THE DYNAMICS OF EMPLOYMENT SUB-CENTRE FORMATION IN CITIES OF DEVELOPING COUNTRIES: ANALYTICAL FRAMEWORK FOR POLICY ASSESSMENT

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Abstract: Trends for suburban clustered employment growth in many large cities are found but polycentric employment growth is complicated and subject to many factors. A computer-based analytical framework of research aim, suitable techniques and outcomes for policy analysis are described. Its practical utility to identify clusters and their dynamics is explored with available data for 1985 and 1997 for Istanbul. Impacts on commuting patterns (trip lengths, preference functions and mode share) are analysed for each type of sub-centre identified.

Key Words: urban dynamics, polycentric cities, commuting, personal computer

1 INTRODUCTION

The 1995 Greater Istanbul Master Plan envisages considerable spatial restructuring to accommodate rapid economic growth by 2010, including the location of major employment sub-centres on the European side and the Asian side of the Bosporus Strait. Nevertheless, the determinants of these existing and proposed centres in the planning process were not subject to much analysis, nor understanding of the dynamics of change. A further policy outcome of a more balanced urban environment between homes and workplaces is the containment of commuting distances and travel times, but, again, this has not been subjected to analysis. Such analytical deficiencies in the urban planning process and policy formulation would be common in many cities of the developing world. This is unlike the situation in US cities, for example, where a considerable body of research has accumulated on polycentric employment centres in sprawling metropolitan areas (for example, Cervero and Wu, 1997, 1998; Fujita and Ogawa, 1982; Guiliano and Small, 1991, 1999; McDonald, 1987; Shukla and Wadell, 1991).

This paper describes a practical, personal computer-based analytical framework to guide decision makers when formulating strategic spatial plans. Drawing on data from two Istanbul transport studies at the travel zone level, and information collected from urban planning studies, the methodology is general and could be applied to other cities. Data are coded in TRANPLAN and EMME/2 (transport modelling software) formats, transferred to the spreadsheet programs we have developed then represented visually using GIS software ArcView and 3-D ArcView. Descriptive statistics help identify employment “clusters” and their dynamics, and a novel interpretation of the intervening opportunity trip distribution model (Stouffer, 1940) with its location-specific preference functions, helps determine the spatial extent of urban labour sheds for each employment sub-centre, and how these might have changed over time. The viability of the framework using a personal computer is illustrated with Istanbul as a case study for the period 1985 to 1997.

The analytical framework has been developed from an extensive literature review on urban spatial structure and mono-centric and polycentric employment patterns that is not included in this paper (see, Alpokokin, *et. al.*, in press). Section 2 is based on that literature, but the methodology contained in Figure 1, within a framework of research study purpose and aims, appropriate analytical technique(s), and the expected outcome of the analyses for planning and policy, that we believe is novel, and is included here as a guide for researchers addressing similar planning issues, especially in developing countries. Section 3 illustrates the application of some aspects of the proposed framework to Istanbul – a city straddling the European and Asian continents with a population of some 10 million people (in 1997). The scope is limited to the identification process of employment clusters of differing sizes (four discrete levels), their change from 1985 to 1997, and the associated changes in travel behaviour for selected clusters (mode shares and the spatial extent of commuting). The policy context for Istanbul is only touched upon as details are published elsewhere (see Turkish Republic, Greater Istanbul Municipality, 1988, 1997; Alpkokin, *et al*, in press)

2 PROPOSED ANALYTICAL FRAMEWORK

After a careful review of the analytical methods adopted in previous research we propose a four-step methodology for analysing multi-centric urban form that would be applicable to cities of the developing world. The framework contains three elements: study purpose and aim; the appropriate analytical technique(s); and the expected outcome for planning and policy, as simplified in Figure 1. Each analytical technique has been programmed into spreadsheets used with a personal computer.

Before describing these techniques, it is worth pointing out a little on data preparation and manipulation so as to demonstrate the practical simplicity of the framework. In the case of Istanbul, the data collected from two transport studies by consultants STFA, Planofis and MNL Insaat for the Greater Istanbul Municipality are stored in files as TRANPLAN (for 1985) and EMME/2 (for 1997) formats. If Census data for the journey to work is not collected in any large city then there are probably samples of household travel data, as in Istanbul. The Technical University of Istanbul has operating licences for both of the above software packages. Because we are using both data sets, and Nagoya University only has a licence to operate TRANPLAN, data transfer from EMME/2 was required, taking about one working week (transfer from TRANPLAN to EMME/2 takes less than half of the time). Files from TRANPLAN form the input to the spreadsheet calculations whose outputs are outlined below. Visualisation is achieved with ARCVIEW, 3-D ARCVIEW, and EMME/2 (for the 1997 highway network and journey-to-work desire line graphics).

