POLY-CENTRIC EMPLOYMENT FORMATION IN MEGA-CITIES: ANALYSIS FROM APEC-TR COLLABORATIVE RESEARCH

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Abstract: Factors influencing poly-centric employment formation in metropolitan regions are identified and explained. Less is known about the dynamics of change in cities of the developing world so a comparative study was proposed that was successfully funded by EASTS International Collaborative Research Activity (ICRA). A common analytical framework is outlined. This paper presents preliminary empirical findings for rank-size distributions of employment and for employment specific preference functions for the journey from work to home. Comparative findings are presented and interpreted for Bangkok, Canberra, Dalian, Delhi, Istanbul, Sapporo, Sydney, and Tokyo. Directions for on-going research are outlined.

Keywords: Employment Clusters; Poly-centrism in Mega-cities, Commuting trips
1. INTRODUCTION

The fundamental urban trend of the twentieth century has been the decentralization of people, jobs and services from inner dense core of cities to less densely-developed suburbs. Decentralization has varied among many cities depending on their size; pattern of sub-center growth by their size, and distance from the city center; transport network; and economy (Hall and Pfeiffer, 2000). White (1999) has suggested three main reasons why clusters outside the old city occur: as the city gets larger the CBD reaches to its physical capacity to accommodate more employment, which forces up centralized land prices such that land availability and price in the outer suburbs are attractive location features; transportation-related issues, primarily the commuting cost of the labor force and the transport cost of the products; and agglomeration economies (or external scale economies). These factors are less researched in the case of rapidly growing cities in the developing world. Our literature review suggests that the empirical analysis of poly-centric formations and associated trip characteristics is limited to North American cities (Anas, 1987) and therefore stresses the need for more empirical findings from different cities with different characteristics.

The United Nations has predicted that by 2025, 114 cities from the developing countries will exceed 4 million people (Cheema, 1993). In many Asian, African, South American mega-cities, where, in most cases, there has been some decentralization of job opportunities but the central city still maintains its strong dominant role with much better jobs, public facilities and transport infrastructure (Dick and Rimmer, 2002; McGee, 1991; Shakhs, 1996; Yousry and Aboul Atta, 1996; Richardson, 1993). In order to manage uncontrolled, dispersed development in developing cities, an urban pattern of well-designed hierarchical urban centers not only for jobs but with a variety of other urban functions and associated public transport services may provide a solution (Morichi, 2005).

The primary aim of the paper is to illuminate the current status of growing and decentralizing cities, especially those in developing countries, to study urban policy-making on urban spatial and transport re-structuring, and to propose analytical techniques that facilitate cross city comparisons of the dynamics of change. We empirically explore poly-centric dynamics for spatial re-structuring of employment cluster formation outside the old CBD in terms of multi-centric employment urban form, relevant residential location choices and associated commuting characteristics. EASTS International Collaborative Research Activity (ICRA) has awarded our project, entitled Asia Polycentric Employment Collaborative – Transport (APEC – TR), to review relevant policy-making challenges (section 2), empirically analyze poly-centric location dynamics and its impacts on commutes, based on a common analytical framework that can be employed in cases where precise land-use and transport data might be deficient (Alpkokin, et al, 2005a).
This paper briefly introduces simple and practicable techniques of cluster analysis and employment location preference functions techniques and then further applies them to selected case study cities and presents some preliminary results: (Sydney for 1991 and 2001; Canberra for 2001; Tokyo for 1963, 1981 and 2001; Sapporo for 1972, 1986, and 1996; Istanbul for 1985 and 1997; Bangkok for 1995 and 2005; New Delhi for 2003; and Dalian for 2005). Cluster analysis (section 3) first defines employ clusters and then helps to grasp the dynamics - that is the change over time by comparing how locally peaked, or flat, employment distribution is from the CBD. In section 4, employment preference functions examine the impacts of poly-centrism on residential location choices. We also examine commuting patterns, where the main issues are mode share at the employment destination, and the mean trip lengths (journey times) of those workers. Finally, the conclusion points out the further outcomes of the ongoing EASTS ICRA project that will be presented at the EASTS 2007 Conference in Dalian, China.

