 | 17.00 | 6.61 | 4.51 |
| Bus | 22.40 | 39.57 | 59.74 | 62.00 | 42.00 |
| Car | 10.10 | 15.54 | 5.53 | 6.94 | 4.74 |
| Scooter / motorcycle | 1.00 | 8.42 | 11.07 | 17.59 | 12.30 |
| Three-wheeled scooter taxis | 7.80 | 3.88 | 0.77 | 2.80 | 1.91 |
| Taxi | 4.40 | 1.16 | 0.23 | 0.06 | 0.04 |
| Rail | 0.40 | 1.23 | 1.56 | 0.38 | 0.26 |
| Other vehicles | 17.90 | 2.19 | 4.10 | 3.62 | 2.47 |
| Walking | NA | NA | NA | NA | 31.77 |
| Total | 100.00 | 100.00 | 100.00 | | 100.00 |

* includes Walking mode.

Table 5.03: Delhi - Share of Transport Mode
Source: Tiwari, Geetam (2003) “Transport and Land Use Policies in Delhi” Bulletin of the World Health Organization 81(5).

As vehicle ownership increased, people have tended to live further away from the center of the city and make longer and more frequent trips. To achieve the goal of containment the city proposed the creation of a multi-nodal city organized around 15 commercial district centers. However, only a few of these have been built as of yet.

While vehicle ownership is on the rise, 36% of the people commute by walking or by bicycles. The poor prefer to use these modes as bus fares are beyond their means.

| Mode | Estimated share of transport mode (%) - 1999 | | |
|-----------------------------|--|------------------------|------------------|
| | Low-Income population | High-Income Population | Total Population |
| Cycle | 39 | 3 | 24 |
| Bus | 31 | 36 | 33 |
| Car | 0 | 28 | 12 |
| Scooter / motorcycle | 3 | 29 | 14 |
| Three-wheeled scooter taxis | 1 | 2 | 1 |
| Taxi | 0 | 0 | 0 |
| Rail | 1 | 0 | 1 |
| Other vehicles | 3 | 0 | 1 |
| Walking | 22 | 2 | 14 |
| Total | 100 | 100 | 100 |

Table 5.04 Estimated share of transit modes by income groups. Source: Tiwari, Geetam (2003) "Transport and Land Use Policies in Delhi" Bulletin of the World Health Organization 81(5).

Currently public transit is primarily by the bus services operated by the state run Delhi Transport Corporation and a number of private operators. Three wheeled scooter taxis is the other preferred mode of transit, but is more expensive than the bus.

A cause of concern has been the growing air pollution rates. Forced by judicial activism, the Delhi government brought out regulation making it mandatory for all public transit vehicles to run on CNG

(Compressed Nitrogen Gas) instead of petroleum based fuels like gasoline and diesel. The advantage of CNG being that it burns much cleaner than conventional fuels. Yet as CNG gains ground, it has prompted an array of energy-sector strains and demands. Long waiting lines at the gas stations have become a constant sight. How those pressures are addressed will ultimately determine the fuel's progress—or lack thereof—in capturing additional market share.

The ongoing construction of the first phase of the mass rapid transit rail system is being seen as an important counter measure to reduce congestion and pollution. [Refer Fig. 5.08] The mass transit system is expected to reduce energy consumed by vehicles, because it will consume only 10% of that consumed by individual transport modes.

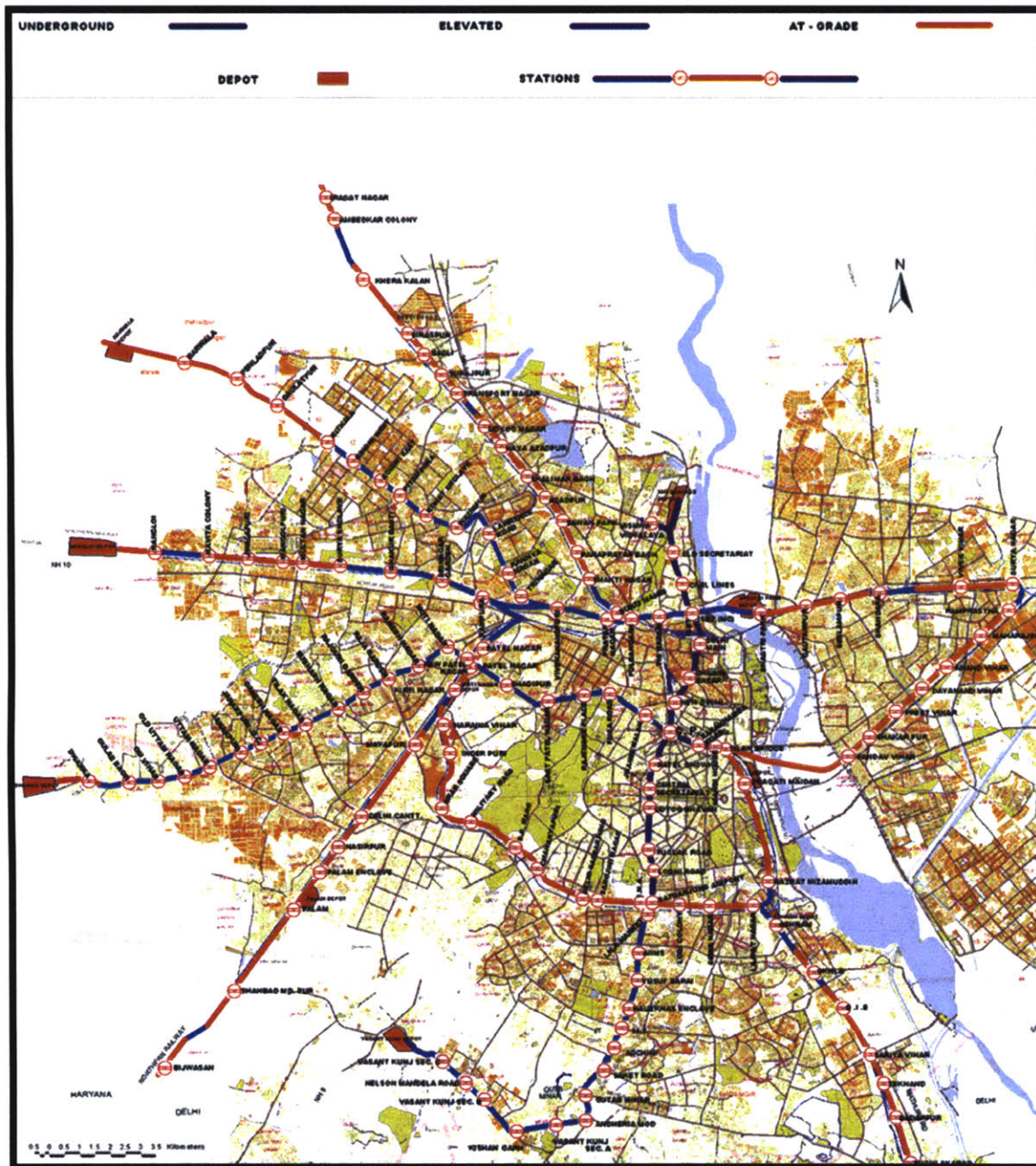


Fig. 5.08: Map showing proposed routes for Delhi's metro rail.

Source: Delhi Metro Rail Corporation

DELHI'S GROWTH MANAGEMENT POLICIES

The 1962 Master Plan called for acquisition of land in the periphery, which would then be developed by DDA at medium density levels. "The city was to be multi-functional with the government, distributive trade and industries (other than heavy industries) offering the main economic thrust; multi-modal public transport was to be given priority along with bicycles in a land-use pattern where work and home were to be largely segregated at zonal levels; social and physical infrastructure was to be at appropriate standards; and a hierarchy of greenery was to be developed permeating through the urban fabric, incorporating protected monuments where feasible"¹³ The 1961 Master Plan did away with the need for private enterprise and placed all development (which was preplanned and pre-deterministic) with the government.

The problem with the plan was that the ring towns (at the doorstep of the city) grew at a much faster rate, making the city a much larger urban contiguous agglomeration than ever before. "Without an adequate land protection machinery, usurpation of large tracts of unprotected land was rampant - both by those who could afford and those who were drawn to the city for survival."¹³ DDA, which was solely responsible for the development of the peripheral land, was unable to keep pace with the demand for new housing; hence land remained vacant for large periods of time. In an effort to belatedly solve the problem a lot of hasty development was undertaken with

disastrous implications.