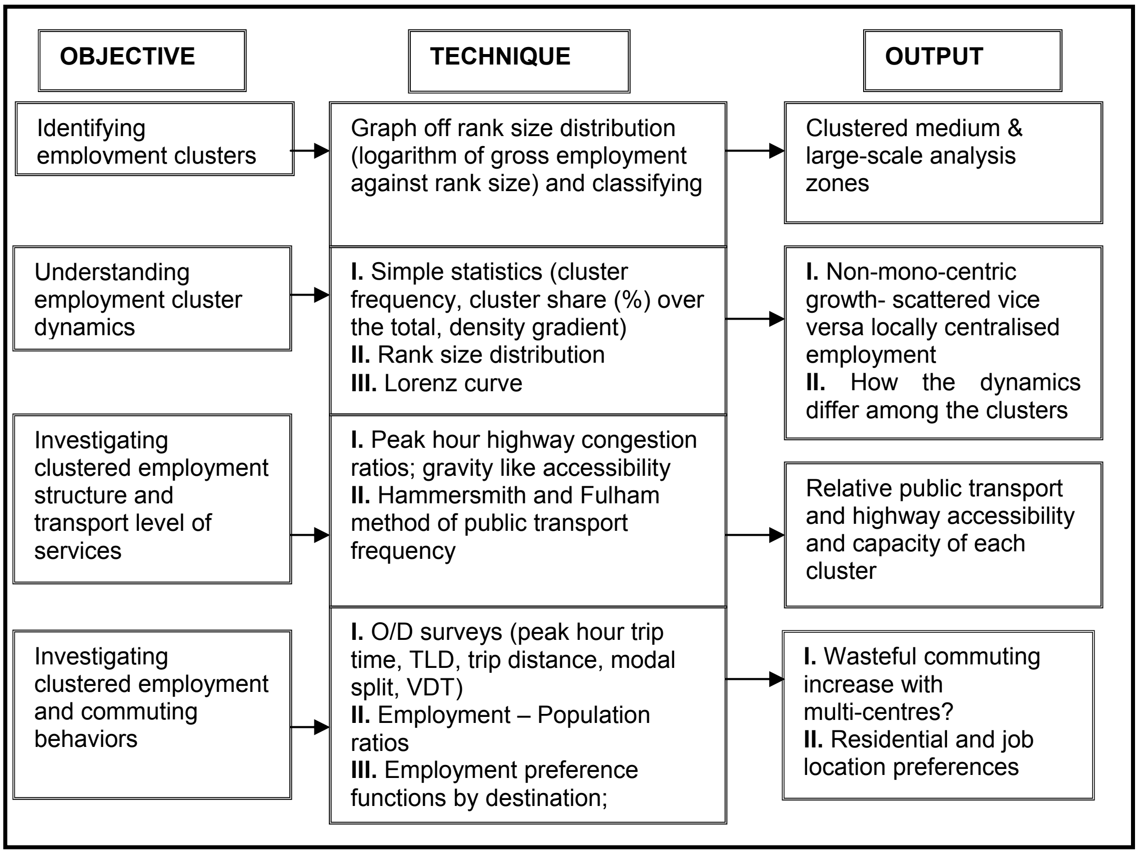

Figure 1 Scheme for the Analysis of Multi-centric Urban Dynamics

Illustrations that are included in this paper are to merely demonstrate typical outputs from the computer programs. A comprehensive application of all techniques and their value in the decision making process is beyond the scope of this paper, and our aim is to publish this in due course using Istanbul as a case study. The scope of this paper is confined to employment cluster identification and cluster dynamics, and to changes in transport and associated travel behaviour. The following sub-sections describe in more detail the contents of the boxes in Figure 1.

2.1 Identifying Employment Clusters

Sub-centres are usually described as the contiguous set of small census tracts each with a minimum density, where all together a minimum total employment cut off is reached. The problem is that this cut-off has varied for different cities.[1] Another method of classification is achieved according to some locational and employment-specific characteristics, such as edge city or Post- World War 2 suburban development that are not necessarily ranked (McMillen and McDonald, 1998).

Our proposed methodology is a simple way of clustering the employment locations, particularly when the data are more aggregate with medium or large scale of traffic analysis zones that most of the trip data in developing cities is based on. Gross employment density is used instead of net employment density in order to omit the very small local density peaks that may lead to wrong conclusions (see, McDonald, 1987). Gross values are also preferred because different land-use functions other than employment may also have a potential capacity for accommodating economic activity in the future.

There have been many studies adopting Zipf's Law[2] to a rank size distribution of cities at the regional scale and national scale, as was demonstrated in Zipf's book, but there have been few at the urban level. One example is Guiliano and Small (1991), who found a good fit for 29 centres in Los Angeles. Logarithmic employment density is plotted against rank size. The rank size distribution thus classified is visually inspected for "changes in gradient" and this ultimately decides the range and the number of the clusters in any specific data set.

The next crucial step is how to decide the number of major employment clusters and their classification. The number of clusters depends on the size of the city, the degree of detail aimed at the analysis and also the sizes of the tracts or zones. As the data are plotted as a two-dimensional graph, simple techniques of "Cluster Analysis" (Kaufman and Rausseeuw, 1990) are appropriate. These are correlations between the variable and the rank using the Pearson coefficient, equal intervals, and similarities of Minkowski distance[3] between the variables. Data groups are searched

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[1]Minimum employment per gross acre and minimum total: For Los Angeles 10 and 10,000 Guiliano and Small (1991) also 20 and 20,000 Small and Song (1994); For San Francisco 7 and 10,000 Cervero and Wu (1997); for Cleveland: 8 and 5000 Bogart and Ferry (1999).

[2] $R_i^{\alpha} \times S_i = K$

[3] The Minkowski distance is:

$$d(i, j) = \left[\sum_{q} \left| x_{i1} - x_{ji} \right|^{q} \right]^{1/q}$$

and it is simplified for one dimension and becomes that each give best fit for linear correlation between logarithmic employment density and rank within themselves using the Pearson correlation coefficient. Once the main clusters are decided by Pearson coefficients further classification can be done either by following equal interval scales or by dividing into sub-clusters proving distance similarities.