2. POLY-CENTRIC POLICY-MAKING AND CASE CITIES

There have been applied many policy concepts on non mono-centric urban form, such as “Edge cities in periphery”, “Corridor development”, “Secondary sub-centers for office parks”, “Tiers of locations” in many mega-cities of the developed and the developing world. (See for detailed review on policy-making our complementary ICRA paper of EASTS 07 “Policies for employment centers in metropolitan regions” by Klug, Alpkokin, Black, Hayashi)

We have found the main goals that are crucial to those metropolises of the developing world are to mitigate the stress in the city center that can hardly accommodate any more jobs and on the highway and public transport that inefficiently carries the inward trips, especially commuters. Congestion contributes to time loss, pollution, and the number of accidents. However, one adverse affect of the emerging employment sub-centers is that the suburban areas are very poorly served by public transport, and commuting by car adds much to the vehicle-kilometers traveled (VKT). Nevertheless, poly-centric structures have been promoted because of reductions in trip lengths: Gordon (et al., 1986) found such results for Los Angeles, but Cervero and Wu (1998) showed that, for San Francisco between 1980 and 1990, the average trip distance and time increased by 12%, and 5%, respectively. However, Gordon (1991) found a shortened car commuting time for 20 USA cities.1

1 Automobile commuting time 1980-1985 : New York, from 28.1 to 26.3 minutes; Boston, from 22.0 to 20.4 minutes; and Chicago, from 25.4 to 23.9 minutes.
Some examples that point out some of these issues follow from some of the cities involved in our research project. In Shanghai, public transport share declines substantially with the distance from the city center. The downtown Shanghai public transport share is 30% but the ratio reduces to 20% and to 5%, 20 km and 50 km away, respectively, from city center. Because of financial resource constraints in Bangkok, only the 15 percent of the investment need projections was realized in the “National economic and development plans” between 1997 and 2001 and hence the inner city road traffic congestion became more severe. In Jakarta, the current urban pattern of “Stronger old urban core together with the new and emerging urban cores” contributes to longer trips.

Jakarta decentralization plans were not successful because of a strong investment identity of the old city center. There is detrimental increase of the commuting trips of the morning peak hour especially inbound trips, and the congestion of the roads are becoming more severe. In New Delhi the share of car and two wheelers is higher in the inner city than the outer city (70-75% in the inner city compared with 64% in the outer city). High dependency on two-wheeler transport is another common problem in developing countries apparently contributing to more accidents worsening of road safety.

Istanbul has witnessed emerging centers on the outer skirts of the city, along by the expressways. Although poly-centrism is a long-standing policy in Istanbul, the city has taken on a multi-centric structure more by market driven forces (similar comments apply to Sydney) and the construction of Bosporus bridges and its beltways. However, the extensive bus and minibus network in Istanbul developed along with highway construction: the share of public transport (1997) varied between 58% and 39%. In Sydney, it is only the CBD and North Sydney that retain a high share of commuting trips by public transport (rail, light rail, bus and ferry). Tokyo has been included in this study as a good example for policy-making especially in cities that do not have a rail network. Tokyo is by far the largest metropolitan area in the world, which can be mainly explained by its relatively low commuting costs and highly developed, seamless network of commuter rail and subways. In addition, there is a reimbursement of the commuting expenses by almost all employers, and a very strong culture of railway use.

3. EMPLOYMENT LOCATION DYNAMICS BY CLUSTER ANALYSIS

Early research attempts of identifying sub-centers were not generalizable; but recent approaches in a number of North American cities have described a sub-center as the contiguous set of small size census tracts with given cut offs of minimum and maximum employees per gross acre and tract total employment (Giuliano and Small, 1991; 1999;

Cervero and Wu, 1997; 1998). The way to define these tiers is crucial to any research investigation, especially for comparative studies because different findings on the number of clusters are likely for the same data set and different classifications mislead different and biased results.

Here, on the purpose of deciding the clusters of employment stock in developing countries, where almost in most cases the data is aggregated into medium, or large-scale, traffic analysis zones, we propose a simple and compatible way of defining clusters by employing Zipf’s law of rank frequency distribution, noting that although many studies exist adopting Zipf’s law to a rank size distribution of cities at the regional scale and national scale, there have been only few at the urban level. Logarithmic employment density is plotted against rank size. The exponential relation was obvious since the beginning of 1900’s for the American cities but as also noted by Fujita et al (1999), the rank size rule does not only work well for the American cities that has shown a high speed growth but also for the other countries whose population growth rate was less than that of US cities.

