ABSTRACT: With an estimated 13.8 million people in Delhi in 2001, an overwhelming 93% was urban. Given the highly urbanized character of Delhi, industry, trade and manufacturing offer the maximum employment opportunities for people. In order to study the dynamics of employment distribution over NCT Delhi and to assess the policies outlined for Delhi, certain specific metrics are employed. These include the rank-size distribution and the employment specific preference functions. Results indicate towards the formation of employment centers within Delhi, other than the CBD. Accessibility is an important component of Quality of Life (QoL), which may influence the choice of residential areas. Accessibility indices for different types of land-use activities, i.e. work, education, health and commercial centers are estimated. Accessibility to work has been perceived as the most important by the respondents in Delhi, underpinning the need to investigate job agglomerations in a city where city limits are expanding to accommodate more job opportunities. Transport policies aim to integrate the NCT and the NCR with special focus on the satellite cities, which show high concentration of work centers.

Key words: non-monocentric development, employment specific-preference functions, accessibility, Quality of Life, Delhi
1. INTRODUCTION

India is the world’s second most populous country with a population of more than 1 billion. The population of Delhi stands at almost 15 million with the population density of 10,360 persons/Km$^2$ (2005). It is the third most populous city in India, after Mumbai and Kolkata and ranked 10th amongst the most populous cities of the world. Between 1991-2001 the population grew by 4.1%, making it the fastest growing city in India. Delhi has the largest vehicle population in the country with a close to 4.5 million vehicles in 2004-05. It is more than the sum total of vehicles registered in three other metropolitan cities of Mumbai, Kolkata and Chennai. Interestingly, Delhi which contains 1.4% of the Indian population, accounts for nearly 7% of the total vehicles in India. It is also one of the most polluted cities of the world, according to the Asian Development Bank (ADB/UNESCAP 2000). It has 23% of the land area allocated for roads (as compared to a usual 10-15% for developing countries). The estimated GDP for Delhi stood at 11 billion US $ and a per capita income of 869 US $ in 2005, which is two and a half times the national average. The annual economic growth rate stands at 9.9%. 78% of Delhi’s State Domestic Product (SDP) comes from a strong and growing service sector comprising of trade, hotels and restaurants, transport, communications, financial and insurance services, real estate and public administration. (Economic Survey of Delhi, 2000-2001). Of these, banking and finance, real estate and insurance account for 30% of Delhi’s SDP. Both primary and secondary sectors have been shrinking over the past decade with a contribution of 20 and 1% respectively.

Given the highly urbanized character of Delhi, industry, trade and manufacturing offer the maximum employment opportunities for people. Employment opportunities have steadily increased in Delhi over the years. According to Census of India, Delhi’s workforce went up from 49 % in 1991 to 53% in 2001. Employment in Delhi can be categorized under two sectors, namely organized and unorganized. Close to 75% of Delhi’s organized labor force in employed by central, state or quasi-governments and local bodies. Private sector employs around 25% of Delhi’s organized labor force. An estimated 3.5-4.3 million workers are employed in Delhi’s unorganized sector. Retail, hotels and restaurants account for one-third of the unorganized sector employment. Another 27% are employed in the manufacturing sector.

The objective of the paper is to understand the sub-centre formation and its impacts on commuting patterns for Delhi. Early research into employment location in the mono-centric city (Alonso, 1964) has given way (Anas, 1987) to the observation of a different form of metropolitan structure where offices and firms tend to cluster in sub-centers. Such a non-monocentric structure, where CBD is still the strongest centre, but looses its share of relative metropolitan employment can be of two types. These are dispersed employment and locally-centralized employment (Gray, 1990). In the first, economic activities are rather scattered, and the employment density gradients are somewhat flat outside the CBD. In the second archetype, there is an urban pattern where firms and businesses are clustered, either in some sub-centres or along major transportation corridors where local density gradients are observed.