2.2 Understanding Employment Cluster Dynamics

Dynamics is concerned with change over time. For developing countries, in the absence of periodic Census data collections, resort must be made to sampling of employment and travel as part of periodic land-use and transport studies. Examining the clusters with the available data set for two (or more) time points is needed to understand the change in job location patterns and the embryonic emergence of some new sub-centres. A number of simple descriptive statistics, such as zone frequencies in clusters, ratios for cluster shares over the total, and employment density gradients, are applied. For its simplicity and relevant explanatory power, linear density function with the distance from CBD is used to analyse the local peaks and steepness around the sub-centres.[4]

Lorenz curve drawn for the cumulative area and the cumulative employment also tells something about the employment layout; as the curve approaches to the diagonal, it indicates a more equal, or a more flat distribution of employment but does not reveal sub-centring or clustering structure and trends. For example, Wadell and Shukla (1993) plotted for Dallas Forth Area and Small and Song (1994) for the Los Angeles area to prove only the employment dispersion. However, the rank size distribution changes can tell us more about the pattern of growth by comparing the rank size distribution over two time periods (Figure 2). If the increment of employment growth is exactly the same in every zone then the two distributions are parallel (Figure 2a). Other theoretical patterns are possible: smaller increments in the big centres and larger increments in the smaller zones – decentralization (Figure 2b); larger increments in the big centres and smaller increments in the smaller zones – centralization (Figure 2c); and the possibilities of absolute declines in employment in the larger zones (or in the smaller zones).

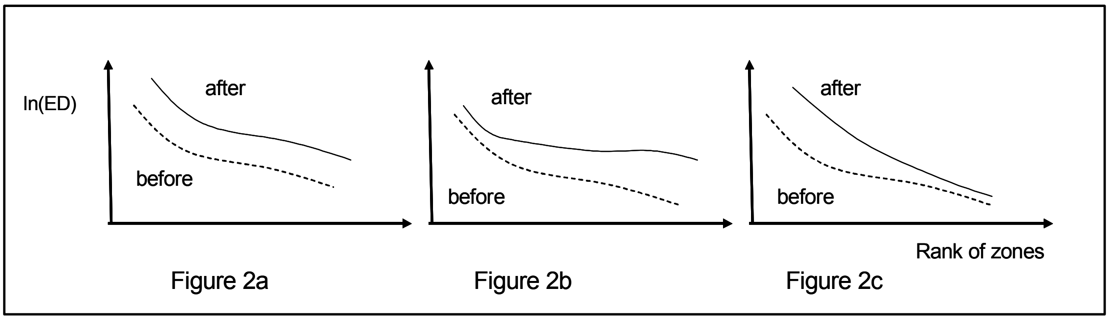

Figure 2 Rank-Size Distribution for Employment Changes and Cluster Dynamics

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$d(i, j) = |x_i - x_j|$

where, x is the logarithmic employment density on the y axis.

[4] Numerous researchers have examined types of density functions and similar studies appeared for the cities with sub-centres (Heikkila *et al*, 1989; Small and Song, 1994, McDonald and Prather, 1994).

2.3 Transport Level of Service and Clustered Employment Structure

Employment clusters are located at places that often have relative locational advantage in terms of the accessibility provided by road and public transport. In the mid – 1990s The London Borough of Hammersmith and Fulham (1995) pioneered a way of measuring relative public transport accessibility levels for any area. The model provides the basis for calculations of public transport frequencies and the level of public transport provision across any specified study area. The model generates a contour map of public transport accessibility levels. The means to calculate these contours are explained on a website: http://www.eng.kagawa-u.ac.jp/~doi/sig1/. Another means to calculate the potential accessibility of a centre - suitable for both road and public transport - is that derived from the Hansen (1959) model (Cervero *et. al.*, 1999).

Although the potential accessibility surface can be constructed in terms of transport mode travel times (including congested highway conditions) or generalised cost the relative accessibilities may be compromised by over crowding on the public transport system necessitating longer waits for service. The carrying capacity of public transport and the spare capacity available on particular routes serving each centre should also be analysed using standard traffic and transport engineering approach.

2.4 Investigating Clustered Employment Structure and Commuting Behaviour

A number of studies have examined the impacts of polycentrism on residential location choices and commuting patterns, where the issues are mode share at the employment destination and the mean trip lengths (or journey times) of those workers. Since the subject of commuting is quite complicated with its different components, it is necessary to analyse the cluster-specific trip distances, times and modal splits; and, also, to plot the trip length distribution and the total vehicle distance travelled of the trips attracted by the zone of the clusters (for example, see Guiliano and Small, 1991; and Cervero and Wu, 1997). Table 1 briefly summarises some measures and evidence of varying commuting patterns among the centres for two US cities.

Table 1: Cluster-Specific Commuting Changes in Los Angeles and San Francisco, 1970 - 1990

Measure	City	Result
Center shares over total	Chicago (1980)	Old city: 8.2 %; Edge city: 20.7%
Center share changes over total	Chicago (1980-90)	Old city:-23.3% ; Edge city: 61.6%
Downtown employment **&** *growth*	Los Angeles (1970-80)	615,000 - 605,000 **&** -1.5%
Subcenters employment **&** *growth*	Los Angeles (1970-80)	793,000 - 990,000 **&** 24.8%
Total employment **&** *growth*	Los Angeles (1970-80)	4,000,000 - 5,300,000 **&** 32,5%
Employment density gradients	S. Francisco (1980-90)	general increase more steep in downtown

Population - employment ratios in centres have also been widely used to understand the degree of mixed land-use development patterns, especially for the housing market in polycentric cities (see, for example, McDonald and McMillen, 1990). However, population-employment ratios when employed to analyse transport should be the ratio between the employments of a given zone to the total population within a region of a specified radius from that zone (Alpkokin, *et al*, 2005; Shukla and Waddell, 1991). It is a simple method to establish a relation between shorter trips and sub-centres with high population and employment ratios.

