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Spatial patterns and functions of employment centres in Metropolitan Sydney, 1981 - 1996

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INTRODUCTION

In the last decade considerable empirical research on urban spatial structure has focused on the following themes: transitions from monocentric to polycentric density patterns (McMillen and McDonald, 1998); the formation of 'edge cities' (Garreau, 1991); polycentricity or dispersion (Gordon and Richardson, 1996); the identification of employment centers (Giuliano and Small, 1991); the relationship between commuting and employment sub-centres (Cervero and Wu, 1998); and the application of GIS and spatial analysis to employment patterns (Scott and Lloyd, 1996). Equally important has been research on theoretical analyses of urban areas that deals with functional forms of polycentric density functions, the development of non-monocentric models, and how agglomeration theories underly the formation of polycentric employment centers and their configurations and characteristics. Anas et.al (1998) provide an excellent review of theoretical and empirical analyses of urban areas. Much of this literature is confined to North America and Europe, but the debates are also relevant to Sydney in the broader context of suburbanisation of population and employment, urban economic restructuring, emerging production spaces, equity of access to services, and urban sustainability (Connell, 2000).

A necessary and initial step in empirical investigations of urban spatial configuration is the identification of economic centers, sometimes referred to as clusters or nodes and called subcentres. The identification of centers is also the basis for more detailed analyses of the characteristics of these centers – beyond simple confirmation of the polycentric character of urban areas – to testing theoretical concepts related to most of the above contemporary themes in urban patterns. In the context of employment suburbanisation, it is also important to evaluate the quantum of deconcentralised employment and to evaluate changes in the nature of employment: changes in the hierarchy of centers, specialization or diversification of centers, spatial segmentation of employment, etc. We also subscribe to the approach of Baumont et.al (2002) who suggest it is useful to know the sector-based composition of economic activity in each centre for different periods.

The aim of this paper is an empirical investigation of the changing spatial organization of economic activities and the functions of identified employment centres within the context of a polycentric and dispersed employment pattern. Our

fundamental question is what economic roles these employment centres play and how this has changed between the period 1981 and 1996. Further we examine the role of spatial variables such as distance from the CBD in understanding the spatial patterning of centres, the specialisation of centres and their size distribution. We do not purport to develop or discuss agglomeration theories in this paper. (The reader is referred to Anas et.al (1998) for an excellent review of this literature).

Our study employs journey-to-work tables for 1981 and 1996 travel zones in Sydney which comprises the continuously built-up areas of the city at each respective census year, but excludes that part of the Greater Sydney Metropolitan Region (GSMR) which extends north to the central coast and up as far as Newcastle, south to Wollongong, and west to the Blue Mountains. Our study area is commonly referred to as the Sydney Metropolitan Area (SMA) or the Sydney basin. These data record the number of people employed and the employing industry (one-digit ANZIC) for each travel zone. Our study area comprises a total of 649 travel zones in 1981 and 725 zones in 1996. This area is composed of two primary commercial centres (Sydney CBD and Parramatta CBD) and nine secondary commercial centers nominated in the New South Wales Government's joint metropolitan strategies of 1995 "Cities for the 21st Century" and the "Integrated Transport Strategy (ITS)" which contain a significant proportion of GSMR employment (NSW Government, 1995). However, our study also considers other non-commercial centres with equally (if not higher) employment levels. The major employment centres we identify in our study may include several of these nominated centres, or may include part of the travel zones which comprise the commercial boundary of a centre.

We begin by identifying major employment centres of the SMA by applying a modification to the standard method for identifying centers developed by Giuliano and Small (1991). These centres – also referred to as employment poles (Baumont et.al, 2002) – are then investigated in relation to their location, mixed character (residential and economic) or otherwise, and their composition by sector of activity. Principal Components Analysis is used to identify different profiles of employment concentrations and their possible change over the time period of the study in relation to Sydney's new spaces of production and the 'new economy' versus 'old economy' dichotomy (Fagan, 2000; O'Connor and Healy, 2002). Of particular interest, given suburbanisation of service employment and decline of manufacturing in Sydney, is

the extent to which the dynamism of concentrations in Western Sydney may have changed and whether new employment concentrations are more reflective of new economy industries, and the nature and extent of previously reported evidence of a recent re-centralization of employment. Cluster analysis is used to more clearly identify typologies of employment concentrations and their functional role(s).

Our approach enables us to reflect and comment on success or otherwise of planning policies which have attempted to focus the GSMR's future economic activity in key 'centres' as part of the integration of economic development, environmental management, and transport and land use planning, to achieve broader environmental, economic, social and financial outcomes. In addition, we can reflect on debates about centre versus periphery; and discussions on the commuting impacts of metropolitan centres.