This paper contributes to research on multi-centric employment centers, with focus on Delhi. Delhi is being studied here as a part of the EASTS International Research Collaborative Activity (IRCA). Earlier work (Alpkokin, 2005) elaborates the dynamics of a non-monocentric structure and the associated commuting patterns. Here, aggregated travel behavior and accessibility are examined for Delhi. The paper is structured as follows. Section 2 describes the study area followed by a brief demographic profile in section 3. Section 4
outlines the Metropolitan Spatial Plans for Delhi. Section 5 focuses on Land-use and Transport Planning as enumerated in the Master Plans for Delhi followed by a brief description of employment centers in Delhi in section 6. Sections 7 describe the analytical tools i.e. Rank size distribution and Preference Functions that are employed to assess the travel behavior in the non-monocentric structure of Delhi. Accessibility is an important component of Quality of Life (QoL), which may influence the choice of residential areas (Kachi, N. 2005). To grasp the perceptions of the people in Delhi towards accessibility, a questionnaire survey was conducted. The results of the survey are indicated in section 8 along with the accessibility indices for different land-uses. Finally the results and conclusions are presented in section 9.

2. STUDY AREA

The national capital territory, Delhi (NCTD) consists of three sub-areas (Fig 1). **New Delhi Municipal Corporation (NDMC)** area is at the core. This is the imperial Delhi spread over an area of 42.74 sq. km. which was established in 1911. It consists of government offices, residential areas and commercial nodes with wide roads, parks and open spaces. **Municipal Corporation of Delhi** includes a total area of 1397 sq. km. (599.6 sq. km. of urban area and 797.7 sq. km. of rural area). It consists of the rather larger spread of Delhi. This area includes the areas of Old Delhi comprising of walled city (Shahjahanabad) and densely built up areas between the Red Fort and New Delhi railway station on the periphery. It includes Civil Lines along the ridge, new development across river Yamuna comprising of Shahadara in North, Patparjhang and Mayur Vihar in South. **Delhi Cantonment** between airport and the NDMC area, is spread over an area of 42.97 sq. km. The Delhi Metropolitan Area (Fig 2) consist of the the NCT region along with the important designated Satellite cities of Delhi, which are Gurgaon, Faridabad, Noida, and Ghaziabad.

3. DEMOGRAPHIC PROFILE

With an estimated 13.8 million people in Delhi in 2001, an overwhelming 93% was urban and
spread over nine districts (Census of India, 2001). Delhi was a uni-district in 1991 census, whereas in 2001 census it was divided into 9 districts. Between 1991 and 2001 the change in the percentage of population in the core city areas has decreased, where as it has largely increased in the spread. There is thus a clear trend in population decentralization, which also is contributing to the phenomenon of urban sprawl. The North-West district constitutes 20.66% of Delhi’s population which is the highest share, where as New Delhi district with 1.25% has the least population. In terms of area, the North-West district occupies the largest share of 29.66% compared to the Central district which occupies a mere 1.68% of the total area of NCT Delhi. As per the 2001 census the population density of NCT Delhi stood at 9294 persons/Km2. North-East district recorded the highest density where as the South-West district showed the lowest population densities. Figure 3(A) shows the ward-wise population distribution and the population density is shown in figure 4(A). The ward wise working population distribution is shown in Figure 3(B) and the corresponding densities are shown in figure 4(B). The proportion of total workers to population is the highest in New Delhi district and the lowest in North-East district.
4. METROPOLITAN SPATIAL PLAN

Master Plan for Delhi (MPD), the first comprehensive plan, for the development of the city was promulgated on 1st September 1962, and has been the frame for guiding developments since then. The land use plan (2001-2021) (MPD- Delhi, 2021) has been prepared based on (i) The policies enunciated for different urban activities (ii) Requirement of additional social and physical infrastructure (iii) Transportation and work centres (iv) Restructuring the land use along the MRTS corridor. The concept of the master plan 2021 is based on a polynodal, polycentric distribution of work centres, largely based on road transport nodes. To achieve spatial balance development should take place according to new corridors of mass movement (Fig. 5). This has implications in terms of land use planning along major transport corridors and the mass rapid transit system. The regional plan 2021 has been drawn up with the reference to the following four policy zones:

- **NCT Delhi**: It is envisaged that no new major economic activities, which may result in the generation of large scale employment related inflows, should be located in this zone, and only activities necessary to sustain the local population, should be permitted.