In 1986, the National Capital Region (NCR) Planning Board was created as an autonomous agency in charge of formulating the regional plans for the Delhi region (which included parts of the neighboring states of Rajasthan, Haryana and Uttar Pradesh). The board came out with NCR-Regional Plan 2001, whose main agenda was to deflect population growth from Delhi to identified Regional Centers or 'Priority Towns' in NCR by the year 2001.

The Master Plan for Delhi, 2001 (MPD-2001) also called the concept plan, recommends reduced growth rate in Delhi; normal rate of growth in the NCR and accelerated growth rate in counter-magnets, which are outside commuting distances of Delhi. The aim is to guide planned decentralization of the growth to the outer areas of the city, and develop the satellite towns (such as Meerut, Faridabad and Sonapat) surrounding it.

While the 2001 Master Plan was touted as a land use cum transportation plan, the MPD 2021 plan is to be an integrated urban services cum transportation cum land use structure plan that is flexible in structure with periodic checks on its projected growth expectations. Apart from the creation of the satellite towns, other measures include

- Expanding the Delhi Urban Area. (4000 ha of new residential land)
- Densification of census towns of Najafgarh, Nangloi, Bawana and Alipur.

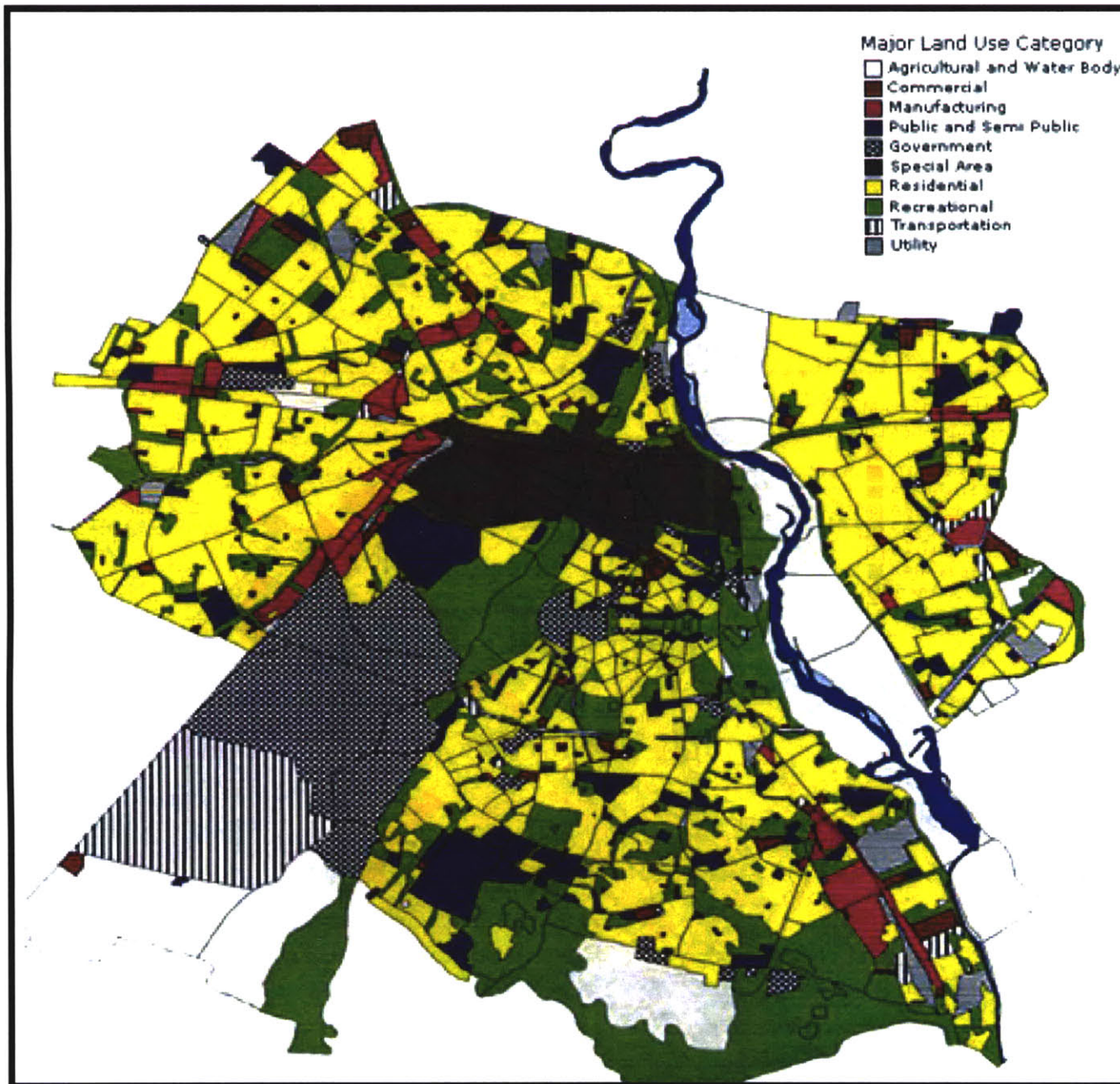


Fig. 5.09: Delhi Land Use Plan

Source: Master Plan for Delhi 2000

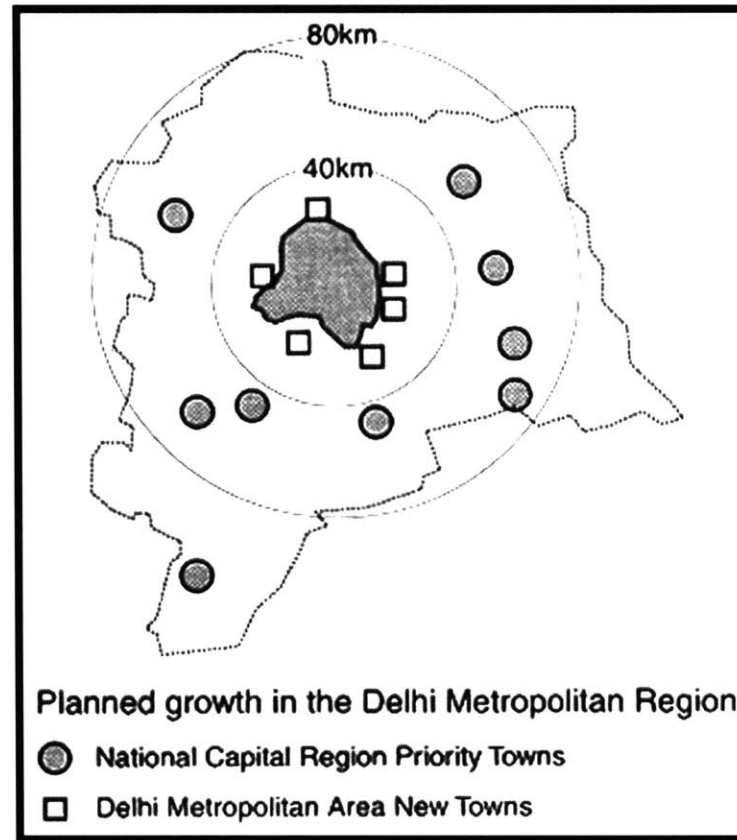
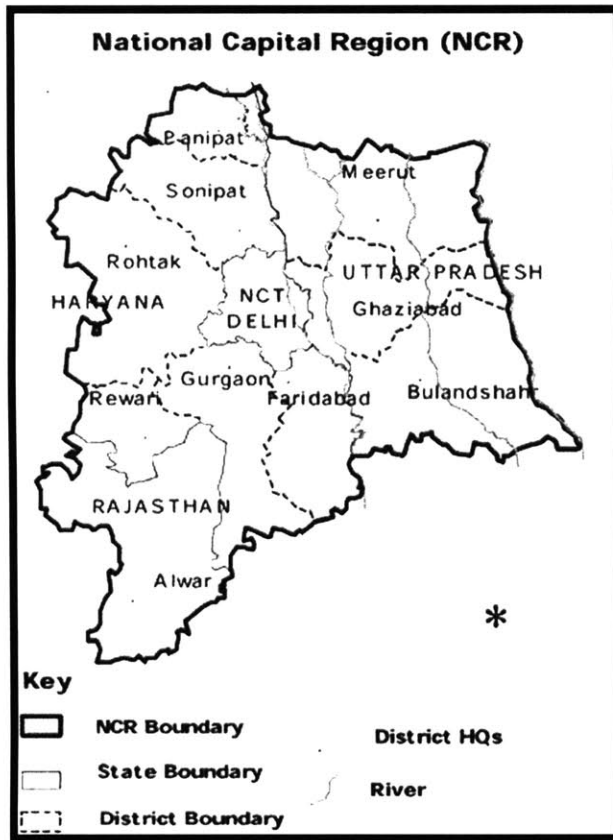


Fig. 5.10: (far left) National Capital Region- showing neighboring cities that fall under this category.