After plotting the rank size distributions as a two-dimensional graph where gross employment density on the y-axis and the ranks on the x-axis, the change in job location patterns and the embryonic emergence of some new sub-centers may be examined by plotting for the available data set for different time points that can tell us more about the pattern of growth (Figure 1). If the increment of employment growth is exactly the same in every zone then the two distributions are parallel (Figure 1 a). Other theoretical patterns are possible: smaller increments in big centers and larger increments in smaller zones – decentralization (Figure 1 b); larger increments in the big centers and smaller increments in the smaller zones – centralization (Figure 1 c); and the possibilities of absolute declines in employment in the larger zones (or in the smaller zones).

Next step is how to decide the number of major employment clusters, and their classification through breaks of gradient in the rank-size distribution. In terms of the number of clusters, there is a tendency for grouping zones into four clusters, or tiers, but the actual number will arise from the data depending on the size of the city. Here, for the degree of spatial detail aimed in this analysis, we divide the zones into four clusters.

\[ N = kS^{-a} \], where \( N \) is the number of cities with population larger than \( S \); and \( k \) and \( a \) are empirically derived parameters.

One example for the few applications of the rank size distribution at the metropolitan level is by Guiliano and Small (1991) who found a good fit for 29 centers in Los Angeles.
The diagram is visually inspected and divided into parts indicated by obvious break of the first slope for the old city center as the highest density zones with the highest ranks and the last slope for the zones with the least dense zones as the zones that are not necessarily accommodating many job opportunities. The medium part of the line is divided in two parts defining Cluster II and Cluster III zones (Figure 2). Cluster analysis by rank size distributions is simple and applicable to the comparative research by providing a normalized way of clustering zones where employment densities may vary by the size of the zones, location of the zones and the extent how densely they are populated with jobs.

One way to explore the spatial extent of the commuting trips attracted to each major employment zone in poly-centric cities is to plot employment specific preference functions (these will be discussed in the next section). Another way is to employ well-known parameters from transport planning studies, such as: vehicle-kilometres travelled; modal share; trip length frequencies (TLF) for the journey-to-work trips attracted to each representative zones selected from each of the employment clusters and to compare different locations over the whole metropolitan area.

Figure 1: Rank-size distributions for employment changes and cluster dynamics

Figure 2: Rank size distribution and classification into clusters
3.1 Results - Case Study Cities

Figure 3 illustrates the approach with the results of rank size plots for four of our case studies: Tokyo, Istanbul, Sydney and Canberra. Tables 1 to 4 further summarize the results of the clustering employment location patterns by giving the total number jobs and metropolitan share for each cluster.

It is obvious that, depending on the cut-offs determining the clusters, the results from each city are very likely to vary. However, we have made a substantial effort not to allow any misspecification having the classification based on the simple way of clustering described in section 3. Upon examining the case cities individually, there are some similarities and also some discrepancies. In all the cases, the steep curve for the CBD (Cluster I) is obvious and similarly a different steep line for the lowest cluster of the zones (Cluster IV).
This is also one result of the zoning policy when conducting classical transport planning studies with medium or large sized zones that is the relatively smaller of the zones in high densely central city areas but larger zones for low density outlaying zones but may provide a compatible base for comparison. Although there is not a clear cut-off between cluster II and cluster III zones, we preferred to divide into two the remaining section as cluster II and cluster III after deciding on more obvious cut-offs for the clusters I and IV to get four tiers of zones in all cases.

Notably, one fact compatible in almost all the cases that the Cluster I zones are still the most dominating zones, having the highest share of the metropolitan total. Only in the case of New Delhi (for 2003) is the employment stock of Cluster II zones almost two times more than those of Cluster I zones showing a substantial decentralization and agglomerations in Cluster II type of zones. There is a very slight increase of the absolute value for the employment stock of the cluster I zones except for Bangkok (not illustrated here) where a considerable loss of job opportunities is apparent.