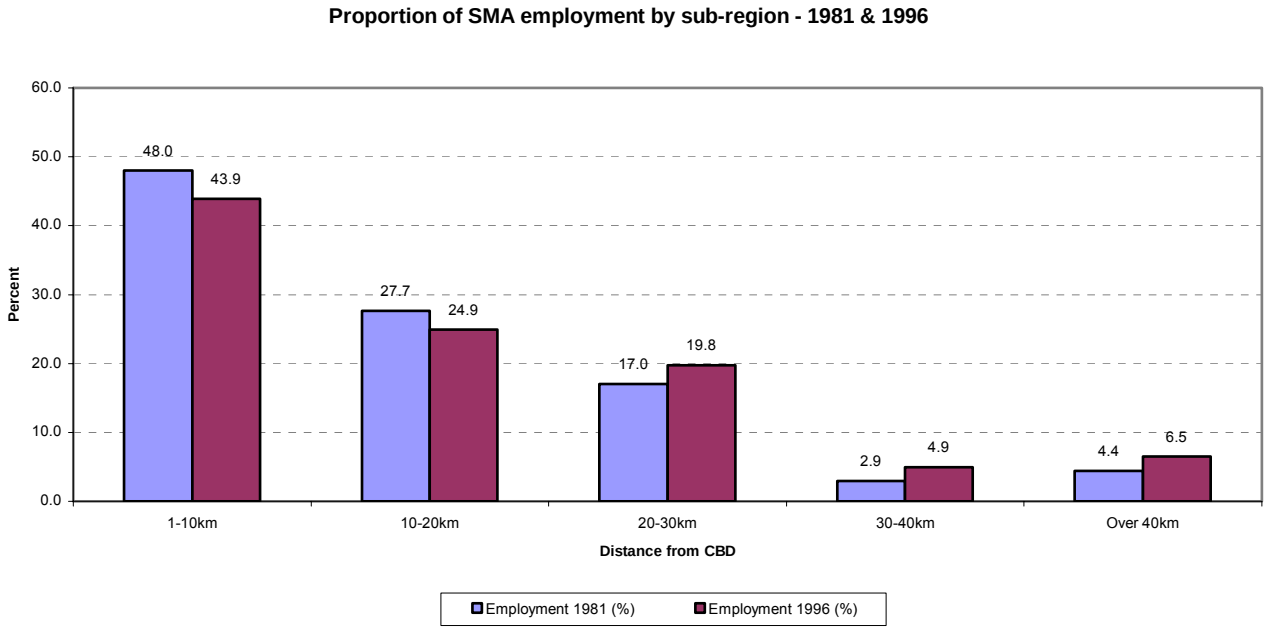
BACKGROUND: CHANGES IN LOCATION OF EMPLOYMENT AND WORKFORCE PATTERNS

Over the past several decades Sydney, Australia's largest metropolis with a population approaching four million, has succumbed to global processes of metropolitan restructuring (Fagan, 2000). A new geography of employment has emerged in the office, financial, high-tech, and producer services sector of the metropolitan economy, while suburbanisation of population has led to changing trends in the journey to work with likely effects on the geography of accessibility to employment opportunities (Freestone and Murphy, 1998; Parolin et al., 2001). A key characteristic of the new geography over the period 1981-96 is the dispersal of employment to non-CBD locations, in particular the movement of manufacturing firms to suburban locations, the growth and dispersal of planned suburban shopping centres, and the dispersal of office activities into the suburbs. In general, employment is now widely dispersed throughout the metropolitan area (Forrest, 1996), but our

contention is that a significant component is concentrated or clustered in diverse locations which exhibit higher densities than the surrounding area.

During the period between 1981 and 1996 jobs in the GSMR increased from about 1.4 million to 1.8 million, an increase of 23.9%. Over this same period the proportion of GSMR jobs in the CBD declined from 12.2% to 10.3%, but the central city CBD remains a major commuting magnet. Of interest is the distance effect of the spatial patterning of jobs (Figure 1). Approximately 48% of Sydney region jobs were located within 10 kilometres of the CBD in 1981. This figure had deceased to 44% of regional job totals by 1996. Even within the distance band up to 20 kilometres there has occurred a decline in regional jobs; from 76% in 1981 to 68% in 1996. As indicated in Figure 1, the largest percentage changes in regional jobs occurred beyond 20 kilometres of the CBD, where the proportion of regional jobs increased from 24% in 1981 to 35% in 1996. The extent to which this growth pattern displays evidence of concentrated or clustered employment is a key concern of this paper.

Figure 1 Changes in Employment Location by Distance from CBD, 1981 to 1996



As regards the suburbanisation of the workforce several trends have emerged over the period of study that mirrors the new geography of employment. Our analysis

indicates that approximately 30% of the workforce live within 10 kilometres of the CBD, with up to 55% residing within 20 kilometres of the CBD, and within reasonable distance of the city's main rail corridors. The largest percentage increases in the

suburbanisation of the workforce over the study period have also occurred beyond 20 kilometres from the CBD, into the northwestern, outer western and southwestern suburbs (mainly associated with the growth in outer residential areas). However, the growth in the workforce in these suburbs continues to exceed growth in employment opportunities; these suburbs contain 35% of total regional jobs but 45% of the work force.

Some preliminary evidence of the concentration of employment in Sydney is provided from analyses undertaken by the NSW Department of Transport (1999) for 15 centres (13 officially nominated policy centres and two other major centres – Macquarie/North Ryde and Central Industrial Area/Airport). Their analysis showed that employment in the regions 15 centres grew by 18.3% between 1981 and 1996, from 406,841 to 481,454. However, there was no significant change between 1981 and 1996 in the share of people employed in the centres compared to the GSMR as a whole (declined slightly from 28.5% to 27.2%). Of interest is that all secondary centres experienced an increase in employment from 1981 to 1996, with an overall increase of 37.1%. The centres with the greatest employment growth – Campbelltown, Chatswood, Liverpool and Penrith, were with one exception located beyond 20 kilometres of the Sydney CBD. Employment in the primary centres also increased by 8.9% from 1981 to 1996, but this was confined to the Sydney CBD (increased by 5%) and to Parramatta CBD (workforce increased by almost 70%, from 19,807 to 33,040).

It should be stressed that the above study is confined to selected commercial centres which, while important, are not reflective of the urban spatial configuration of employment in Sydney. The task is to include non-commerical centres (such as those with a manufacturing base) and other specialised centres around universities, hospitals and other large institutional employers for a more realistic assessment of the extent of concentration of employment in Sydney.