A more analytical way of grasping the residential location preferences for a given employment centre is to plot graphically by destination specific employment preference functions based on a reverse form of the intervening opportunity model (see, Cheung and Black, 2005, in press, for theory derived from Stouffer, 1940). The original model, when applied to trip distribution in the Chicago Area Transportation Study, had one global preference function as a calibration parameter (l-factor), but our application of the model generates zone-specific preference functions. For each employment zone, residential zones are ranked according to increasing transport distance or travel time by either car or public transport or a weighted combination of the two away from that zone, and 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-centre imply a broader spatial labour market. Curve fitting allows parameters of different functions to be readily contrasted in terms of gradients.

3 EMPLOYMENT CLUSTER DYNAMICS IN ISTANBUL

Istanbul has a key role and position between Europe and Asia, connecting them through the Bosporus Strait. The city grew rapidly after the First World War and became the core of the Turkish economy. A polycentric and mixed urban land-use pattern over an area of more than 150,000 ha has emerged. Two transport master plan studies, from where our database is derived, were conducted in 1985 and 1997 for 209 traffic analysis zones. Between these two years, population increased from 5,347,147 to 9,057,747 (or by 33 per cent) and employment increased from 1,875,500 to 2,532,211 (by 35 per cent). Istanbul continues to grow at an annual rate of 4.3 per cent, and today’s population of 10 million is expected to reach 16 million by the end of 2030. Despite the spatial re-structuring of employment centres in greater Istanbul, as proposed in the Master Plan (see, Alpkokin, *et. al*, in press) until now no rigorous analyses of employment nodes and their dynamics have been undertaken.

3.1 Cluster Classification and Cluster Dynamics

The rank size distribution methodology described in section 2 was applied and the logarithmic employment gross density rank size distribution was drawn (Figure 3(a)). The change over time from 1985 to 1997 in Istanbul reveals a pattern similar to that depicted in Figure 2b, above. Although previous work (Alpkokin, *et. al*, in press) grouped the zones into three clusters, here, using a far more elaborate analysis of cluster dynamics, we have now identified four tiers of clusters. Cluster 1, 2, 3, 4 comprises zones with a logarithm of employment density larger than 5, between 4 and 5, between 3 and 4, less than 3, respectively. We have excluded zones with zero employment or with very small employment (with a negative logarithm value) - 86 zones in 1985 and 71 zones in 1997.

Figure 3 (b) compares the rank size distribution for 1985 and 1997. The real urban dynamics of change are occurring outside the cluster 1 zones all of which are in the old city centre. Istanbul has kept developing this traditional CBD centre without loosing its primacy but there is almost no change for the first tier of zones. The largest growth is in cluster 2 and 3 zones, proving an urban form of local centralisation. The Lorenz curve was drawn for 1997, and it approaches the diagonal compared to that of the 1985 Lorenz curve. Although the “flatness” may mean a more homogenous distribution, or sometimes more sub-centres with rather high densities, in the case of Istanbul it is interpreted as more local peaks, but this is difficult to distinguish by only looking at the Lorenz curves. Therefore, the authors emphasise to researchers applying these techniques to other cities of the importance of applying a rank size distribution analysis.

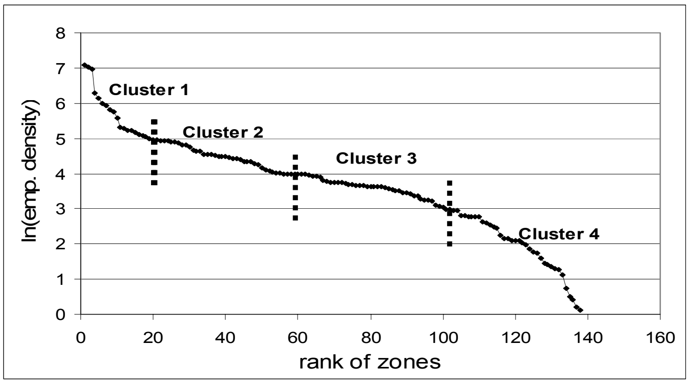

Figure 3(a): Four employment clusters for 1997

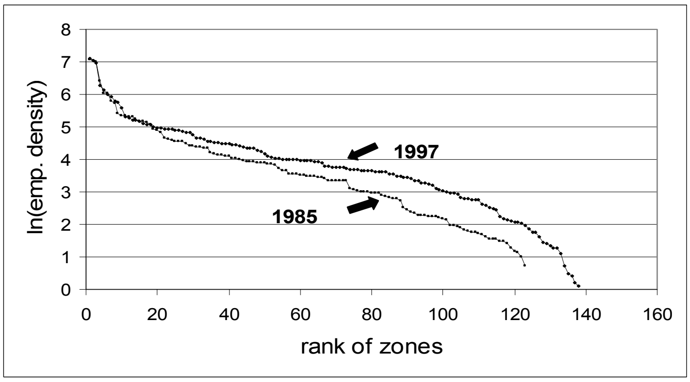

Figure 3(b): Rank size distribution for 1985 and 1997

Figure 3: Rank-Size Distribution and Employment Clusters, Istanbul, 1985-1997

Table 2 further outlines the cluster dynamics by simple means of descriptive statistics for cluster share and change from 1985 to 1997. When compared to Table 1, it is incorrect to assume that a similar pattern is evident for Istanbul to that found by other researchers in USA cities. In Istanbul, CBD employment grew slightly but its percentage share of metropolitan employment dropped from 13 per cent to 9 per cent. Similarly, the share of the “downtown” employment (see Figure 5, below) dropped by one percentage point. Off the four suburban clusters we have identified cluster 2 grew the most in relative terms, followed by cluster 3. Cluster 4 also lost relative share, as with the CBD and down town.