Tokyo has shown a higher degree of decentralization between 1963 and 1981 showing a high increase of the office stock in Cluster II type of zones compared to the growth between 1981 and 2001 where there has been observed more parallel growth. Land-use plans firmly designate urban nodes for high density center developments both within and outside the Tokyo central area, although there has been some successful stories, in general, Tokyo preserved its highly concentrated structure. The extensive rail network had been improved before, and, together with the rapid growth during the economic boom, has led to concentrations near by the major stations contributing to high public transport share but on the other hand not allowing a more decentralized structure (See for detailed discussion on Tokyo metropolitan area, the complementary ICRA paper of EASTS 07 “Metropolitan Area and its non mono-centric structure in line with its extensive rail network” by Alpkokin, Komiyama, Takeshita, Kato).

In Istanbul (for 1997) Cluster II zones have exceeded Cluster I zones by their share of the total metropolitan area indicating a concentrated decentralization outside the old CBD zones. Results confirm that the real urban dynamics have been occurring outside the Cluster I zones - all of which are located downtown. The largest growth was observed in cluster II and III type of zones proving an urban form of locally centralized, rather than saturated development in line with the “Istanbul Metropolitan Area sub-region master plan” strategies of “Abandoning the concept of concentric development as the single biggest danger that can destroy the historical identity of old city” and “Promoting a growth of the urban macro form in a linear and multi-centered fashion, but with a degree of hierarchical ranking encouraging employment sub-centers, specifically wing attraction centers to control the growth” (Alpkokin,
et al, 2005b).

For the Sydney analysis, rank size distributions were plotted from Census data for 1981, 1991, 1996 and 2001, where the spatial unit of analysis the traffic zone. An estimate was made for its shape in 2031 according to planning targets and various assumptions in the current Metro Strategy, *City of cities: A plan for Sydney’s future*. In the 20 years from 1981 to 2001 there has been an increase in the employment density in all zones. Higher density zones have shown the least change over this period, whilst the biggest change has occurred in lower density zones between 1981 and 1991. Relatively little change has occurred between 1996 and 2001 (see Figure 3c), indicating limited spatial restructuring in that period.

The results for Canberra (although small in population the metropolitan region extends over a large area) are interesting because they reflect the successful implementation of a new, planned city arranged with separate new towns in a broadly linear pattern (extending about 35 km north to south), each with their hierarchy of town, district and local centers, and conforming to a spatial plan devised in the late 1960s (NCDC, 1970) that remains the basis for policy to guide land-use activities (ACT planning and land authority, 2004).

The density of employment is constrained in the central area because of the Griffin legacy – the original design for the new capital city in 1911 by Walter Burley Griffin, a Chicago-based architect, determined that the maximum height of all buildings in the “Parliamentary triangle” be below the height of Parliament House located on Capitol Hill. A policy of decentralized employment into the new towns has meant that zones in Woden and Belconnen also have high densities of employment amidst an otherwise low-density urban landscape.

Similar to Canberra, Dalian also as medium sized but developing city of China is still in the shape of mono-centric accommodating half of the office stock in its central district most of which are the cluster I type of zones. Dalian is also a specific case because of its geographical constraint of being located among the mountains that the limited land resources have been forcing a multi-centric structure. This finding emphasizes all most cities topography is immutable, and can be a major factor in urban form and directions for expansion.
Table 1: Clustering dynamics of employment location in Tokyo metropolitan area

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<td>Total employment</td>
<td>Share over total</td>
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<tr>
<td>Cluster I</td>
<td>4,530,000</td>
<td>56.8%</td>
<td>7,680,000</td>
<td>52.4%</td>
<td>+69.5%</td>
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<td>Cluster II</td>
<td>2,100,000</td>
<td>26.3%</td>
<td>5,370,000</td>
<td>32.6%</td>
<td>+155.7%</td>
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<tr>
<td>Cluster III</td>
<td>1,140,000</td>
<td>14.3%</td>
<td>1,530,000</td>
<td>10.4%</td>
<td>+34.2%</td>
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<tr>
<td>Cluster IV</td>
<td>210,000</td>
<td>2.6%</td>
<td>77,000</td>
<td>0.6%</td>
<td>-63.3%</td>
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Table 2: Clustering dynamics of employment location in Istanbul and Bangkok metropolitan area