Source: Tiwari, Geetam (2003) "Transport and Land Use Policies in Delhi" Bulletin of the World Health Organization 81(5).

Fig. 5.11: (left) Planned growth in Delhi Metropolitan Region
Source: Jenks, Mike and Burgess, Rod (eds. 2000) "Compact Cities"

- Increasing the holding capacity of existing development. (Allow individual owners of plotted land to build 3 stories instead of 2 ½)
- Encourage group housing (apartments) rather than plotted low-rise development.
- Creation of two sub-cities – Rohini and Dwarka.
- Creation of self contained divisions. The Delhi Master Plan calls for a cellular structure, where each unit is self-sufficient.

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9. EWS - Economically Weaker Section
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MIG - Middle Income Group
SFS - Self Financing Scheme

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6

EPILOGUE

CHAPTER OUTLINE

- 6.1 INCREASING THE HOLDING CAPACITY OF THE INNER CORE
 - Repealing ULCRA and imposition of Vacant Tax
 - Political will need to convert bungalows to high rise structures
 - Improve infrastructure to accommodate intensified usage
 - Review reasons for high vacancy rates
 - Repeal Rent Control
 - 6.2 DENSIFICATION OF PERIPHERAL CENSUS TOWNS/ SUBCITIES
 - Link transport and employment to new housing settlements
 - Review role of DDA
 - Strategize ways to prevent developers from undertaking leapfrog development
 - Strengthen farming activities
 - 6.3 TRANSPORTATION POLICY TO REDUCE TRAVEL LENGTHS AND AIR POLLUTION
 - Review policy of self-sustained neighborhoods
 - Operation of Delhi Metro
 - Taxing policies
 - 6.4 SATELLITE TOWNS TO ACT AS COUNTER MAGNETS FOR IN-MIGRATION
 - Better co-ordination needed between the various towns
 - Review Squatter settlement policies
-

Delhi's urban spatial structure makes it unique amongst Indian cities. Due to political, historical and the plotted bungalow development the city has suppressed density levels in the center. Hence unlike Mumbai which has a density of 600+ persons per hectare, Delhi's 100 persons per hectare appears miniscule. At the same time the city faces massive immigration, and realises it has to expand and also increase its own holding capacity in order to contain so many people. The city agencies have taken measures to address these problems. Delhi growth management policies can be divided into the following four categorizations.

- INCREASING THE HOLDING CAPACITY OF THE INNER CORE,
- DENSIFICATION OF PERIPHERAL CENSUS TOWNS / SUBCITIES,
- TRANSPORTATION POLICY TO REDUCE TRAVEL LENGTHS AND AIR POLLUTION and
- SATELLITE TOWNS TO ACT AS COUNTER MAGNETS FOR IN-MIGRATION.

6.1 INCREASING THE HOLDING CAPACITY OF THE INNER CORE

(i) BRINGING VACANT/DERELICT LAND TO PRODUCTIVE USE: REPEALING ULCR Act

By repealing the infamous Urban Land Control and Regulation Act (ULCRA) the government hoped to release a significant amount of vacant land for development purposes.

In 1977, the then government advocating socialist policies had passed the Urban Land Control and Regulation Act to check the concentration of finite and valuable resources like land in the hands of a few. The act was a sequel to the ceiling placed on the agricultural land. The idea was to prevent speculation and profiteering and to ensure equitable distribution of land in urban agglomerations to sub serve the common good. In class A cities like Mumbai and Delhi, one could thus not own more than 500 sq. mts of land. However the law provided the state governments the right to grant discretionary exemptions under a host of pretexts. Many of the landowners in collusion with the powers to be got themselves the exemptions. Thus only 8% of the total land identified was actually confiscated.¹ In spite of its noble intentions the act ended up restricting the supply of housing; effecting the poor and the middle class. Over the years it was felt that releasing this land back for development would help ease out the housing situation. Hence in 1999, the government repealed the act.

However opponents of the repeal argue that this would not help ease out the problem of housing for the poor since most of the released land exists in the center of the city, which would have rents far from the reach of the poor. They argued that since the reversion of the land also accompanied investments made by the government in providing infrastructure to this land, the value of the land being reverted had accrued many fold. Hence developers would have to buy land at prime rates, making it difficult for them to build housing for the low-income groups.

In my view, since most of the land being released is in the center of the city, consequently the demand for floor space too shall be high [refer Rodriguez-Bachiller model in section 4] This should result in more intense compact development, especially since the developer would want to extract maximum profits. Although the poor might not necessarily consume these developments, it shall cause a trickle down effect by releasing floor space for the lower income group in other areas as the rich shift from their housing location. Also, policies can be set in place that mandate a certain percentage of housing be kept aside for those below a certain income level. This is a practice commonly followed in neighboring cities of Noida and Gurgaon.

Further, the report presented by the National Commission of Urbanization (1990) to look into the issue of ULCRA had recommended the imposition of a vacant land tax. Any land that was kept vacant and not being developed in cities should have a tax/fine imposed on them, ranging from INRs 2 to INRs 50 per sq.mt, depending on the size of the town and location of the land amongst other things. This money would then be paid to the town's shelter fund. While the ULCRA was repealed, there was no mention of the vacant land tax. The Bangalore Municipal Corporation charges a vacant land tax on any land in excess of three times the built up area of the property at 30 per cent of the rate applicable to the built-up area.² This would act as a deterrent for landowners and builders that leave land vacant for speculative reasons.

Delhi should consider imposing a similar vacant land tax to augment the gains made by repealing the urban land ceiling act.

(ii) INTENSIFICATION OF THE BUNGALOW ZONE

In a city where space and affordable housing are scarce, there exist government bungalows in the NDMC area (that house ministers and high ranking civil servants) sitting on huge plots of land. The government rightfully argues for the densification of the 'Lutyen's Building Zone.' Not much has been done in this regard, due to lack of political will.

This is a step in the right direction. The government should clarify to the critics, that this act does not entail eating away the green spaces; rather it is an intensification of existing built areas.

(iii) ALLOWING EXISTING OWNERS OF INDIVIDUAL PLOTS TO INTENSIFY

The government allowed existing owners to build an additional 1/2 floor. Hence structures, which were previously allowed 2 1/2 floors, could now build upto 3 floors. A large part of the inner core of Delhi is composed of small plotted residential land.

As family size increased, it was a common practice in households to illegally add some rooms or even an additional floor over the allowable limit. People figured that DDA would subsequently legalize these illegal developments. Hence this act achieves little but legalizes these structures. Through this act the city tacitly admits that there is considerably more demand for floor space than the allowable limit. Throughout the city, private builders in collusion with the owners of the plot have even built 4-5 stories, when legal provision is for only 2 1/2 stories.

Many argue that the city's infrastructure is not upto scratch to deal with such intensification. Land development entails the provision of a host of services (such as water supply, drainage, sewerage, solid waste management, electricity and roads). These are provided by public agencies using age-old technologies. There is an urgent need of reforms – incorporation of alternative and appropriate technologies.

(iv) REVIEW REASONS FOR THE HIGH VACANCY RATE

Vacancy rate reflects the number of houses that are physically vacant. Internationally a vacancy rate of 5% is considered the norm. Delhi's vacancy rate of 11.2% is considerably high considering the fact that the city has an acute shortage of housing. Three possible explanations can be provided. Although no regulations exist to tackle this problem. I am propose some

actions that the city government could consider.