The research of Pfister et.al (2000) identified patterns of employment centres in Sydney which included commercial, non-commerical and other specialized centres. Their analysis showed that while the absolute number of jobs in their defined centres increased from 1981 to 1996 (as with the number of employment clusters that can be defined as centres), these never represented a majority of regional employment. In

1981, almost 40% of GSMR jobs were located in centres. By 1996, this had decreased to just over 35% of jobs. A key conclusion from their study was that the total number of jobs outside centres has risen significantly providing evidence of Gordon and Richardson's (1996) alternative hypothesis of generalized dispersion.

Many of the centres identified in their study were discussed relative to a typology of office-based suburban employment centres based on observations of size, built form, recency of development, and economic functions (Freestone and Murphy, 1998)) defined a. The typology recognised nine different categories depending on whether the centres are traditional (fringe CBD, second CBD, suburban town centres, office corridors, business zones) or new (regional business parks, office parks, free-standing office campuses, technoburbs).

IDENTIFICATION OF EMPLOYMENT CENTRES

A variety of methodologies have been used in the literature to define employment concentrations. The most widely used indicators are total employment (Giuliano and Small, 1991), employment density (McDonald and Prather 1994) and job-population ratios (MacDonald, 1987). An employment concentration is an area with both a high density and high quantity of employment and, typically, is identified from travel zones (TZ).

The methodology developed by Giuliano and Small (1991) in their study of Los Angeles has proved popular in the literature and was adopted by Pfister et.al (2000) in their application to Sydney. The method requires identifying TZ with dense employment, combining adjacent employment-dense TZ into groups, and measuring total employment in groups. An employment concentration is defined as a cluster of contiguous TZ, all with gross employment density exceeding 2,470 persons/km^2 and

with total employment exceeding a threshold size of 10,000 employees. On this basis Pfister et.al (2000) identified 102 travel zones as centres in 1981 and 107 in 1996. Their mapping of the pattern of TZ identified a mixture major employment centres.

We view the use of employment thresholds developed for US urban areas (especially Los Angeles) as problematic given size and density differences with Sydney, and

differences in the geographic scale of TZ to represent the urban area. However, the choice of thresholds is important because each threshold value produces a different picture of centrality of the urban area: the higher the thresholds the fewer employment concentrations are identified. For example, variability in thresholds used for the Los Angeles urban area in 1980 showed that a threshold of 10,000 jobs and 10 jobs per acre finds 32 centres (Giuliano and Small, 1991) compared with 10 centres for thresholds of 20,000 jobs and 20 jobs per acre (Small and Song, 1994) or only 6 centres for thresholds of 35,000 jobs and 15 jobs per acre (Song, 1994).

Our focus is on the identification of employment concentrations from discrete centres rather than the identification of discrete centres per se. We use the TZ for Sydney obtained from the Transport Data Centre (NSW Department of Transport) as our unit of analysis and define concentrations as a TZ or set of contiguous TZ with employment characteristics that were significantly higher than neighbouring zones. Employment data were based on the 1-digit industry classification used by the Australian Bureau of Statistics (ABS) which comprises 17 standard industry groupings.

Our approach was as follows. First we identified “potential” employment concentrations for use in further analysis. A “potential” concentration was defined as a zone with total employment that was significantly higher than the regional mean. Employment data were standardised by subtracting each zonal value from the regional mean and then dividing the difference by the standard deviation. All zones with standardised employment values (Z-scores) above 0 were considered as “potential” concentrations (see Table 1). This approach identified 155 zones in 1980 and 231 in 1996. We then further refined our potential zones by selecting only those which met the criteria of employment density greater than 2470 jobs per sq km or an employment-population ratio greater than 1. This identified 91 zones in 1981 and

117 zones in 1996; these zones are treated as employment centres in our definition. Single or contiguous zones were then merged to produce 28 employment concentrations or clusters in 1981 and 41 employment concentrations in 1996. Their locations are shown in Figure 2 and Tables 2 and 3 provide summary statistics.

Table 1 Distribution of employment by thresholds

Employment Z-score threshold	Employment threshold		% total employment		Number of employment centres	
	1981	***1996***	***1981***	***1996***	***1981***	***1996***
> 0.00	2,125	1,835	65.5	72.9	155	231
> 1.00	5,231	4,483	40.9	41.4	51	70
> 2.00	8,410	7,107	29.2	25.8	27	31
> 3.00	11,567	9,755	21.9	19.1	17	19
> 4.00	18,259	12,735	11.9	13.2	7	11