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<td>Share over total</td>
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<tr>
<td>Cluster I</td>
<td>1,764,846</td>
<td>27.8%</td>
<td>1,585,323</td>
<td>26.6%</td>
<td>-10.2%</td>
<td>626,213</td>
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<td>Cluster II</td>
<td>3,102,130</td>
<td>48.9%</td>
<td>2,978,931</td>
<td>50.0%</td>
<td>-4.0%</td>
<td>496,514</td>
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<tr>
<td>Cluster III</td>
<td>1,124,646</td>
<td>17.7%</td>
<td>1,013,341</td>
<td>17.0%</td>
<td>-9.9%</td>
<td>449,955</td>
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<td>Cluster IV</td>
<td>358,083</td>
<td>5.6%</td>
<td>384,902</td>
<td>6.5%</td>
<td>7.5%</td>
<td>308,966</td>
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Table 3: Clustering dynamics of employment location in Sydney metropolitan area

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<tbody>
<tr>
<td>Cluster I</td>
<td>28.1 %</td>
<td>28.6 %</td>
<td>0.5 %</td>
<td>30.2 %</td>
<td>1.6 %</td>
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<tr>
<td>Cluster II</td>
<td>24.9 %</td>
<td>22.9 %</td>
<td>-2.0 %</td>
<td>21.8 %</td>
<td>-1.0 %</td>
</tr>
<tr>
<td>Cluster III</td>
<td>40.0 %</td>
<td>40.3 %</td>
<td>0.4 %</td>
<td>40.1 %</td>
<td>-0.3 %</td>
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<tr>
<td>Cluster IV</td>
<td>7.1 %</td>
<td>8.2 %</td>
<td>1.1 %</td>
<td>7.9 %</td>
<td>-0.3 %</td>
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Table 4: Clustering dynamics of employment locations in New Delhi, Dalian, Canberra

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<tr>
<td></td>
<td>Total employment</td>
<td>Share over total</td>
<td>Total employment</td>
</tr>
<tr>
<td>Cluster I</td>
<td>93,299</td>
<td>61.1 %</td>
<td>563,855</td>
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<tr>
<td>Cluster II</td>
<td>42,248</td>
<td>27.7 %</td>
<td>1,058,360</td>
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<tr>
<td>Cluster III</td>
<td>11,989</td>
<td>7.9 %</td>
<td>339,133</td>
</tr>
<tr>
<td>Cluster IV</td>
<td>5,126</td>
<td>3.4 %</td>
<td>186,186</td>
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4. EMPLOYMENT PREFERENCE FUNCTIONS

Suburbanization, and the emergence of the edge cities, together with the outer highways and expressways, has contributed to the stability and even a slight decrease in travel times as cities have expanded (Garrison and Ward, 2000). A number of studies have examined the impacts of poly-centrism on residential location choices and commuting patterns, where the issues are mode share at the employment destination, and the mean trip lengths (journey times) of those workers. There are two contrary arguments and empirical findings. With a decentralized employment and spatial mismatch, cross commuting increases, resulting in more wasteful, or excess, commuting in terms of longer distances traveled. Dubin (1991) discussed that as cities get larger in terms of area and population, they might produce more cross commuting for mono-centric cities than in poly-centric cities, as the workers will possibly tend to reduce their commuting time by taking opportunities provided by a multi-centric structure. This was discussed for hypothetical urban spatial structures by Black and Katakos (1987) who examined the upper and lower bounds to commuting travel based on distance minimizing and distance maximizing theoretical behaviors of workers.

A more analytical way of grasping the residential location preferences for a given employment center is to plot graphically the destination specific-employment preference functions, based on a form of the intervening opportunity model (see, Black, et al., 1993). The estimation of the shape of the zonal preference functions requires data for the zonal number of resident workers, the zonal number of job opportunities, the destination-origin pattern of traffic, and the inter-zonal transport impedance matrix. The estimation of the raw preference function for each employment zone is set out in the following six steps.

I. Residential worker (destination) zones are ranked in order of increasing distance from the employment zone (origin zone).

II. The cumulative numbers of labor-force workers are calculated at increasing distance from the employment zone and these are expressed as a proportion of metropolitan total.

III. From the D/O data, the number workers residing with destinations at increasing distance from the employment zone is set out.

IV. The D/O flows are expressed as a proportion by residential worker (destination) of the zonal trips attractions to the employment zone.

V. The proportions are plotted as a graph.

VI. Finally, a quadratic function in the form of $Y = aX^2 + bX + c$ is determined for curve fitting (other functions could be employed).