(a.) Property owners receive little or no support from the law enforcing agencies. Most house owners preferred to lock up their property rather than renting them out to unknown people. This is because of their own bad experience, or what they have heard or read about the bitter experiences of others, and the fact that rent control laws favor tenants.

The Delhi Rent Control Act 1958 freezes rent according to the levels fixed by the Rent Controller. The act applies to all houses that are rented below INRs 3,500 per month. [However, it does not apply to houses rented by the government or religious organizations or foreign nationals.] This act has killed the incentive to build housing for rent, especially affecting the rental market for the poor.

Of the built stock, rent control has mostly affected housing in the Old Delhi areas and commercial properties in the downtown Connaught Place. Renters of such spaces have exerted tremendous political pressure to ensure that the act is not repealed. In 1995, the Delhi High Court amended the Act arguing that the rule was not fair to the right of the landlord to obtain his/her livelihood. The three sections amended include

1. Section 6, which did not permit increase of rent of the old properties for the purpose of expenditure, improvement, and any structural alteration
2. Section 4 that had barred the recovery of any rent in excess

of the fixed standard rent and

3. Section 9 that provided that the standard rent was to be fixed by the rent controller.

“Illustrating the relation between increase of rent allowed under Section 6 of the Act and devaluation of rupee since 1939, the court said a house rented out for INRs 100 that year would merely fetch INRs 229 to a landlord in 1998, while the value of rupee had decreased from INRs 38.26 to INRs 2.97 during the same period.”³

Sauvik Chakraverti (2002) points to the case of Kathmandu, which has no slums. According to him this is due to the fact that there is no rent control provision in that city.

“It is noteworthy that there are no slums in Kathmandu, Nepal, although the per capita income there is much lower than in Delhi, simply because there is no rent control and landlords have an incentive to invest in housing. These landlords rent out their properties happily to poor people because they are secure in the knowledge that the law will not side with the tenant and deprive them of their properties some day.”⁴

(b.) There have been instances where housing schemes have been located in areas with no employment opportunities. A case in point is the relocation of thousands of families to Narela and Bawana. The project aimed to “relocate and rehabilitate slum dwellers from the most untenable and disaster prone sites of Delhi by providing them access to land at affordable

rates, infrastructure and also tenurial status for land ownership in the joint name of the husband and wife”⁵ Poor planning on the part of the government in choosing such remote areas for development has resulted in the DDA being able to allot only 1000 out of the total 8000 flats built by it in early 1990s. On its part the Delhi Government has promised to connect the region with the metro rail network. (The earliest that could possibly be achieved is the 4th phase of the metro, which is scheduled to be operational in 2016). In spite of offering 30% discounts on the already subsidized low cost housing, there are few takers. Adding to the problem is the small size of the plots and the poor construction quality.

Since 2000, more than 100,000 slum settlements have been displaced 10-25 km. from their original locations. “This has led to not just reduced employment opportunities but also increased dependence on motorized transport for that is often too expensive for households that survive on limited casual income from the informal sector.”⁶ Delhi can learn from Stockholm, where many of the suburbs have regulations that allow developers to build only to the extent that they can prove that there are a corresponding number of jobs in the neighborhood.

(c.) Overbuilding of higher-end apartments by the numerous builders based on an expected boom in the market that failed to take place. Inherently in real estate supply lags demand (due to construction time). The housing delivery process is

such that developers start construction based on perceived expected demand. On many occasions the housing stock appears in the market when that demand has waned or did not take place as expected. At this stage the builder is not willing to sell at a low rate nor is the market ready to absorb new space, hence housing stock remains vacant until demands picks up or if the developer is ready to sell at a lower price. This phenomenon is compounded by the fact that there are far too many players in the market trying to cash in on the new demand.

It is difficult to accurately predict what the demand will be in the future; hence overbuilding is inevitable to a certain extent. However, access to greater information on data such as current floor space construction, etc might reduce overbuilding.

6.2 DENSIFICATION OF PERIPHERAL CENSUS TOWNS / SUBCITIES

(i) LINK TRANSPORT AND EMPLOYMENT TO NEW HOUSING SETTLEMENTS

[Refer section 6.1 (iv) (b)]

(ii) REVIEW THE ROLE OF DDA

The creation of the sub-cities Rohini and Dwarka can be classified as successes for the DDA. They reflect DDA’s commit-

ment to high-rise, high-density development.

However, with the DDA being involved in numerous other responsibilities, it has become difficult for the agency to keep pace with development and disposal of serviced land under it. The government needs to review the monopolistic role of DDA.

Private participation has been successful in lands where DDA found it expensive and time consuming to negotiate. The new means of acquiring land for development is being advocated through "a) guided land development for large areas, b) land pooling for compact areas, c) land reconstitution for in-situ upgrading in small parcels in core areas, and d) acquisition for a public purpose under Central or State Acquisition Acts."⁷

Further the success of private builders in developing land in Gurgaon and Noida, suggests that DDA should restrict its role to that of a guiding body.

6.3 TRANSPORTATION POLICY TO REDUCE TRAVEL LENGTHS

(I) REVIEW POLICY OF SELF-SUSTAINED NEIGHBORHOODS

Vehicle traffic forms the largest source of energy consumption in the city. Travel lengths are continuously increasing in the city. To achieve the goal of reducing travel length and hence

energy consumption, the master plan has divided the city into 15 regions. (7 Urban and 8 Rural). The aim is to create multi nodal, self sustained neighborhoods around a Commercial District Center (CBD), which is to be the source of employment for those living around it. Each neighborhood is to be self sufficient in terms of markets, schools and employment. Thus the city authorities feel bulk of the need to travel shall be taken care of.

As mentioned in chapter 2, the ability to control the dispersion of home and work locations is limited. Such a policy will have limited effect on travel behavior.

- Housing is expensive in Delhi and not many people prefer to rent due to few safeguards for the landlord. Hence moving costs are enormous and people will prefer the extra commute than shift to a new location.
- Those living in multi-worker households and able to relocate would prefer home locations that are in-between their respective jobs.
- Of the 15 proposed CBD's only 4 have been completed. This has caused increased travel commutes for those who have to work in one of the CBD's not in their neighborhood.

Further policies that mandate that children attend a school within a 8 km. radius of their homes, deny the children/parents the opportunity to choose a school of their preference.

(ii) CONSTRUCTION OF THE MASS RAPID TRANSIT SYSTEM

It is argued that the metro rail will take quite a while to catch up with the current service levels of the state run bus service. The metro rail will need 200 km of transit lines to match the catchment area of the state run bus service that runs on about 650 different routes.

The mass rapid system should operate in conjunction with the existing Bus Service, and not as competitor. Working in tandem, the coverage of public transit will be greatly enhanced. Also, the mass rapid transit will bring make development competitive in many of the outlying regions.

Some papers suggest that the construction of the mass transit might lead to less congestion on the roads. This in turn would encourage the use of cars. In a sense the poor shall subsidize for the rich to use the roads. This line of thought is debatable.

Of greater concern is the pricing policy for public transit. At today's rates, public transit is beyond the reach of the poor. Those that use it might reconsider if public transit is not seen as competitive enough to private transport cost wise. Private transit has an edge over public transit in that it provides direct work to home service with no waiting periods. A study conducted in Delhi shows that 11% of those who use the private buses (popularly called chartered buses in Delhi - these are more expensive than the state run buses) own cars and 44%

own a motorcycles or scooters.⁶ The cost of a ride on these private buses charge a flat rate of INRs 10 (which is what state buses charge for distances over 10kms). This is the cost needed to run a scooter or motorcycle for approximately 10 kms. If prices are raised further, many of those who commute on these buses might consider using their two wheelers.

6.4 SATELLITE TOWNS TO ACT AS COUNTER MAGNETS FOR IN-MIGRATION

(i) NEED FOR BETTER CO-ORDINATION BETWEEN CITIES

Delhi will have to continue to grow in geographical terms to accommodate the natural growth and the new migrants. Since land within the city core will always be finite, the city will have to pass on some of the development to areas in the neighboring states. Due to this reason the National Capital Region board was appointed to look into development in the Delhi metro region. The idea of a National Capital Region is laudable, though it has a potential problem - it requires coordination between the city of Delhi and the three neighboring states, whose perceptions and priorities might not match. However Delhi should take the initiative in ensuring there is cooperation between the states.