Figure 2 Employment concentrations (clusters) 1981 and 1996

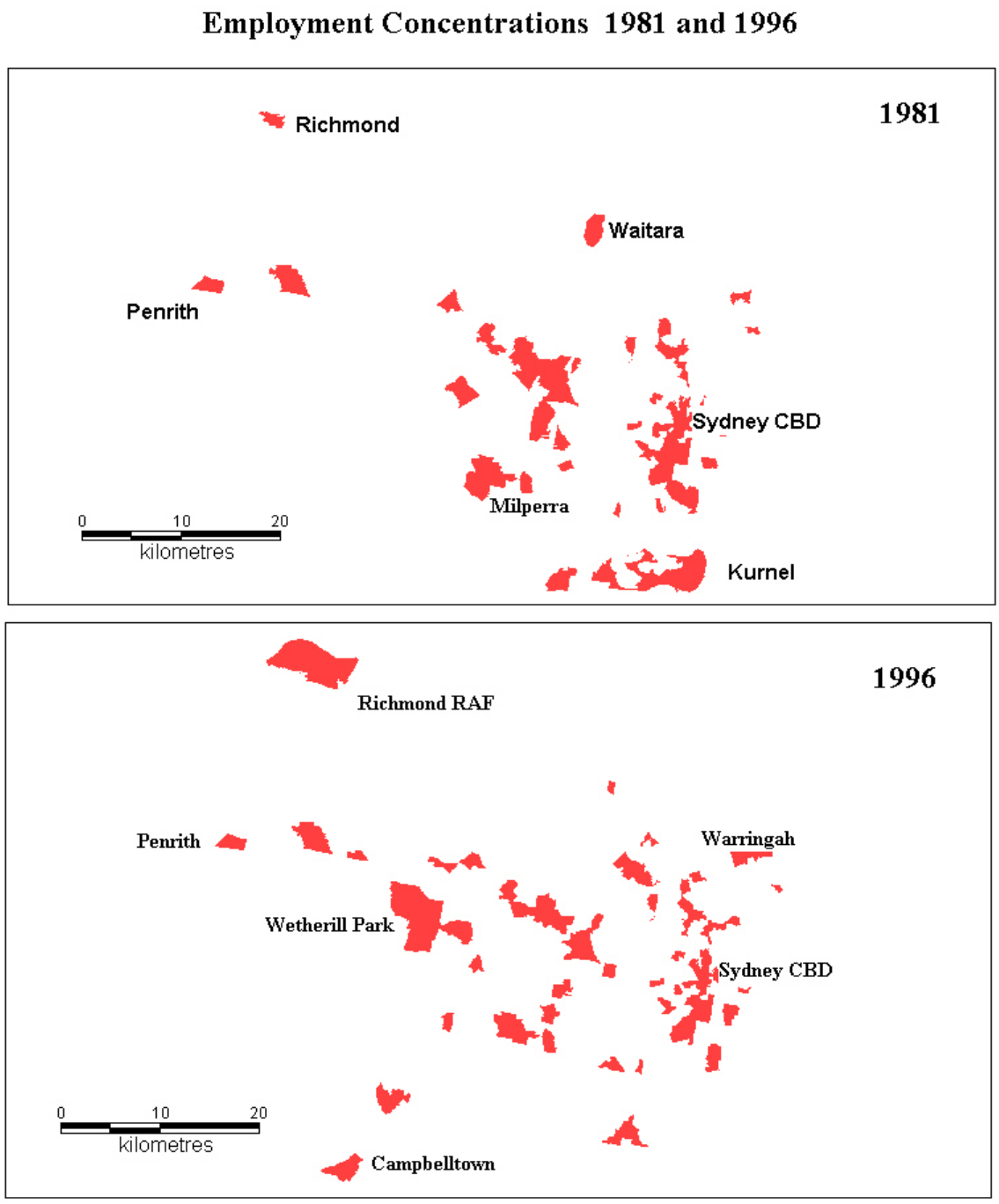


Table 2 Major employment concentrations in Sydney, 1981 and 1996

1981					1996				
Rank	Location	Emp[1]	Emp Density	Emp/ Pop ratio	Rank	Location	Emp[1]	Emp Density	Emp/ Pop ratio
1	CBD	160853	109087.6	129.4	1	CBD	192672	76309.9	202.8
2	Central Industrial Area/Airport	84378	5264.4	34.0	2	CBD Fringe	53872	11671.9	9.5
3	CBD Fringe	49628	13230.5	14.0	3	St Leonards-Chatswood	53089	9243.0	5.6
4	Flemington/ Silverwater/ Rydalmere	34885	1777.4	5.0	4	Central Industrial Area /Airport	52128	5037.2	7.7
5	Lower North Shore	31090	23707.2	27.3	5	Parramatta/Westmead	45390	5420.5	2.2
6	Chatswood	28236	5269.9	1.8	6	Lower North Shore	39663	24978.6	6.6
7	Parramatta/ Westmead	17129	4156.7	3.2	7	Wetherill Park /Smithfield	21407	952.0	10.6
8	Milperra	16221	2167.3	2.7	8	Macquarie/North Ryde	17775	2410.2	7.9
9	Kurnell	12832	1849.2	.9	9	Blacktown/Seven Hills	14637	3191.3	6.1
10	Brookvale	8952	5185.7	5.3	10	Warringah	14075	4200.1	9.4
11	Hornsby	7978	15873.5	.7	11	Homebush	12822	1663.6	4.6
12	Yenora	7291	1310.1	1.1	12	Penrith	10376	2858.4	3.0
13	Enfield	6533	2021.9	1.4	13	Miranda	10285	2424.9	1.1
14	Penrith	6459	1795.6	1.7	14	Silverwater/Rosehill/ Rydalmere	10278	1708.6	3.7
15	UNSW	6424	3587.7	.8	15	Bankstown	10021	3776.8	1.1
16	Chullora	6247	1049.7	2.8	16	Burwood/Strathfield	9894	5870.6	1.2
17	Padstow	6149	2314.4	3.1	17	Liverpool	9755	5841.3	1.4
18	Dunheved (ACI)	5554	768.9	1.2	18	UNSW	8699	3390.5	.7
19	Bondi Junction	5191	4800.8	.8	19	Hurstville	8073	3790.1	.9
20	Blacktown/ Seven Hills	5147	1675.2	2.9	20	Campbelltown	7496	2612.1	5.9
21	Manly	3641	4830.8	.7	21	Bondi Junction	6759	11265.0	1.2
22	Richmond	3629	1080.6	1.1	22	Padstow	6372	2422.8	3.0
23	Kogarah	3507	4762.4	1.4	23	Kogarah	6287	8382.7	2.5
24	Banksmeadow	3489	1229.0	34.5	24	Marrickville	6131	4001.5	3.8
25	Balmain	3042	3421.8	.6	25	Milperra	6011	2129.5	2.6
26	Lane cove	2915	2045.6	2.7	26	Lane Cove	5336	3629.9	3.9
27	Leichhardt	2770	3182.1	.6	27	Milperra	5192	1002.3	4.4
28	Rhodes Peninsula (AGL)	2011	1733.2	2.8	28	Dunheved (ADI)	4965	669.1	1.2
					29	Pymble	4849	4452.1	3.0
					30	Chullora	4602	1710.8	2.9
					31	Fairfield	4282	2676.3	.6
					32	Hornsby	3740	4921.1	.9
					33	Banksmeadow	3653	1020.4	8.5
					34	Ingelburn	3593	616.3	1.1
					35	Leichhardt	3564	4096.6	.9
					36	Manly	3220	6708.3	1.3
					37	Balmain	2833	3046.2	.5
					38	Mt Druitt	2656	1910.8	2.1
					39	Double Bay	2413	7312.1	1.4
					40	Richmond RAF	2370	92.9	4.0
					41	Camperdown	2028	2704.0	.5