For each employment zone, residential zones are ranked according to increasing distance, or better, transportation travel time (by either car or public transportation, or a weighted combination of both) away from that zone. 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 around a sub-center imply a broader, metropolitan-wide, spatial labor market (Figure 4).

Figure 4: Employment location-specific preference functions

4.1 Results - Case Study Cities

The results given in Figures 5 to 8 are an important contribution to the knowledge on comparative urbanization, showing for the first time on the same scale, employment-specific preference functions from job locations to surrounding housing opportunities. Bangkok (Figure 8) displays all of the characteristics that allow interpretations of other graphs and inter-city comparisons to be made. First, when normalized by the opportunity(or accessibility) surface of housing opportunities there is vastly different behavior in each employment zone. The CBD zones have the largest spatial housing markets with very few workers living in that employment zone or relatively nearby. On the other hand, in the outlaying suburban clusters typically about 60% of the workers find their homes in the same or adjacent zones. In Figure 8 the topmost preference function depicts a highly localized spatial housing market for its workers.

Figure 5: Location specific employment preference functions for New Delhi, 2003
Figure 6 makes this point clear for the case of Istanbul. Examples of employment zones drawn from three clusters are depicted in separate colors. The CBD zones have the largest spatial catchment areas for their labor-force. Sapporo (which has a strong mono-centric urban structure) is included here to demonstrate that the preference functions can be used to show change over time as journey-to-work data are available for 1972, 1983 and 1994. Note the stability of the three curves over time for the CBD, and the widening of the spatial labor market with time for the cluster III, outer zone.

Figure 6: Location specific employment preference functions for Istanbul, 1997

Figure 7: Location specific employment preference functions for Sapporo, 1972, 1983, 1994

Figure 8: Location specific employment preference functions for Bangkok, 2005
The richness of interpretation possible using a comparative metric such as the employment-specific preference function can be illustrated by the results obtained for Delhi (Figure 5). The shape of the preference function for the CBD is concave upwards. Other zones have a relatively small (in comparison with other cities) proportion of their workers taking up local housing opportunities. This implies spatial separation and relatively long commutes to these clusters – a matter for further investigation, as will be also undertaken by comparing the shape of the functions obtained for Canberra, Sydney and Tokyo.

5. CONCLUSIONS

Urban structures with “Decentralized concentration of employment” have been observed more frequently since the 1980’s due to population increase and suburbanization; economic growth and industrializations; and motorization and increasing car dependency. Urban planning in some large cities, not only the metropolises of North America but in the cities of the developing world of Asia, Africa and Latin and South America, emphasizes multi-centric urban development. Yet planners, intuitively propose the location, size and location plans without much understanding of poly-centric urban dynamics and their likely economic, social and environmental impacts, and, more crucially, often without well-coordinated transport policies. Our research aims to fulfill some of those gaps by producing a manual for practicing planners and policy makers with examples of analysis and policy assessment by providing some empirical results, based on a framework, especially for those cities that have not been much explored for their poly-centric re-structuring trend and also by interpreting the results for better understanding the poly-centric urban dynamics, a study area which obviously requires different case studies with different characteristics.

This EASTS International Collaborative Research Activity (ICRA), entitled Asia Polycentric Employment Collaborative – Transport (APEC – TR), is the first step towards that goal. This paper contributes to the literature by exploring the non mono-centric configuration of eight urban areas based on an analytical framework. The main focus is on understanding the clustering pattern of employment and relevant residential location choices and commuting characteristics. More leveling or ranking of centers by size and location and compatible transport policies is one very promising solution for the growing cities. Therefore, this collaborative project also aims to illuminate future land-use and transport policy making in line with the decentralized concentration, especially those policies suitable for implementation in developing countries. In order to better utilize the public transport (mass transit) concentrated spot or corridor development is necessary. Beginning with the express buses on priority lanes at the early stage and then moving to higher capacity public transport services is one very efficient strategy to support centers (for example, Canberra).
The next steps are to extend the analysis of case studies and to provide a rigorous descriptive interpretation of the results. The final report will provide more analytical results for cluster analysis and employment preference functions than was possible to provide here within the limitation of space. We will produce maps for spatial visualization of all the case cities, including maps for land use and transport information data illustration/visualization in using GIS.

ACKNOWLEDGEMENTS

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