- **Central NCR**: The Central NCR (earlier the Delhi Metroloplitan Area) as defined in the regional plan-2021, comprises of the notified/controlled areas of the neighboring towns of Ghaziabad, Loni, NOIDA, Greater NOIDA, Gurgaon, Faridabad, Bhandurgarh and Kundli, and the extension of the ridge in Haryana, having an area of about 2000 sq. km.. It has been suggested that the opportunities presented by the Central NCR should be maximized to enable it to compete effectively with NCT Delhi, offering comparable employment, economic activities, comprehensive transport system, housing, social infrastructure.

- **Highway corridor zone**: The NCR Plan has proposed promotion of planned and regulated development along the national highways. However, while planning for these zones, due care has to be taken to ensure that the activities being permitted are segregated from highway traffic through proper green belts, and regulated and controlled access to the highways.

- **Rest of NCR**: In the rest of the NCR (approx. 28795 sq. km.), the basic policy of regional plan-2021 is aimed at accelerated development of urban and rural areas. For this infrastructure has to be substantially upgraded at local and regional level (both by the State and Central governments) in order to induce growth in these areas, specifically in identified settlements/metro centers. This will make them more attractive for locating economic and allied activities and for attracting private sector investment, with a corresponding impact by way of checking migration.

5. LAND USE PLANNING AND TRANSPORT PLANNING

Growth of Delhi over the years has been on a ring and radial pattern, with reliance on road based public transport system. The development envisaged by the previous plans was polynodal with a hierarchy of commercial centres located on either ring or the radial roads. The proposed MRTS network is thought to have a sizeable impact on the structure of the city.

- **Road Network**: Delhi is predominantly dependant on road based transport. Transport network consists of road network and rail network catering to intra-city and inter-city movement of traffic. There are nine major inter urban corridors catering to major intercity traffic. These are National Highways, NH1, NH2, NH8, NH10, NH24, NH24 bypass, NH58, NH57 and Loni Road (State Highway). The road network comprising of ring and radial pattern has CP as the focal point.
Rail Network

The existing railway network in Delhi comprises of two rings and four radials (144 Kms.). The two rings are: Main ring from Nizamuddin to Nizamuddin passing through Lajpat nagar, Patel Nagar, Delhi Kishan Ganj, Sabzi Mandi, New Delhi and Tilak Bridge station (35 kms.), The other ring from Tilak Bridge to Tilak Bridge, through Anand Vihar, Sahibabad, Delhi Shahdara, Delhi main and New Delhi stations (32 Kms.)
About 4.5 Kms stretch between Sadar Bazar and Tilak Bridge Station is common to both the rings. The four radials are one each from Sonepat in the North, Rohtak in the West, Bijwasan in the South-West and Thughlakabad in the South.

- **Mass Rapid Transit System (MRTS)**
  The Metro rail Network for the entire city has been identified in various phases, which comprises of a network of underground, elevated and surface corridors aggregating to approximately 250 kms. within the city (Fig. 6). Extensions are proposed in the routes to the sub cities like Rohini and Narela and additional links of MRTS forming a loop for existing MRTS network. By 2010, phase II of metro rail covering 80% of Delhi and a part of NCR will be completed.

Delhi’s transportation system comprises of personalized transport which has expanded at an extraordinarily fast pace post 1990, and public transport which comprises of mainly buses and recently introduced metro rail. The intermediate public transport (IPT) play a significant role in meeting the transport demand in the absence of an adequate and efficient public transport facility. This has also lead to a substantial increase in the number of personalized means of transport. In the NMT category, the share of bicycle and rickshaws has shown a decreasing trend. The share of mass transit has remained the same low and unacceptable level for the last two decades as shown in the table (Singal B.I, 2003).

<table>
<thead>
<tr>
<th>Table 1: Modal Split trend in Delhi</th>
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<tr>
<td><strong>Modal Split (in percent)</strong></td>
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<tr>
<td>Bus</td>
</tr>
<tr>
<td>Car</td>
</tr>
<tr>
<td>Two-wheeler</td>
</tr>
<tr>
<td>Bicycle</td>
</tr>
<tr>
<td>Cycle Rickshaw</td>
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<tr>
<td>Other</td>
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</table>

In a study by Central Road Research Institute, the modal share of different categories of vehicles has been estimated for different areas of the city (CRRI, 2002). The share of personalized modes (cars and two wheelers) is estimated at 70%, 75% and 64% for inner, middle and outer areas respectively. The share of buses remains at almost 5% in these areas. The IPT modes constitute 19%, 13% and 8% respectively. SMVs constitute 4%, 3% and 16% shares in the total modal share. For Delhi, the average number of trips per person per day has increased from 0.49 in 1969 to 1.10 in 2001 (Ranganathan N. 1995). The average trip length in Delhi has increased from 5.4 Km. in 1969 to 13.5 Km in 2001. The annual growth of travel demand is increasing at the rate of 9.5% in Delhi (Report of the working group on urban transport, Ministry of urban affairs and employment).