By building efficient transportation links to the surrounding areas and developing the suburbs, would enable the growth of secondary and tertiary towns.

(ii) HOUSING THE POOR - "SHELTER FOR ALL"

In 1991, about 14.5% of the population lived in slums. High rates of rural-urban migration and the inability of the authorities to provide housing have resulted in the gulf between housing demanded and that provided for. Only 62.17% of the houses in Delhi have electricity, toilet and safe drinking water. Rent control and the ULCRA have killed the incentive to provide housing for rent. [Only 4% of the squatter settlements in Delhi pay rents.] Added to this, mismanaged strategies of relocating slum dwellers have backfired. Parth Shah suggests ways to increase effective supply of land in the cities. "First, allow high-rise construction. Second, build proper transportation links - roads, monorails - to the surrounding areas; let the suburbs develop. Efficient transportation would also enable growth of secondary and tertiary towns"¹⁶

While there are ample banks and housing finance agencies providing loans for the MIG/SFS and even LIG housing, no such mechanism exists for the lowest strata of society. There is need for providing indirect funding for those desirous of a EWS housing unit. This shall bring the EWS housing be in the reach of a far greater percentage of poor employed in the informal sector.

Building byelaws should incorporate special provisions for the urban poor concerning plot size, built up areas, setbacks

and other relevant parameters. It is important to note that the needs of the urban poor are different, for example their household formation rates are twice that of the others. The city has been working on building night shelters for the poor.

Some urban planners and economists have argued for the inclusion of the private sector in solving the problem of increasing the housing supply, as practiced in Haryana (Delhi's neighboring state). The Haryana government insists on the inclusion of 20% EWS houses for any land developed by private developers. These houses are for persons with a monthly family income of less than INRs 2,500 per month and allotment is made by draw of lots. The state government fixes the size of the plot and their rates. Mumbai offers a 20% increase in the permissible Floor Space Index for developers allotting 60% of the plots for LIG or EWS housing.

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APPENDIX A: CODE FOR HYPOTHETICAL MODEL

```
#include <math.h>
#include <stdlib.h>
#include <assert.h>
#include <gsl/gsl_cdf.h>

#define XDIM 11
#define YDIM 11

#define AVG 2
#define MAXBLOCKS 60

#define MINDIS 4.23

#define NSAMPLES 1000

#define RANDSEED 0

#define d(p1, p2) (sqrt(pow(p1.x-p2.x, 2.0)+pow(p1.y-p2.y,
2.0)))
#define min(a, b) (((a)<(b))? (a):(b))

typedef struct {
    int x;
    int y;
} point;

point grid[XDIM][YDIM];

point work1[1];
point work2[4];

int blocks[XDIM][YDIM];
```

```
void init();
void allocateBlocks();
int checkBlockAllocation();
point *findClosest(point p, point works[], int nWorks);
point *findFurthest(point p, point works[], int nWorks);

main() {
    int i, j, k;
    float totalDis;

    init();

    for (i=0; i<NSAMPLES; i++) {
        do {
            allocateBlocks();
        }
        while (!checkBlockAllocation());

        // case 1
        totalDis = 0.0;
        for (j=0; j<XDIM; j++) {
            for (k=0; k<YDIM; k++) {
                float dis;

                dis = d(grid[j][k], work1[0]);
                // printf("d[%d,%d]=%f\n",j,k,dis);
                if (dis>=MINDIS)
                    totalDis += blocks[j][k]*dis;
            }
        }
        printf("%f", totalDis/(AVG*XDIM*YDIM));

        // case 2
        totalDis = 0.0;
        for (j=0; j<XDIM; j++) {
```

```

for (k=0; k<YDIM; k++) {
    float dis;

    dis = d(grid[j][k], (*findClosest(grid[j][k],work2,4)));
    if (dis>=MINDIS)
        totalDis += blocks[j][k]*dis;
    }
}
printf("\t%f", totalDis/(AVG*XDIM*YDIM));

// case 3
totalDis = 0.0;
for (j=0; j<XDIM; j++) {
    for (k=0; k<YDIM; k++) {
        float dis;

        dis = d(grid[j][k], (*findFurthest(grid[j][k],work2,4)));
        if (dis>=MINDIS)
            totalDis += blocks[j][k]*dis;
        }
    }
printf("\t%f", totalDis/(AVG*XDIM*YDIM));

printf("\n");
}
}

void init() {
    int i, j;

    srand(RANDSEED);

    for (i=0; i<XDIM; i++) {
        for (j=0; j<YDIM; j++) {

```

```

            grid[i][j].x = 3*i+1;
            grid[i][j].y = 3*j+1;
        }
    }

    work1[0] = grid[XDIM/2][YDIM/2];

    work2[0] = grid[XDIM/4][YDIM/4];
    work2[1] = grid[(XDIM*3)/4][YDIM/4];
    work2[2] = grid[XDIM/4][(YDIM*3)/4];
    work2[3] = grid[(XDIM*3)/4][(YDIM*3)/4];
}

void allocateBlocks() {
    int i, j;
    int totalBlocks = 0;

    for (i=0; i<XDIM; i++) {
        for (j=0; j<YDIM; j++) {
            if ( ( ((i==XDIM/4) || (i==(3*XDIM)/4))
                && ((j==YDIM/4) || (j==(3*YDIM)/4)) )
                || ( (i==XDIM/2) && (j==YDIM/2) ) ) {
                int t;
                t = min(AVG, XDIM*YDIM*AVG-totalBlocks);
                blocks[i][j] = t;
            }
            else if ( (i!=(XDIM-1)) || (j!=(YDIM-1)) ) {
                double r, t1;
                int t3, t4;
                r = (rand()+0.0)/RAND_MAX;

                if (r<0.08)
                    blocks[i][j] = (XDIM*YDIM*AVG-totalBlocks+0.0)/
                    ((XDIM-i-1)*YDIM+(YDIM-j));
            }
        }
    }
}

```

```

else {
    t1 = gsl_cdf_gamma_Pinv(r, 2.0, 1.0);

    t3 = (int)rint(t1);
    t4 = min(t3, XDIM*YDIM*AVG-totalBlocks);
    blocks[i][j] = t4;
}
}
else
    blocks[i][j] = XDIM*YDIM*AVG-totalBlocks;

totalBlocks += blocks[i][j];
// printf(" %d", blocks[i][j]);
}
// printf("\n");
}
}

```

```

int checkBlockAllocation() {
    int i, j, nzeros;
    nzeros = 0;
    for (i=0; i<XDIM; i++) {
        for (j=0; j<YDIM; j++) {
            if (blocks[i][j] == 0)
                nzeros++;
        }
    }

    if ( (nzeros+0.0) > (0.3*XDIM*YDIM) )
        return 0;

    return 1;
}

```

```

point *findClosest(point p, point works[], int nWorks) {

```

```

    int i;
    float dis, tmp;
    point *res;

    dis = 3*(XDIM+YDIM);
    res = works;

    for (i=0; i<nWorks; i++) {
        if (d(p,works[i]) <= dis) {
            res = &(works[i]);
            dis = d(p, works[i]);
        }
    }

    return res;
}

```

```

point *findFurthest(point p, point works[], int nWorks) {
    int i;
    float dis, tmp;
    point *res;

    dis = 0;
    res = works;

    for (i=0; i<nWorks; i++) {
        if (d(p,works[i]) >= dis) {
            res = &(works[i]);
            dis = d(p, works[i]);
        }
    }

    return res;
}