Table 2 also shows for the four clusters the number of zones in 1985 and 1997 that make up each cluster type and the gross employment density associated with each cluster. The density of jobs per hectare dropped in cluster 1 from 351 to 292. The density in cluster 2, despite rapid growth, increased from 83 to 91 jobs per hectare. In the other two clusters, gross employment density also fell slightly.

Table 2: Descriptive Statistics for Cluster Dynamics in Istanbul, 1985 - 1997

Measures	**1985**	**1997**	**Change (1985-97)**
CBD employment **&** *share over total*	243,295 **&** 12.9 %	249,549 **&** 8,9%	+2.6 % **&** -30.7 %
Downtown employment **&** *share over total*	651,561 **&** 34.5 %	657,748 **&** 23.5%	+1.0 % **&** -31.8 %
Cluster 1 employment **&** *share over total*	626,213 **&** 33.2 %	773,347 **&** 27.7 %	+23.5 %**&** -16.5 %
Cluster 2 employment **&** *share over total*	496,514 **&** 26.3%	954,975 **&** 34.2 %	+92.3%**&** +29.9 %
Cluster 3 employment **&** *share over total*	449,955 **&** 23.8 %	766,793 **&** 27.4 %	+70.4 %**&**+ 15.1%
Cluster 4 employment **&** *share over total*	308,966 **&** 16.4 %	209,108 **&** 10.7 %	- 3.2 **&** -34.6 %
Cluster 1 number of zones **&** *density*	18 **&** 351.4 E/ha	18 **&** 291.7 E/ha	0 **&** -17 %
Cluster 2 number of zones **&** *density*	24 **&** 82.7 E/ha	37 **&** 90.7 E/ha	+13 **&+** 9.7 %
Cluster 3 number of zones **&** *density*	36 **&** 36.4 E/ha	45 **&** 35.9 E/ha	+ 9 **&** -1.5 %
Cluster 4 number of zones **&** *density*	45 **&** 8.6 E/ha	38 **&** 7.8 E/ha	- 7 **&** -9.3 %

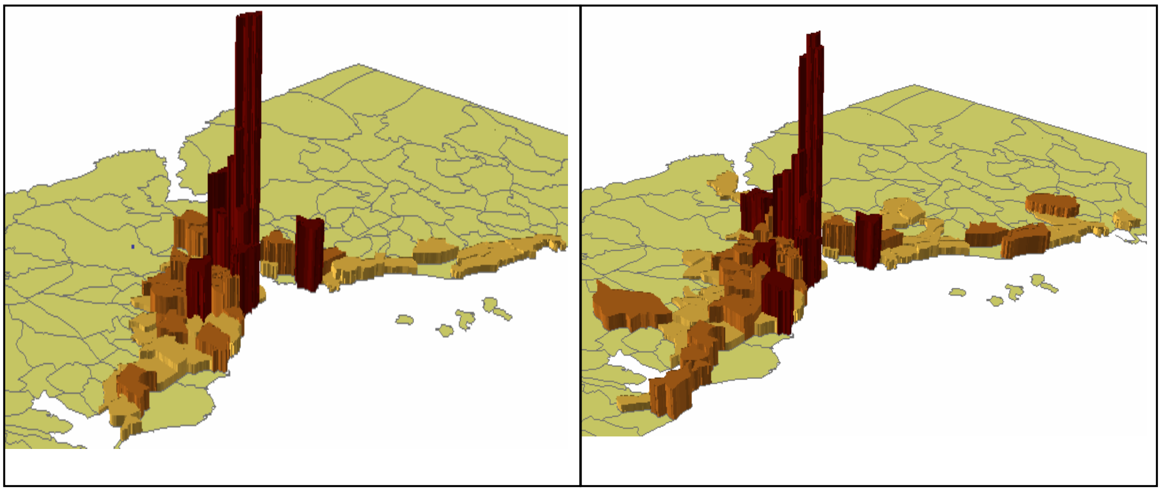

Figure 4 (a) Year 1985 **Figure 4 (b) Year 1997**

Figure 4 Employment Density Changes in Istanbul, 1985 - 1997

Cluster analysis also demonstrates that there has been a considerable increase in the number of cluster 2 and cluster 3 zones and their share of the total employment in the study area. Cluster 4 zones lost share - interpreted as a less saturated and more multi-centric urban form. Figure 4 draws the employment densities for both years using GIS and database of EMME/2. The linear clustering of employment particularly within the presumed wing attraction points of the Master Plan is noticeable.

4 EXAMINING CLUSTER ASSOCIATED TRANSPORT IN ISTANBUL

Istanbul has a rather distributed highway network grid (Figure 5), and hence uniform road-based public transport services over this network. In 1997, 29 per cent of the total trips are made by car and 65 per cent are by public and private service buses or minibuses. There was not a noticeable modal share shift in the twelve years despite car ownership almost doubling, reaching 98 cars/ 1000 inhabitants in 1997.