<table>
<thead>
<tr>
<th>Table 2: Average number of trips per person per day in Delhi</th>
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<tr>
<td><strong>Purpose</strong></td>
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<tr>
<td>Work</td>
</tr>
<tr>
<td>Education</td>
</tr>
<tr>
<td>Others</td>
</tr>
<tr>
<td>All purpose</td>
</tr>
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</table>
6. DESCRIPTION OF EMPLOYMENT CENTERS

Metropolitan city centres (CBDs)
The existing CBDs, which may also be considered as Metropolitan City Centers, are Walled city and its extension, Connaught Place and its extension and Karol Bagh. These metropolitan centers need to be seen in the light of the historical legacy of the pre-colonial and post-colonial capital cities, of the so-called Old and New Delhi.

District Centers / Sub Central Business District
The district centers are meant to serve as the apex of the multi-nodal activities of the community which should be conceived as major shopping centers, while serving the community with a reasonable variety of other services and facilities as indicated in the table above, and also centers of socio-cultural activities where the community can get together. Some of the District centers already developed or in an advanced stage of development are Nehru Place, Rajendra Place, Bhikaji Cama Place, Janak Puri, and Laxmi Nagar

Wholesale Trade
As per the Economic Survey of Delhi 2001-2002, there are about 37,000 wholesale enterprises in Delhi with an employment of 1.6 lakhs. In addition there are about 6500 enterprises of storage and warehousing providing employment to 27,000 people. Around 20% of the total wholesale trade enterprises of urban Delhi are located in the walled city, accounting for 12% of employment. The average enterprise in the walled city has less employment but high turnover in comparison to units in other areas. The wholesale markets are dealing with 27 major commodities.

Industry
As per the Economic Survey of Delhi 2001-2002, there were about 1,29,000 industrial units in Delhi. The issue of industries in Delhi has been a subject of extensive debate, controversy and concern over the past decade. This has centered mainly on the negative aspects of industries on the environment and the continued growth of the industries in non-conforming areas and the issue of classification and permissibility with reference to household industries.

Government offices
Delhi being the country’s capital provides excellent opportunities in service sector. It has attracted people in government and quasi-government sector from all parts of India. The growth of the sector was significant till 1981. However, as per the report of the Economic Census, 2003, the employment in all government offices except that of Central government and Delhi government is on decline. Government of India, government of NCTD and local bodies are occupying prime land in Delhi for their offices. Most of the offices have been set up immediately after independence. Large areas are underutilized or have completed their economic life. Major GNCTD offices which were located in the Old Secretariat have been shifted to Indraprastha Estate.

7. Employment Distribution and Aggregate Travel Behavior (Preference Functions)

7.1 Rank size distribution: Identifying Employment stock tiers

In order to study the distribution of employment over NCT Delhi and to assess the policies outlined for Delhi, certain specific metrics are employed. These include the rank-size distribution and the employment specific preference functions. The first step is to identify the employment clusters in the study area. The methodology followed is a simple way of clustering the employment locations based on the Traffic Analysis Zones (TAZ) for Delhi. The total number of TAZ for Delhi is 208. From the available OD matrix for all trips, the
work trips (commute trips) are derived based on the percentage of work trips which is 35% of all trips in Delhi. Although this may not give us the precise employment figures, nonetheless this gives a fairly accurate distribution of employment over the study area. Employment density is calculated subsequently for individual traffic zones. In order to identify the employment clusters the logarithmic employment density is plotted against rank size of the zones. The next step is to identify the number of major employment clusters or tiers and their classification through breaks of gradient (Fig 7). The number of clusters depends on the size of the city, the degree of detail aimed at in the analysis and also the sizes of zones. Here the 208 zones are grouped into clusters based upon the visual inspection of the curve. The method adopted for demarcating the zones is as follows. We first identify the rather steep line and mark that as Tier 1. On the other end, a rather tapering curve is identified and marked as Tier 4. The remaining curve is divided into two parts. Thus we divide the curve into 4 Tiers. Four tiers of clusters can also be identified using the Spearman Rank correlation to find out the cut-offs for clustering.