Note: [1] Identified concentrations may consist of more than one travel zone.

Table 3 Aggregate statistics within and without concentrations, 1981 and 1996

	Total employment		Total population		Employment density (jobs/sq km)		Population density (/sq km)		Employment / population ratio	
	1981	***1996***	***1981***	***1996***	***1981***	***1996***	***1981***	***1996***	***1981***	***1996***
Within Concentrations (Clusters)	532,181 (48%)	693,263 (42%)	214,373 (7%)	259,483 (8%)	2729	3519	1099	1317	2.5	2.7
Not Within Concentrations (Clusters)	578,559 (52%)	973,505 (58%)	2,736,456 (93%)	3,195,319 (92%)	184	244	738	802	0.21	0.30
All Zones (SMA*)	1,110,740	1,666,768	2,950,829	3,454,802	336	399	893	827	0.38	0.48

Note: * The Sydney Metropolitan Area – Sydney basin - is the area defined for our study.

Several major characteristics of employment concentration are evident from Figure 2 and Tables 2 and 3. The CBD remains the single most important employment node in the Sydney area despite a decline in the region's share of total employment. However, the number of people employed in the CBD increased over this period. When coupled with growing CBD fringe areas, which are precincts contiguous to the CBD to the south, east and west (Darlinghurst-Woolloomooloo, Surry Hills, Central-Redfern, and Pyrmont-Ultimo) and the Central Industrial Area/Airport the dominance of the central core for employment and density is overwhelming. Employment opportunities gradually decline away from the central core. Employment-population ratios remain extremely high in the central core relative to other concentrations indicating low levels of intermixing of population and employment up to 1996. Since this time, however, there has occurred considerable population growth in the central core (CBD, CBD fringe areas, and Central Industrial Area/Airport) due to residential developments of a high-rise nature which will generate high levels of intermixing of population and employment. The lower North Shore area (Milson's Point and North Sydney) is an extension of the Sydney CBD but generally exhibits lower densities and a great deal of intermixing of population and employment. A North Shore corridor of concentrations had developed by 1996 between Milson's Point and Chatswood.

After the first four ranked areas in 1981 and 1996, the remaining concentrations are major suburban nodes which generally appear to fit the typology of office employment centres outlined in Freestone and Murphy (1998). Parramatta is the official second CBD of Sydney, with corporate, state and federal government offices serving western Sydney. The contiguous precinct of Westmead is associated with a specialisation around the hospital. Suburban commercial concentrations (e.g., Hurstville, Liverpool, Kogarah, Manly, Hornsby, Penrith, Burwood, Bondi Junction, Campbelltown) are strong traditional centres located at major rail and bus interchanges. Office corridors are represented by the St. Leonards-Chatswood and Burwood-Strathfield concentrations. Many of the remaining areas represent more traditional business zones with a manufacturing bias (Wetherill Park/Smithfield, Brookvale, Blacktown/Seven Hills, Padstow, Milperra, Flemington/Rydalmere, Maryfields, Banksmeadow). More specialised concentrations are found in North Ryde (technoburb), Macquarie University, Cabarita (AGL site), Holsworthy (Army barracks), Dunheved (ADI site), Kurnell (oil refinery) and University of NSW. (Since 1996, several of these sites have been or are currently being re-developed for residential purposes).

The addition of twelve concentrations between 1981 and 1996 is further testimony to the growing polycentric or multipolarised nature of the metropolitan area, and to the persistence of strong agglomeration forces. Several of these newer concentrations (Fairfield, Mt. Druitt, Richmond RAAF, Ingleburn, Miranda), which met our criteria for inclusion as centres in 1996, are located in the outer suburbs (beyond 20 kilometres) and are beneficiaries of the suburbanisation of employment opportunities which occurred over the time period of our study. A striking feature of Table 3 is that while the proportion of employment within identified concentrations has declined between 1981 and 1996, there remains over 40% of employment which is clustered at identified concentrations – a higher proportion than that reported by Pfister et.al (2000) (36%) and higher (33%) than that reported for Los Angeles (Giuliano and Small), a city with which Sydney is often compared.