```

APPENDIX B - DATA SET

| CITY | Residential Density | Travel time per work-trip (mn) | World Bank Income Level |
|-----------------|---------------------|--------------------------------|-------------------------|
| Mbeya | 90.4 | 20.00 | Lower |
| Accra | 65.2 | 21.00 | Lower |
| Varanasi | 241.6 | 22.40 | Lower |
| Kampala | 171.4 | 22.70 | Lower |
| Chennai | 296.2 | 23.00 | Lower |
| Chisinau | 105.0 | 24.60 | Lower |
| Bujumbura | 91.0 | 25.00 | Lower |
| Mwanza | 142.0 | 30.00 | Lower |
| Niamey | 45.1 | 30.00 | Lower |
| Tangail | 237.0 | 30.00 | Lower |
| Ulaanbaatar | 127.0 | 30.00 | Lower |
| Bangalore | 246.3 | 30.00 | Lower |
| Medan | 189.0 | 30.00 | Lower |
| Mumbai (Bombay) | 603.0 | 33.00 | Lower |
| Bishkek | 85.0 | 35.00 | Lower |
| Surabaya | 206.2 | 35.00 | Lower |
| Porto Novo | 54.9 | 40.00 | Lower |
| Douala | 128.1 | 40.00 | Lower |
| Khartoum | 67.2 | 42.00 | Lower |
| Delhi | 351.5 | 44.00 | Lower |
| Ibadan | 30.7 | 45.00 | Lower |
| Kigali | 78.6 | 45.00 | Lower |
| Dhaka | 258.3 | 45.00 | Lower |
| Abidjan | 424.5 | 45.00 | Lower |
| Nouakchott | 131.6 | 50.00 | Lower |
| Baku | 67.6 | 56.50 | Lower |
| Kinshasa | 207.5 | 57.00 | Lower |
| Lagos | 193.8 | 60.00 | Lower |

| CITY | Residential Density | Travel time per work-trip (mn) | World Bank Income Level |
|-------------------------|---------------------|--------------------------------|-------------------------|
| Cotonou | 117.0 | 60.00 | Lower |
| Bangui | 82.1 | 60.00 | Lower |
| N'Djamena | 86.7 | 64.00 | Lower |
| Tbilisi | 215.9 | 70.00 | Lower |
| Cochabamba | 98.9 | 17.00 | Lower-middle |
| Cajamarca | 126.3 | 20.00 | Lower-middle |
| Windhoek | 37.1 | 20.00 | Lower-middle |
| Novi Sad | 75.7 | 21.00 | Lower-middle |
| El Alto | 173.0 | 25.00 | Lower-middle |
| Tirana | 198.0 | 25.00 | Lower-middle |
| Asuncion | 158.0 | 25.00 | Lower-middle |
| Nis | 91.9 | 25.00 | Lower-middle |
| Podgorica | 87.3 | 26.00 | Lower-middle |
| Santa Cruz de la Sierra | 101.6 | 29.00 | Lower-middle |
| Trujillo | 126.3 | 30.00 | Lower-middle |
| Curitiba | 216.8 | 30.00 | Lower-middle |
| Sofia | 162.50 | 32.00 | Lower-middle |
| Quito | 281.7 | 33.00 | Lower-middle |
| La Paz | 201.7 | 35.00 | Lower-middle |
| Recife | 209.5 | 35.00 | Lower-middle |
| Bogota | 193.6 | 39.00 | Lower-middle |
| Belgrade | 96.0 | 40.00 | Lower-middle |
| Guayaquil | 177.3 | 45.00 | Lower-middle |
| Rio de Janeiro | 136.3 | 51.00 | Lower-middle |
| Cairo | 660.2 | 59.50 | Lower-middle |
| Camaguey | 120.3 | 60.00 | Lower-middle |
| Moscow | 225.2 | 62.00 | Lower-middle |
| Pinar del Rio | 99.6 | 80.00 | Lower-middle |

| CITY | Residential Density | Travel time per work-trip (mn) | World Bank Income Level |
|---------------|---------------------|--------------------------------|-------------------------|
| Rennes | 109.7 | 14.00 | Upper |
| Koper | 45.7 | 15.00 | Upper |
| Strasbourg | 215.8 | 15.00 | Upper |
| Des Moines | 13.4 | 16.40 | Upper |
| Dubai | 160.5 | 17.50 | Upper |
| Cardiff | 54.4 | 20.00 | Upper |
| Salt Lake | 6.43 | 20.00 | Upper |
| Hartford | 15.0 | 21.00 | Upper |
| Amsterdam | 152.1 | 22.00 | Upper |
| Copenhagen | 47.9 | 22.00 | Upper |
| Toronto | 91.6 | 23.00 | Upper |
| Portland | 12.9 | 23.60 | Upper |
| London | 44.86 | 24.00 | Upper |
| Seattle | 18.8 | 24.00 | Upper |
| Melbourne | 67.0 | 25.00 | Upper |
| Marseille | 98.3 | 25.00 | Upper |
| Atlanta | 9.2 | 26.00 | Upper |
| Hertfordshire | 50.7 | 27.00 | Upper |
| Maribor | 28.8 | 28.00 | Upper |
| Stockholm | 23.9 | 28.00 | Upper |
| Ljubljana | 101.8 | 30.00 | Upper |
| Singapore | 60.50 | 30.00 | Upper |
| Paris | 109.0 | 35.00 | Upper |
| New York | 72.0 | 36.50 | Upper |
| Hong Kong | 174.9 | 44.00 | Upper |
| Tokyo | 133.96 | 45.00 | Upper |
| Seoul | 480.70 | 47.00 | Upper |
| Athens | 94.7 | 53.25 | Upper |

| CITY | Residential Density | Travel time per work-trip (mn) | World Bank Income Level |
|------------|---------------------|--------------------------------|-------------------------|
| Prague | 111.4 | 22.00 | Upper-middle |
| Bratislava | 71.2 | 34.00 | Upper-middle |
| Tallin | 73.2 | 35.00 | Upper-middle |
| Santiago | 94.0 | 38.00 | Upper-middle |
| Budapest | 123.0 | 40.00 | Upper-middle |