In contrast to many Western cities experiencing growth, commuting times on the road network have actually declined for the journey to work. Average morning peak hour trip time for motorised trips decreased from 53 minutes in 1985 to 41 minutes in 1997 – a remarkable outcome given the growth in traffic over that period. Such a 12-minute decrease during 12 years is explained by both the construction of the second Bosporus Bridge and the multi-centric growth of the city, putting more jobs within reach of suburban residences.

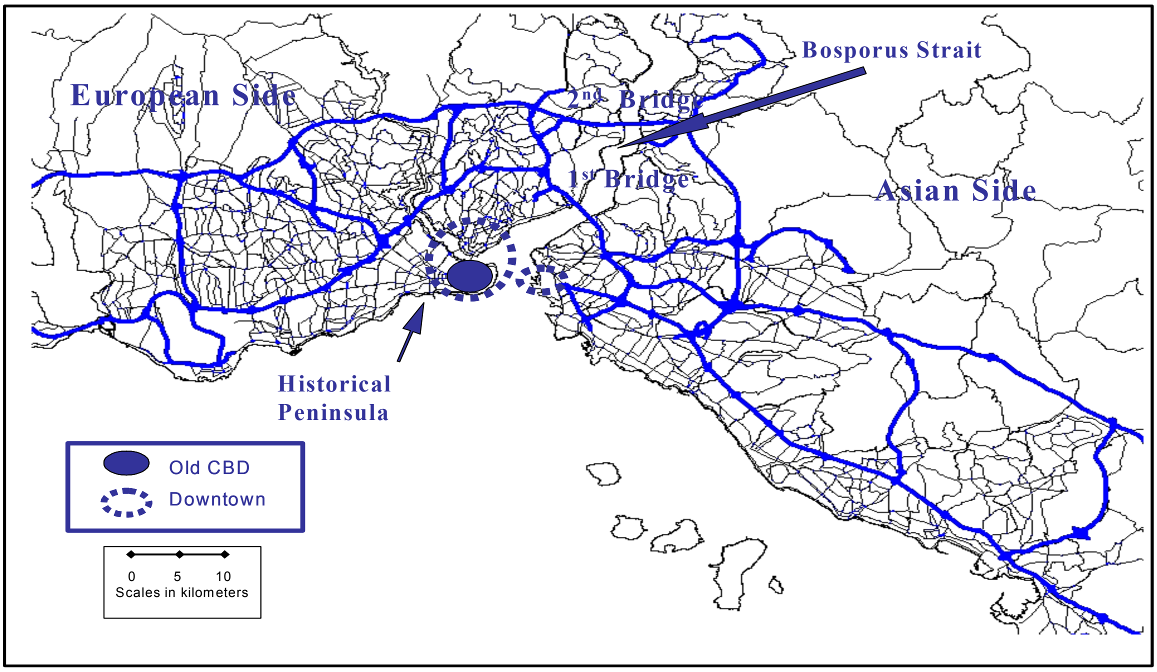

Figure 5 Highway Network, CBD and Downtown in the Greater Metropolitan Area of Istanbul

Figure 6 is a comparison of 1985 (black bars) and 1997 (shaded bars) motorised home-based travel to work trip-length frequency distribution, based on door-to-door travel time. There was an increase in the shorter duration trips in 1997, especially between 10-30 minutes, compared to 1985. It is also important to note that there is a small proportion of commuters (falling from

1985 to 1997) travelling over 100 minutes one-way and up to 200 minutes (over 3 hours).

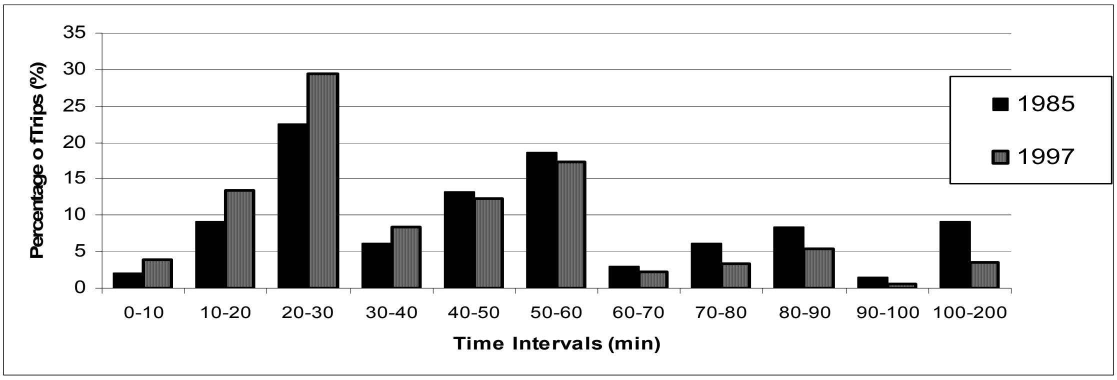

Figure 6 Travel-Time Frequency Distribution for Work Trips

4.1 Commuting Patterns

This section further analyses commuting behaviours by means of commuting times, locational preferences and mode choices mentioned in Figure 1. We have analysed ten zones but selected five zones to describe, based on location and representative examples of the clusters to which each was belonging in 1985 and 1997 (Figure 7). Zone 96 is in the old CBD cluster 1 on the European side; zone 149 is in the old town cluster 1 on the Asian side;180 is in cluster 2 located far west on the Asian side; 154 is cluster 3 on the Asian side; and zone 21 is in cluster 4 far west on the European side. Zones 21, 154, and 180 are envisaged as sub-centres of the future by the Metropolitan Area Sub-Region Master Plan, 1995.