Closer examination of the spatial location of employment within identified concentrations indicates that 71% in 1981 and 62% in 1996 respectively is located within 10 kilometres of the CBD – an area sometimes referred to as the inner city. Outside of this area, employment and employment densities decline rapidly with

distance (with some notable exceptions). Employment density, in other words, is strongly correlated with distance from the CBD. The Spearman rank correlation between employment density and distance for identified concentrations in 1981 and 1996 is –0.64 and –0.61 respectively (significant at the one per cent level). Distance from the CBD accounts for 55% and 50% respectively of the variance in employment density in 1981 and 1996, based on a least squares estimate of a simple power density function (gradient of –0.69 and –0.63 for 1981 and 1996 respectively).

The identified concentrations for 1981 and 1996 also appear to have a size distribution which is consistent with the idea of a hierarchy of functions – the rank-size rule. We follow the example of Giuliano and Small (1991) and Anderson and Bogart (2001) and characterize this distribution by estimating the following regression for our indentified concentrations in 1981 and 1996:

1981: Ln (rank) = 9.33 – 0.99 Ln (employment)

(0.176) (0.019)

(Standard errors are given in parentheses)

1996: Ln (rank) = 10.46 – 0.98 Ln (employment)

(0.216) (0.024)

The coefficient of Ln (employment) for both models was statistically significant at the 95 per cent level. These rank-size rule regressions explain 98% and 97% respectively of the variance in Ln (rank) and assert that the rank-size rule (rank times size is constant through out the distribution) holds extremely well in Sydney. Following Anderson and Bogart (2001), a coefficient on Ln (employment) less than 1 in absolute value implies that employment is more concentrated in larger employment concentrations than predicted by the rank-size rule – a situation we described above.

SPECIALISATION AND FUNCTIONS OF EMPLOYMENT CONCENTRATIONS

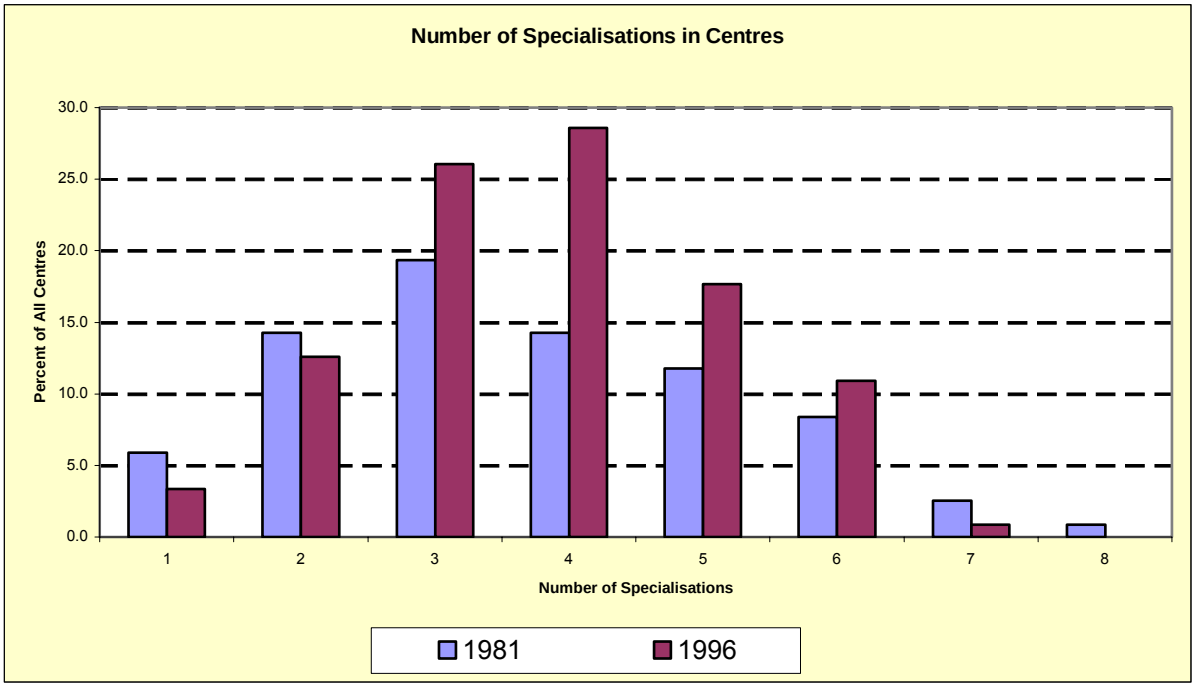
The relative concentration of industries in different parts of the SMA was measured by the Location Quotient (LQ). Bogart and Ferry (1999) and Anderson and Bogart (2001) used a similar technique to measure employment specialisation across a range of cities in the USA. The LQ is the ratio of an industry's share of the local employment in a travel zone to the industry's share of the total metropolitan employment. This method describes the specialization of the smaller geography as compared to that of the wider geography (Anderson and Bogart, 2001).

An LQ greater than 1 indicates a high concentration of a particular industry and hence a tendency for the travel zone to specialise in that industry sector. An LQ less than 1, on the other hand, indicates a relatively low concentration, while a value equal to 1 shows that the distribution of the industry in question is the same as the metropolitan average. Following Anderson and Bogart (2001), we use an LQ of 1.25 or higher as a benchmark to identify zones that specialise in a particular industry sector. This threshold suggests that the zone's employment in that industry sector is 25% higher than the metropolitan average.

We proceed by examining the degree to which employment centres are specialized and the extent to which this specialization has changed during the period 1981 to 1996. Figure 3 shows the number of specializations in employment centres. The maximum number of specializations found is 8 in 1981, in Parramatta. By 1996 the maximum number of specializations was 7, in the Sydney CBD. At the other extreme there were only a few centres with one specialisation between 1981 and 1996. A key finding highlighted in Figure 3 is the increasing percentage of centres (travel zones) with additional specialisations between 1981 and 1996, with the largest increases occurring for the range of 3-6 specialisations – an indication of the increasing mix of specializations within centers and of diversification of their economic functions. This would suggest that more and more of the employment centres in 1996 had developed very similar specializations as part of their employment growth and employment profiles.