Possible definitions of the four clusters can be given below as:

I. Tier 1 zone as: mature old centers
II. Tier 2 zones as rather developed sub-centers
III. Tier 3 zones as emerging as a sub-center
IV. Tier 4 zones as not necessarily now, but likely to be a sub-center in the long term

Figure 8 shows the zones based on rank size distribution. It may be noted that the number of zones in tier 2 is the largest. Table 3 enumerates the details of the employment stock tiers. It is evident that tier 2 has the largest share of employment (49%) as compared to tier 1 (26%). It may be inferred that the share of CBD in total employment in the case of Delhi is decreasing. This may also be attributed to the policies which plan to decongest the city centre by relocation of employment centers and policies which restrict the establishment of new employment centers in the core city.

Table 3: Details of the different employment stock tiers (2003)

<table>
<thead>
<tr>
<th></th>
<th>Tier 1</th>
<th>Tier 2</th>
<th>Tier 3</th>
<th>Tier 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employment</td>
<td>563855</td>
<td>1058360</td>
<td>339133</td>
<td>186186</td>
</tr>
<tr>
<td>Share over total (%)</td>
<td>26</td>
<td>49</td>
<td>16</td>
<td>9</td>
</tr>
<tr>
<td>No. of zones</td>
<td>24</td>
<td>70</td>
<td>64</td>
<td>50</td>
</tr>
</tbody>
</table>
7.2 Travel pattern and Preference function

Operationally, a Journey-to-work preference function is the relationship between the proportions of travelers from a designated origin zone who reach their workplace destination zone given that they have passed a certain proportion of total metropolitan jobs. Employment specific preference functions are explained elsewhere (Cheung and Black, 2005). For understanding the linkage in between emerging sub-center and associated residential location choices and hence commuting profiles in terms of time and distance, one analytical way is to plot the destination specific employment preference function based on the form of intervening opportunity model. For each employment zone, residential zones are ranked according to increasing distance, or transportation travel time, by car or public transportation, or a weighted combination of the two. The number of residential workers living in each zone is a proxy for housing opportunities. By plotting the cumulative distribution of residential workers reached, a “housing” opportunity surface around that employment zone is constructed. Steep gradients imply a nearby choice of residential location; shallow gradients imply a broader, metropolitan wide spatial labor market. Figure 9 shows the employment preference function plot for the selected zones. The graph shows that the CBD and nearby zones have a wider catchments areas, meaning that people tend to make longer trips to this area. This implies that these zones have the largest spatial housing markets with very few workers living in that employment zone or relatively nearby. On the other hand, the zones located in the outlaying zones, tend to attract shorter trips. This is thought to reflect that the people are showing more tendency to take advantage of choosing residential location closer to where they work in case they commute to the suburban sub-center to lessen the cross commuting.

8. Tracking accessibility and individual perception for urban facilities

Accessibility has a long history in urban planning and increasingly gaining more interest as a tool and key concept in transport and land use development plans. It is an important component of QoL which may influence the decision of residential location. In order to assess the perceptions of the residents regarding accessibility in Delhi, a questionnaire survey was conducted at six different sites (Connaught Place, Chandini Chowk, Vasant Vihar, Sarojini
Nagar, Janak Puri and Shadara) over a total sampling size of 338 respondents. Out of the total sample size 92% respondents were men. This is likely results of a higher ratio of men population and higher ratio of men engaging in daily activities. As one of the questions within this survey, people were asked to reveal their preferences by weighting among the accessibility to: work places, education facilities, health care facilities and commercial centers. The results are aggregated by gender, age group, occupation and family income and given in Figure 10.