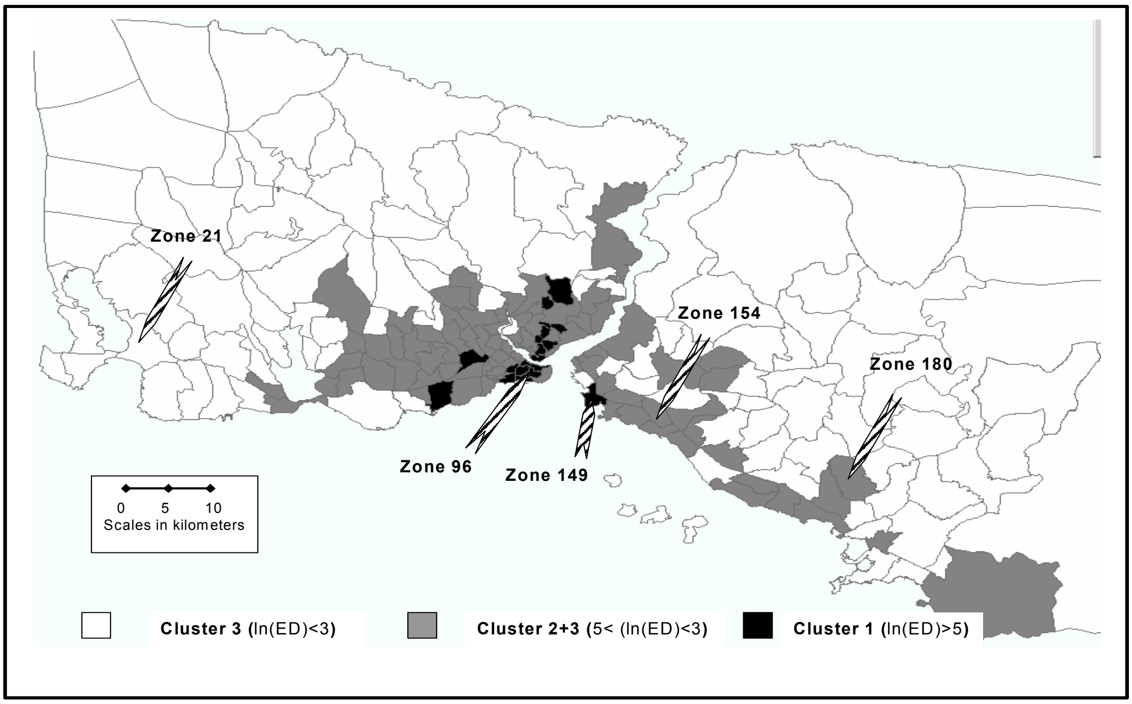

Figure 7 The Location of Zones Examined with their Commuting Patterns

The spatial extent of trips attracted to each zone in 1997 was examined using the employment location-specific preference function (Section 2.3) and the trip length frequency distribution of those commuter journeys to that employment zone. Employment specific preference functions were plotted (Figure 8). The zones labeled in this figure are zones 96 and 146 in cluster 1; zones 20,180 and 122 in cluster 2; zones 154, 103 and 59 in cluster 3; and zones 21 and 177 in cluster 4. Generalized cost between all other zones for the ranking of residential opportunities around each employment zone was used. The noticeable feature of Figure 8 is the different patterns in the zonal preference functions, as highlighted by the three black oval lines. Employment zones 21 and 180 that are outer suburbs on the European and Asian sides, respectively, capture a very high proportion of workers from very nearby residences (from 70 to 80 per cent of all commuter trips) indicating a minimizing approach to the journey to work. On the other hand, for zones 96 ad 149 (cluster 1) only from 5 to 20 per cent come from nearby residential opportunities and these curves, extreme to the right of the other two groupings depict a metropolitan-wide labor market. In between, zone 154 (cluster 3) is representative of zones capturing both local (about half) and wider metropolitan commuters.