Figure 4 highlights changes in the 17 (1 digit ANZIC) industry sectors across identified centres between 1981 and 1996. Several significant results are apparent. First, there is generally less systematic variation in the number of employment

Figure 3 Number of industry specializations in travel zones

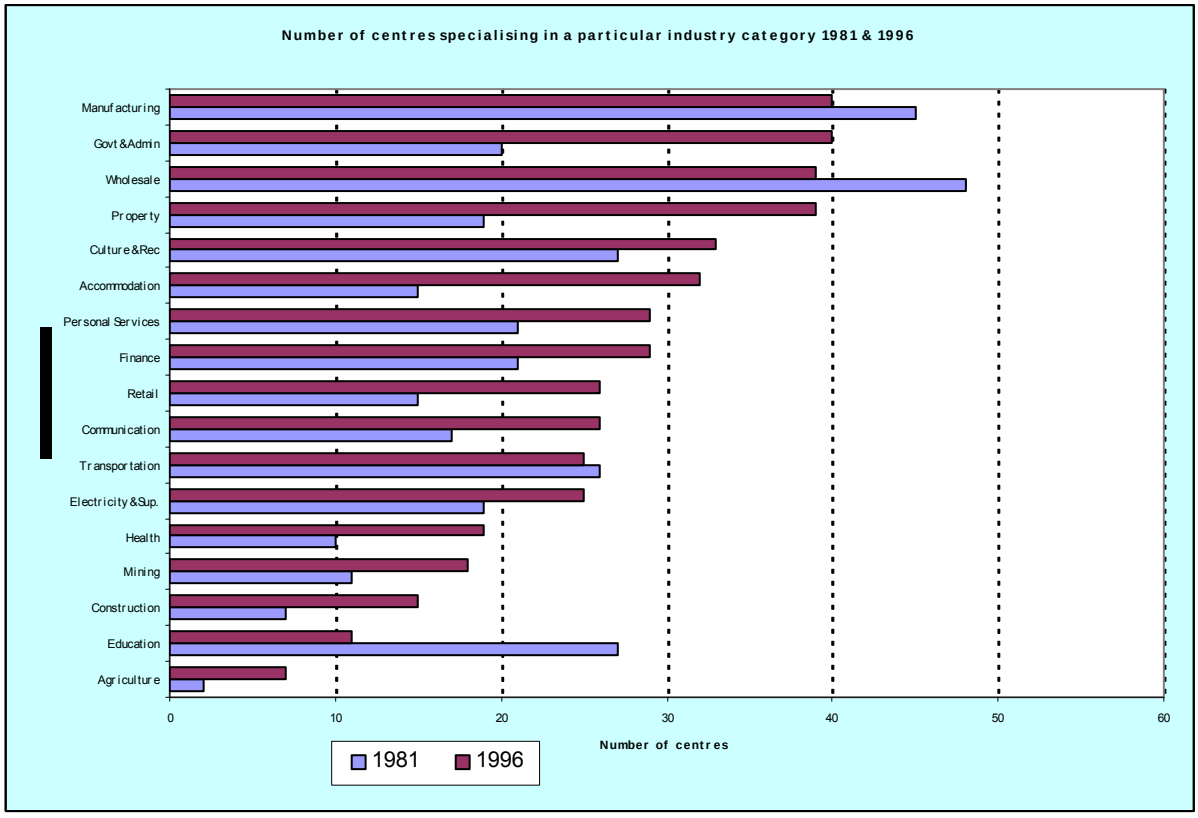


centers that specialize in each sector as compared to 1996. This may indicate that, in general, and with the exception of centers in the central core and CBD, that most other centers exhibited very similar profiles in terms of their economic sectors – with few specializations in each sector (see Figure 3) as compared to 1996. In the latter period, the variation is extensive despite an increase in sector specializations across many centers.

Second, employment in information and producer services sectors (communication, finance, property, administration, business services, etc) is more evenly distributed among the centers in 1996. For example, more than 25 out of the 119 centres shared these service specializations in 1996, which is significantly above the number of centers with these specializations in 1981 – an indication of the importance of these general sectors to the metropolitan economy.

Third, those sectors which experienced a relative decline by 1996 in the number of employment centres that specialize in each sector (manufacturing, wholesaling, transportation) are symbolic of restructuring in the traditional "old economy" sectors. Reduction in the number of employment centers that specialize in education is surprising and would require analysis of more detailed (2 digit) education industry data for possible rationales.

Figure 4 Employment centre specialisation by industry sector



Fourth, despite a reduction in the number of employment centers that specialize in manufacturing (from 45 in 1981 to 40 in 1996), it is evident that this sector remains of importance to the metropolitan economy – about 34% of all employment centers in 1996 have a specialization in manufacturing. However, it is likely that manufacturing specialization in 1996 is a markedly different production process than that in 1981 (Fagan, 2000). Further investigation of which employment centres now specialize in manufacturing as compared to 1981 indicates (with reference to Figure 2) that manufacturing continues to maintain a strong presence in the inner core area of

Sydney (Central Industrial Area), the Flemington-Silverwater –Rydalmere corridor and Milperra-Padstow, but is now also located in other employment centres in Western Sydney. The situation is almost identical to the number of employment centers that now specialize in wholesaling.