APPENDIX C - DATA SET

| CITY | Residential Density | Private motorized | Train/ Tram | Bus/ Minibus | Bicycle/ walking/ Other | NonPrivate | Total | Travel time per work-trip (mn) | Expenditure on road | Automobile ownership - cars/1000 pop. | City product / capita (1993) normalized by Purchasing Power Parity |
|-------------------------|---------------------|-------------------|-------------|--------------|-------------------------|------------|--------|--------------------------------|---------------------|---------------------------------------|--|
| Mwanza | 142.0 | 6.8% | 0.0% | 24.2% | 69.0% | 93.2% | 100.0% | 42.00 | \$0.07 | 39.80 | \$ 192.24 |
| Khartoum | 67.2 | 30.2% | 0.0% | 63.4% | 6.4% | 69.8% | 100.0% | 45.00 | | 7.03 | \$ 204.69 |
| Kano | 267.5 | 9.9% | 0.0% | 55.6% | 34.6% | 90.2% | 100.1% | 44.00 | \$3.98 | 205.40 | \$ 345.00 |
| Varanasi | 241.6 | 2.3% | 0.0% | 21.4% | 76.5% | 97.9% | 100.2% | 70.00 | \$0.73 | 71.00 | \$ 845.77 |
| Bujumbura | 91.0 | 12.4% | 0.0% | 48.2% | 39.4% | 87.6% | 100.0% | 25.00 | \$2.78 | 10.90 | \$ 864.00 |
| Porto Novo | 54.9 | 8.0% | 0.0% | 0.0% | 92.0% | 92.0% | 100.0% | | | 37.00 | \$ 956.16 |
| Delhi | 351.5 | 24.6% | 0.4% | 62.0% | 13.0% | 75.4% | 100.0% | 24.60 | \$1.90 | 60.00 | \$ 1,058.48 |
| N'Djamena | 86.7 | 17.0% | 0.0% | 35.0% | 48.0% | 83.0% | 100.0% | 56.50 | \$1.32 | 46.00 | \$ 1,332.00 |
| Bangalore | 246.3 | 39.6% | 0.0% | 35.7% | 24.7% | 60.4% | 100.0% | 45.00 | \$26.36 | 38.26 | \$ 1,337.03 |
| Abidjan | 424.5 | 15.8% | 0.0% | 49.1% | 35.1% | 84.2% | 100.0% | 23.00 | \$4.41 | 101.80 | \$ 1,457.77 |
| Niamey | 45.1 | 19.4% | 0.0% | 17.0% | 63.6% | 80.6% | 100.0% | 22.40 | \$0.84 | 85.27 | \$ 1,487.50 |
| Trujillo | 126.3 | 18.7% | 0.0% | 74.3% | 7.0% | 81.3% | 100.0% | 35.00 | | 233.00 | \$ 1,658.39 |
| Tbilisi | 215.9 | 2.2% | 64.6% | 32.9% | 0.3% | 97.8% | 100.0% | 30.00 | \$5.83 | 49.50 | \$ 1,671.36 |
| Chisinau | 105.0 | 15.0% | 0.0% | 80.0% | 5.0% | 85.0% | 100.0% | 45.00 | \$33.72 | 27.20 | \$ 1,731.87 |
| Dhaka | 258.3 | 4.6% | 0.0% | 9.2% | 86.2% | 95.4% | 100.0% | 30.00 | \$2.30 | 22.00 | \$ 1,854.84 |
| Freetown | 73.2 | 5.0% | | 84.0% | 11.0% | 95.0% | 100.0% | | \$2.10 | 4.17 | \$ 1,885.80 |
| Kigali | 78.6 | 11.0% | 0.0% | 32.0% | 57.0% | 89.0% | 100.0% | 50.00 | \$4.70 | 81.00 | \$ 1,903.69 |
| Kampala | 171.4 | 17.6% | 0.2% | 44.5% | 37.7% | 82.4% | 100.0% | 22.70 | \$0.50 | 53.30 | \$ 1,923.68 |
| Douala | 128.1 | 28.0% | 0.0% | 11.2% | 60.8% | 72.0% | 100.0% | 26.00 | \$35.00 | 7.30 | \$ 2,436.31 |
| Bishkek | 85.0 | 10.0% | 60.0% | 20.0% | 10.0% | 90.0% | 100.0% | 35.00 | \$0.94 | 109.00 | \$ 2,540.74 |
| Medan | 189.0 | 10.1% | 3.0% | 40.7% | 46.2% | 89.9% | 100.0% | 33.00 | \$29.00 | 81.70 | \$ 2,637.96 |
| Cochabamba | 98.9 | 33.7% | 0.0% | 45.9% | 20.4% | 66.3% | 100.0% | 35.00 | | 47.00 | \$ 2,674.32 |
| Chennai | 296.2 | 1.5% | 4.1% | 37.9% | 56.5% | 98.5% | 100.0% | 30.00 | \$3.38 | 39.00 | \$ 2,770.29 |
| La Paz | 201.7 | 31.2% | 0.0% | 50.5% | 18.2% | 68.7% | 99.9% | 17.00 | \$7.64 | 111.12 | \$ 3,139.32 |
| Santa Cruz de la Sierra | 101.6 | 35.5% | 0.0% | 60.4% | 4.1% | 64.5% | 100.0% | 35.00 | \$10.84 | 70.71 | \$ 3,422.85 |
| Kinshasa | 207.5 | 3.0% | 1.0% | 60.0% | 36.0% | 97.0% | 100.0% | | \$7.20 | 9.20 | \$ 3,494.44 |
| Recife | 209.5 | 28.6% | 1.8% | 44.2% | 25.4% | 71.4% | 100.0% | 28.00 | \$30.47 | 337.00 | \$ 5,546.73 |
| Bogota | 193.6 | 7.4% | 0.0% | 74.8% | 17.8% | 92.6% | 100.0% | 30.00 | \$27.00 | 286.00 | \$ 6,641.16 |
| Athens | 94.7 | 36.0% | 10.2% | 23.8% | 30.0% | 64.0% | 100.0% | | \$89.18 | 350.00 | \$ 8,772.14 |

| CITY | | Private motorized | Train/ Tram | Bus/ Minibus | Bicycle/ walking/ Other | NonPrivate | Total | Travel time per work-trip (mn) | Expenditure on road infrastructure - 1993 US\$/ pers | Automobile ownership - cars/1000 pop. | City product / capita (1993) normalized by Purchasing Power Parity |
|----------------|--------|-------------------|-------------|--------------|-------------------------|------------|--------|--------------------------------|--|---------------------------------------|--|
| Seoul | 480.70 | 20.1% | 32.3% | 38.8% | 8.8% | 79.9% | 100.0% | 17.50 | \$214.00 | 162.00 | \$ 9,672.23 |
| Maribor | 28.8 | 36.0% | 1.0% | 40.0% | 23.0% | 64.0% | 100.0% | 20.00 | \$140.00 | 350.00 | \$ 10,027.17 |
| Moscow | 225.2 | 15.0% | 63.7% | 21.0% | 0.3% | 85.0% | 100.0% | 51.00 | \$51.02 | 177.00 | \$ 10,475.51 |
| Curitiba | 216.8 | 13.6% | 0.0% | 71.8% | 14.6% | 86.4% | 100.0% | 40.00 | \$34.00 | 288.00 | \$ 10,538.78 |
| Asuncion | 158.0 | 65.0% | 0.5% | 30.0% | 4.5% | 35.0% | 100.0% | 62.00 | \$21.30 | 138.00 | \$ 10,562.23 |
| Budapest | 123.0 | 31.1% | 66.3% | 0.0% | 2.6% | 68.9% | 100.0% | 27.00 | \$59.62 | 490.00 | \$ 14,493.45 |
| Bratislava | 71.2 | 13.0% | 25.0% | 47.0% | 15.0% | 87.0% | 100.0% | 22.00 | \$101.00 | 500.00 | \$ 14,888.86 |
| Toronto | 91.6 | 64.8% | 30.1% | 0.0% | 5.1% | 35.2% | 100.0% | 36.50 | \$123.22 | 232.00 | \$ 17,168.78 |
| Tilburg | 87.8 | 44.0% | 3.0% | 3.0% | 50.0% | 56.0% | 100.0% | 22.00 | \$125.00 | 223.00 | \$ 18,196.58 |
| Strasbourg | 215.8 | 46.0% | 7.0% | | 47.0% | 54.0% | 100.0% | | \$83.60 | 471.00 | \$ 18,399.28 |
| Rio de Janeiro | 136.3 | 11.5% | 5.4% | 61.1% | 22.0% | 88.5% | 100.0% | 53.25 | | 354.00 | \$ 19,237.52 |
| Singapore | 60.50 | 25.1% | 14.5% | 38.7% | 21.7% | 74.9% | 100.0% | 15.00 | \$51.60 | 360.00 | \$ 20,756.90 |
| Hong Kong | 174.9 | 8.0% | 34.0% | 53.0% | 5.0% | 92.0% | 100.0% | 28.00 | \$80.00 | 390.00 | \$ 21,649.22 |
| Duisburg | 162.4 | 64.0% | 12.0% | 9.0% | 15.0% | 36.0% | 100.0% | | | 445.00 | \$ 22,401.87 |
| Greater London | 44.86 | 43.0% | 18.0% | 16.0% | 23.0% | 57.0% | 100.0% | 24.00 | | 330.00 | \$ 24,434.29 |
| Stockholm | 23.9 | 35.1% | 34.5% | 13.8% | 16.6% | 64.9% | 100.0% | 25.00 | \$187.00 | 330.00 | \$ 25,065.17 |
| Amsterdam | 152.1 | 60.0% | 22.0% | | 18.0% | 40.0% | 100.0% | 35.00 | \$248.00 | 426.00 | \$ 25,642.03 |
| Atlanta | 9.2 | 93.3% | 4.4% | | 2.9% | 7.3% | 100.6% | 26.00 | \$71.69 | 473.00 | \$ 26,444.00 |
| Seattle | 18.8 | 87.1% | 7.9% | | 4.9% | 12.8% | 99.9% | 24.00 | \$119.10 | 654.00 | \$ 29,633.00 |
| Des Moines | 13.4 | 95.4% | 2.0% | | 2.6% | 4.6% | 100.0% | 16.40 | \$104.04 | 657.00 | \$ 30,414.00 |
| Paris | 109.0 | 55.0% | 33.0% | 7.0% | 5.0% | 45.0% | 100.0% | 24.00 | \$119.10 | 654.00 | \$ 30,514.61 |
| New York | 72.0 | 32.5% | 38.7% | 12.7% | 16.1% | 67.5% | 100.0% | 59.50 | \$5.70 | 59.10 | \$ 30,952.00 |
| Koeln | 186.3 | 41.0% | 0.0% | 17.0% | 42.0% | 59.0% | 100.0% | 21.00 | \$116.00 | 335.00 | \$ 31,835.56 |
| Hartford | 15.0 | 93.3% | 3.7% | | 3.0% | 6.7% | 100.0% | 21.00 | \$116.00 | 335.00 | \$ 44,392.00 |