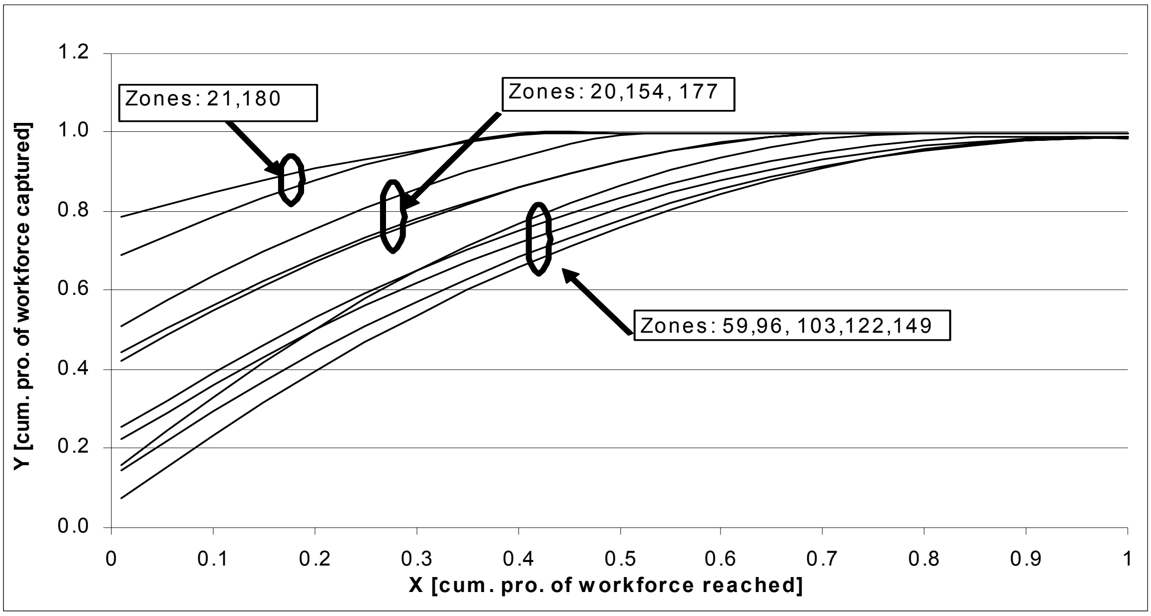

Figure 8 Employment Location-Specific Preference Functions for 1997

The trip length frequency distribution in the morning peak, plotted for the motorised trips attracted to the five zones, also confirmed the findings above (Figure 9). The trip length frequency distributions also tell us that that the old town zones have a more flat distribution and the sub-centres attract a considerable portion of their trips from close to the centre, although they do attract trips from greater distances too. For example, 29 per cent of the total trips for zone 154 are less than 19 minutes; and for journeys to zone 180 26 per cent of the total trips take 73 minutes on average, whereas about half are made in less than 40 minutes.

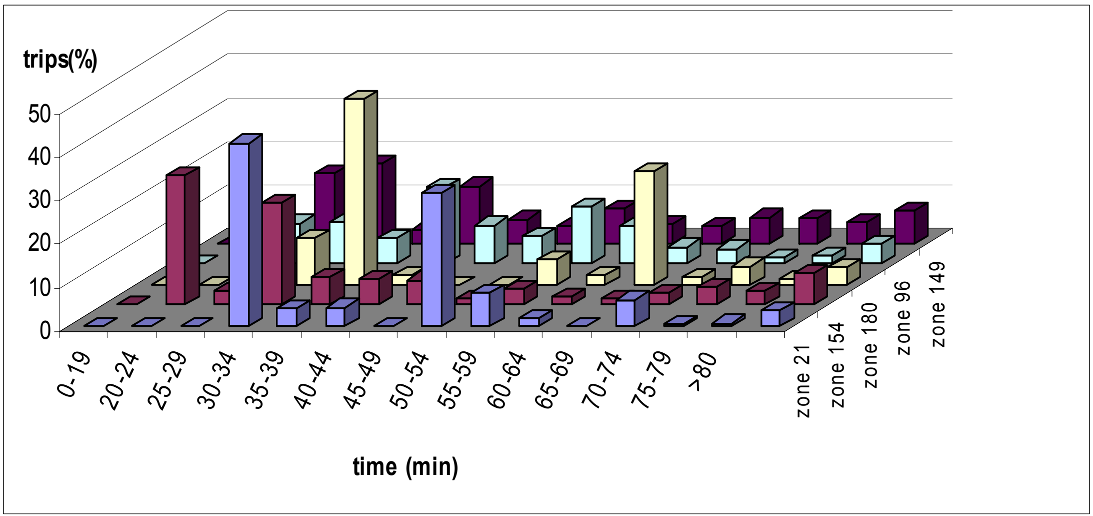

Figure 9 Journey – to - Work Trip Length Distribution for Five Zones, 1997

When considering the modal split, the results are similar to the other empirical findings in the literature.[5] But they are much more moderate in the case of Istanbul as the public transport system is based on an extensive bus system through the whole city. The public transport share is the highest for the old CBD with 58 per cent (zone 96). For the suburban clusters there are rather mixed results. There is a low public transport share with 38 per cent for zone 21 but higher shares for other suburb zones with 47 per cent and 48 per cent for zones 154 and 180, respectively. Further analysis is necessary for the transport level of service in terms of public transport and highway network accessibility and congestion for different clusters as denoted in the methodology introduced in figure by this article to explain these disparities in modal split.

5 CONCLUSIONS

The spatial structure of very large metropolitan regions has evolved with some major concentrations of employment. The literature suggests that the understanding of polycentric employment formations and dynamics of change are limited to North American cities. This paper has described a general framework based on research objectives, suitable analytical techniques, and outcomes for policy analysis for the identification of employment clusters and their evolution with particular reference to the needs of cities in the developing world where data limitations and more aggregate zone sizes are present. The practicality of applying various techniques organised into a personal computer based system has been demonstrated using transport planning study primary data for Istanbul (population 10 million) for 1985 and 1997.

The Master Plan for Istanbul for 2010 nominates future nodes of employment but no analysis along the lines described here was undertaken, and there are no policies that guide such a future pattern. Our findings of trip length frequency distributions and

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[5] In San Francisco the public transport share is 28 per cent for first tier of zones but 8 per cent for second tier zones for the 1990 year data.

preference functions of labour markets for commuting show that the emerging centres do attract shorter trips, and that the public transport mode share is uniformly high with a higher peak for those commuter journeys to the old CBD. Explanations of such findings are currently being explored. Given the topic of employment cluster dynamics is well understood in US cities, the methods described in Section 2 could be readily applied to other large metropolitan regions, of which Greater Tokyo (population 30 million) with its extensive commuter rail network would be an especially interesting case study.

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