Figure 10(a) shows that while men rated accessibility to work as the most important, women rated accessibility to work, education and health services almost equally. In the different age group categories shown in Figure 10(b), respondents in the age group of 30-59 rated accessibility to work as the most important. The age group of 20-29 rated accessibility to education as equally important. Accessibility to health services was rated as the most important by the respondents in the age group of 60-69. Accessibility to work is also rated as the most important by respondents who are engaged in work, (Figure 10c) where as students rated the accessibility to education as the most important. The elderly rated the accessibility to health services as the most important. Figure 10(d) further presents that accessibility to work has been rated almost equally important by all the respondents in different categories of family income. An important observation is that accessibility to commercial centers is not perceived to be an
important factor for the respondents in all the categories, for their choice of residential location. In general access to the work places has received the highest weight from the respondents, underpinning the need to investigate the job agglomerations and the relevant accessibility variations in the cities re-structuring in the form of decentralized concentration. It is not wrong to claim that till date there has been only very few work on the poly-centric dynamics and accessibility changes in the growing metropolitan regions of the developing countries. Since an increase in the accessibility of emerging sub-centers may either be the evidence of a combined transport and land use plans or the dynamics bringing the jobs and houses closer.

In order to discuss the compatibility between the accessibility of different tiers of zones with the non mono-centric urban formation in Delhi we have computed gravity type accessibility indices as the measures indicating the efficiency of reaching opportunities. The basic form of gravity based accessibility function is given by equation 1 (Cervero, R, 1999). Where, \( A_{ij} = \) Accessibility of origin zone \( i \) by the destination zones \( j \); \( L \) is the number of opportunities in zone \( j \); \( f(t_{ij}) \) is impedance function in terms of \( C_{ij} \) as travel time between zones \( i \) and \( j \) for all type of trips.

\[
A_i = \sum_j L \exp^{-\beta t_{ij}}
\]  

(1)

We have calculated the housing accessibility for different types of land-use activities within National Capital Territory (NCT) of Delhi as shown in Figure 11 together with the spatial
distribution of associated urban facilities (Accessibility of work (11a), education (11b), health services (11c) and commercial centers (11d)). Notably, Figure 11a shows that the business centers which accommodate firm office stock tend to locate in the old CBD and the new sub-centers around the old city centers. Evidently, the city centre produced the highest accessibility which decreases towards the city periphery. However, certain agglomerations, most of which are belonging to Tier II, also generated relatively higher accessibility compared to tier III and IV in most cases. Peripheral zones tend to show low values of accessibility, where as peripheral areas near the satellite townships tend to show higher values. The city is therefore expanding its limits into the satellite cities in order to accommodate the overflow of work centers.

One central issue, although not examined here, is to manage a well combined public transport improvements in accordance with a multi-centric urban form evolving in many growing metropolises of the developing countries. Unless such non CBD stocks are served with a public transport network, these sub-centers will add more to the vehicle-kilometers traveled by car as in the case of the North American cities (Morichi, S., 2005) Even more crucially, the cities where two-wheeler and three-wheeler trips are dominating the transport but experiencing a shift from such vehicle to cars will attract more car trips to such sub-centers. Similarly, between 1990 and 2002, the share of two and three-wheeler trips have decreased from to 71% to 66 % and replaced by car trips of which the share has increased from 22 % to 28 %. This paper proved the accessibility variations and increases in the sub-centers within the limitation of available data to authors but it is extremely important to explore not only the tier but also the mode specific accessibility changes.

9. RESULTS AND CONCLUSIONS

The study tries to explore the dynamics of employment distribution based on the analytical framework of employment tiers and associated employment preference curves and accessibility with reference to work, education, health care and commercial centers to understand impacts of non CBD formation residential location and on trip profiles for Delhi. Results indicate that besides the CBD, many areas within the region show a strong tendency towards making an employment centre. Also, relocation of work centers to the satellite cities is leading to further concentration of work centers here, which is shown by the high agglomeration of work centers accompanied by relatively higher accessibility nearby satellite towns. Results of one QoL survey indicate that accessibility to work has been perceived as the most important by the respondents. It is therefore important to target the policies towards better jobs-housing balance. It is evident that the job location into the satellite cities is concentrating along the present highway or the rail network which needs to be further evaluated in line with the public transport improvements.

ACKNOWLEDGEMENTS

This research is funded through EASTS ICRA and the authors thank the society for supporting this project. We also give our special thanks to Prof. Yoshitsugu Hayashi (Nagoya University), Prof. John Black (University of Sydney) for there support and guidance.
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