APPENDIX D - DATA SET

| CITY | Residential Density | Total Urbanized Areas (km ²) | Private motorized | Train/ Tram | Bus/ Minibus | Bicycle/ walking/ Other | Non-pvt Motorized Transit | Travel time per work-trip (mn) | Automobile ownership - cars/1000 pop. | Pump Price for super gasoline (US \$ per liter - 1998) - PPP | City Product / capita (PPP adjusted) (\$ in '000s) |
|-------------------------|---------------------|--|-------------------|-------------|--------------|-------------------------|---------------------------|--------------------------------|---------------------------------------|--|--|
| Dhaka | 258.3 | 1193.9 | 4.62% | 0.03% | 9.19% | 86.16% | 95.4% | 45.00 | 7.03 | 1.74 | \$ 1.85 |
| Porto Novo | 54.9 | 50.0 | 8.0% | 0.0% | 0.0% | 92.0% | 92.0% | 40.00 | 60.00 | 0.76 | \$ 0.96 |
| Bujumbura | 91.0 | 100.0 | 12.40% | 0.00% | 48.20% | 39.40% | 87.6% | 25.00 | 10.90 | 2.88 | \$ 0.86 |
| Douala | 128.1 | 144.0 | 28.0% | 0.0% | 11.2% | 60.8% | 72.0% | 40.00 | 29.00 | 0.92 | \$ 2.44 |
| N'Djamena | 86.7 | 64.0 | 17.00% | 0.00% | 35.00% | 48.00% | 83.0% | 64.00 | 13.00 | 2.35 | \$ 1.33 |
| Abidjan | 424.5 | 369.4 | 15.8% | 0.0% | 49.1% | 35.1% | 84.2% | 45.00 | 38.26 | 1.25 | \$ 1.46 |
| Kinshasa | 207.5 | 590.6 | 3.0% | 1.0% | 60.0% | 36.0% | 97.0% | 57.00 | 25.00 | 2.36 | \$ 3.49 |
| Tbilisi | 215.9 | 203.5 | 2.2% | 64.6% | 32.9% | 0.3% | 97.8% | 70.00 | 71.00 | 1.03 | \$ 1.67 |
| Varanasi | 241.6 | 103.7 | 2.3% | 0.0% | 21.4% | 76.5% | 97.9% | 22.40 | 85.27 | 2.84 | \$ 0.85 |
| Delhi | 351.5 | 624.3 | 24.60% | 0.40% | 62.00% | 13.00% | 75.4% | 44.00 | 205.40 | 2.84 | \$ 1.06 |
| Chennai | 296.2 | 612.0 | 1.5% | 4.1% | 37.9% | 56.5% | 98.5% | 23.00 | 101.80 | 2.84 | \$ 2.77 |
| Nouakchott | 131.6 | 71.8 | 16.50% | 0.00% | 45.00% | 38.50% | 83.5% | 50.00 | 81.00 | 1.60 | \$ 1.23 |
| Chisinau | 105.0 | 131.3 | 15.00% | 0.00% | 80.00% | 5.00% | 85.0% | 24.60 | 60.00 | 0.97 | \$ 1.73 |
| Niamey | 45.1 | 223.8 | 19.4% | 0.0% | 17.0% | 63.6% | 80.6% | 30.00 | 40.00 | 2.15 | \$ 1.49 |
| Kigali | 78.6 | 47.0 | 11.0% | 0.0% | 32.0% | 57.0% | 89.0% | 45.00 | 27.00 | 2.55 | \$ 1.90 |
| Khartoum | 67.2 | 249.0 | 30.2% | 0.0% | 63.4% | 6.4% | 69.8% | 42.00 | 39.80 | 1.21 | \$ 0.20 |
| Mwanza | 142.0 | 93.8 | 6.8% | 0.0% | 24.2% | 69.0% | 93.2% | 30.00 | 12.80 | 1.59 | \$ 0.19 |
| Kampala | 171.4 | 202.0 | 17.6% | 0.2% | 44.5% | 37.7% | 82.4% | 22.70 | 53.30 | 3.85 | \$ 1.92 |
| Cochabamba | 98.9 | 68.0 | 33.7% | 0.0% | 45.9% | 20.4% | 66.3% | 17.00 | 111.12 | 1.20 | \$ 2.67 |
| La Paz | 201.7 | 51.0 | 31.2% | 0.0% | 50.5% | 18.2% | 68.7% | 35.00 | 70.71 | 1.20 | \$ 3.14 |
| Santa Cruz de la Sierra | 101.6 | 165.0 | 35.5% | 0.0% | 60.4% | 4.1% | 64.5% | 29.00 | 99.24 | 1.20 | \$ 3.42 |
| Rio de Janeiro | 136.3 | 1255.3 | 11.5% | 5.4% | 61.1% | 22.0% | 88.5% | 51.00 | 177.00 | 1.64 | \$ 19.24 |
| Bogota | 193.6 | 481.6 | 7.4% | 0.0% | 74.8% | 17.8% | 92.6% | 39.00 | 52.39 | 0.89 | \$ 6.64 |
| Quito | 281.7 | 178.5 | | | | 0.0% | 0.0% | 33.00 | 81.70 | 0.05 | \$ 0.20 |
| Asuncion | 158.0 | 67.1 | 65.0% | 0.5% | 30.0% | 4.5% | 35.0% | 25.00 | 87.00 | 1.28 | \$ 10.56 |
| Trujillo | 126.3 | 45.3 | 18.7% | 0.0% | 74.3% | 7.0% | 81.3% | 30.00 | 49.50 | 1.34 | \$ 1.66 |
| Copenhagen | 47.9 | 2863.0 | 25.0% | 13.0% | 14.0% | 48.0% | 75.0% | 22.00 | 223.00 | 0.81 | \$ 26.43 |

| | | | | | | | | | | | |
|----------------------|-------|---------------|--------|--------|--------|--------|-------|-------|--------|------|----------|
| Strasbourg | 215.8 | 78.3 | 46.0% | 7.0% | | 47.0% | 54.0% | 15.00 | 360.00 | 0.97 | \$ 18.40 |
| Paris | 109.0 | 2586.0 | 55.0% | 33.0% | 7.0% | 5.0% | 45.0% | 35.00 | 426.00 | 0.97 | \$ 30.51 |
| Amsterdam | 152.1 | 201.6 | 60.0% | 22.0% | | 18.0% | 40.0% | 22.00 | 351.10 | 1.03 | \$ 25.64 |
| Maribor | 28.8 | 737.7 | 36.0% | 1.0% | 40.0% | 23.0% | 64.0% | 28.00 | 337.00 | 1.09 | \$ 10.03 |
| Ljubljana | 101.8 | 274.9 | 43.00% | 0.10% | 20.00% | 36.90% | 57.0% | 30.00 | 416.00 | 1.09 | \$ 29.61 |
| Stockholm | 23.9 | 309.0 | 35.10% | 34.50% | 13.80% | 16.60% | 64.9% | 28.00 | 390.00 | 0.75 | \$ 25.07 |
| Hertfordshire | 50.7 | 1604.4 | 70.5% | 2.5% | 4.4% | 22.6% | 29.5% | 27.00 | 490.00 | 1.09 | \$ 12.99 |
| Cardiff | 54.4 | 136.5 | 81.00% | 0.30% | 5.70% | 13.00% | 19.0% | 20.00 | 350.00 | 1.09 | \$ 17.36 |
| Atlanta | 9.2 | 2944.8 | 93.3% | 4.4% | | 2.9% | 7.3% | 26.00 | 473.00 | 0.32 | \$ 26.44 |
| Seattle | 18.8 | 2126.4 | 87.1% | 7.9% | | 4.9% | 12.8% | 24.00 | 654.00 | 0.32 | \$ 29.63 |
| Hartford | 15.0 | 764.1 | 93.3% | 3.7% | | 3.0% | 6.7% | 21.00 | 335.00 | 0.32 | \$ 44.39 |
| Prague | 111.4 | 496.0 | 32.0% | 43.5% | 23.0% | 1.5% | 68.0% | 22.00 | 500.00 | 2.52 | \$ 35.94 |
| Bratislava | 71.2 | 2144.3 | 13.0% | 25.0% | 47.0% | 15.0% | 87.0% | 34.00 | 282.00 | 2.09 | \$ 14.89 |