ECONOMIC PROFILES AND SECTOR BASED COMPOSITION OF EMPLOYMENT CENTRES

We investigate further the results presented above through analysis of the spatial-economic profiles of the identified employment centres in 1981 and 1996. Our central aim is to identify and understand the key axes or dimensions of industry sector employment, particularly in terms of the spatial arrangement of employment and the new geography of industry employment in Sydney based on data from the 1996 census. It can be assumed that any identified trends between 1981 and 1996 are likely to have intensified in the seven years since the 1996 census.

The profiles of the employment centres (travel zones) which met our criteria for definition as a centre in 1981 and 1996 were determined using Principal Components Analysis (PCA). The input variables used describe total employment, employment density, the employment-population ratio, and employment in each of the 17 1-digit industry categories for each travel zone. Component scores for each identified axis for both years are then generated for input to a cluster analysis in order to more carefully identify clusters of employment centres which are differentiated in terms of their economic activities and functions.

A summary of the main features of the PCA are presented in Table 4. These features highlight the organization and change in the spatial pattern of employment in Sydney. For both years of our study, axis one differentiates those centres located in the inner core which are high density, have high employment and high employment-population ratios, and are specialized in the finance and property sectors in comparison to more suburban and peripheral locations (mainly industrial areas) with low density and low employment levels. Axis one therefore highlights a major spatial organization characteristic of Sydney – an extremely high density inner core which is job rich, with a large mix of specializations and higher order functions, and low density suburban

Table 4 PCA of employment centers (travel zones)

1981			
Axes	**% inertia**	**Representative variables**[1]	**Representative centres**[2]
Axis 1	37.21	TotJobs, EmpDensity, Job/Pop Ratio, Transport, Communication, Finance, Property	(+) CBD, Lower North Shore, Central Ind Area/Airport (-) Brookvale, Dunheved, Padstow, Yennora, Parramatta
Axis 2	12.46	Totjobs, Retail, Accommodation, Recreation	(+) Hornsby, Parramatta, Chatswood, Penrith, Fringe CBD (-) CBD, Lower North Shore, Kurnell
Axis 3	10.69	Manufacturing, Construction, Wholesaling, Personal Services	(+) Artarmon, Brookvale, Yennora, Botany, Silverwater (-) Manly, Richmond, Surrey Hills, Bondi Junction
Axis 4	6.74	EmpDensity, Elec/Gas/Water, Property, Education	(+) CBD, Sydney Grammar, Milson's Point (-) Brookvale, Airport, Alexandra
Axis 5	5.09	Administration, Health, Community	(+) Circular Quay, Milson's Point, Westmead, Syd Uni, UNSW, Artarmon (-) Airport, Chullora, Alexandria, Padstow
Total	*72.21*		
		1996	
Axes	**% inertia**	**Representative variables**[1]	**Representative centres**[2]
Axis 1	28.02	TotJobs, EmpDensity, Job/Pop Ratio, Finance, Property, Agriculture, Mining,	(+) Circular Quay, Martin Place (-) Penrith, Miranda, Hurstville, Bankstown
Axis 2	16.29	TotJobs, Retail, Administration, Personal Services	(+) Chatswood, Bondi Junction, Penrith, Parramatta (-) Circular Quay, Darling Harbour
Axis 3	9.57	Manufacturing , Construction, Wholesale	(+) Wetherill Park, Seven Hills, Padstow, Silverwater (-) CBD, North Sydney
Axis 4	7.46	Elec/Gas/Water, Communication	(+) CBD, Lower North Shore (-) Liverpool, Richmond RAF
Axis 5	5.96	Education, Health (Community Services), Cultural Services	(+) Macquarie Uni, UNSW, Westmead (-) Mascot, Airport, Town Hall
Axis 6	5.22	Transport	(+) Airport, Mascot West (-) Richmond RAF, Harris Park Seven Hills, Town Hall
Total	72.51		

Note: [1] Based on assessment of PCA loadings.
[2] Based on assessment of PCA scores.

locations with fewer specializations. Axis two identifies high employment in retail, personal services and accommodation sectors. All of the centres with high component scores on axis two are major retail centres which offer a variety of personal services. This axis identifies what may be termed a mass goods consumption sector in the spatial organization of the Sydney economy.

Remaining axes identified by the PCA for both years identify an urban space occupied by employment centres with manufacturing services (axis three), a specialized communication services function (axis four), education, health and cultural services functions (axis five) and a transport services function (axis six). Of note from Table 4 is that the basic dimensions of organization of employment in centres has not altered dramatically in our study period. However, the PCA extracted six axes for 1996 as opposed to five for 1981 – an indication of increased specialization and differentiation in the economy. Identification of a transport services function (axis six) for 1996 emphasises the key role of movement and connectivity for the provision of goods and services to the local, national and global economy (Sydney airport is a focal point for this connectivity).

Our analysis so far has only enabled identification of the broad dimensions which underly the spatial patterns of employment in centres in the Sydney urban area. Given that a polycentric spatial pattern of employment centres is present, it is now important to know what types of centres can be identified. Do groups or clusters of employment centres demonstrate similarity in their functional economic make-up, and has this typology changed to reflect more specialization or diversification? Furthermore, we are interested in knowing if the composition of the different clusters has changed over time, and for this we need to examine which sectors occupy which centres (and clusters).

To examine these questions we use the PCA component scores for each axis and for each of our employment centres in a cluster analysis. The use of PCA scores for cluster analysis, and for other multivariate analyses, is common practice given that scores for each observation summarise the performance of that observation relative to a principal component. Each principal component, or axis, is uncorrelated and so PCA scores are uncorrelated. The alternative approach of using the raw figures for

the 17 industry categories would introduce substantial multi-collinearity in the data (high correlation between some industry categories).

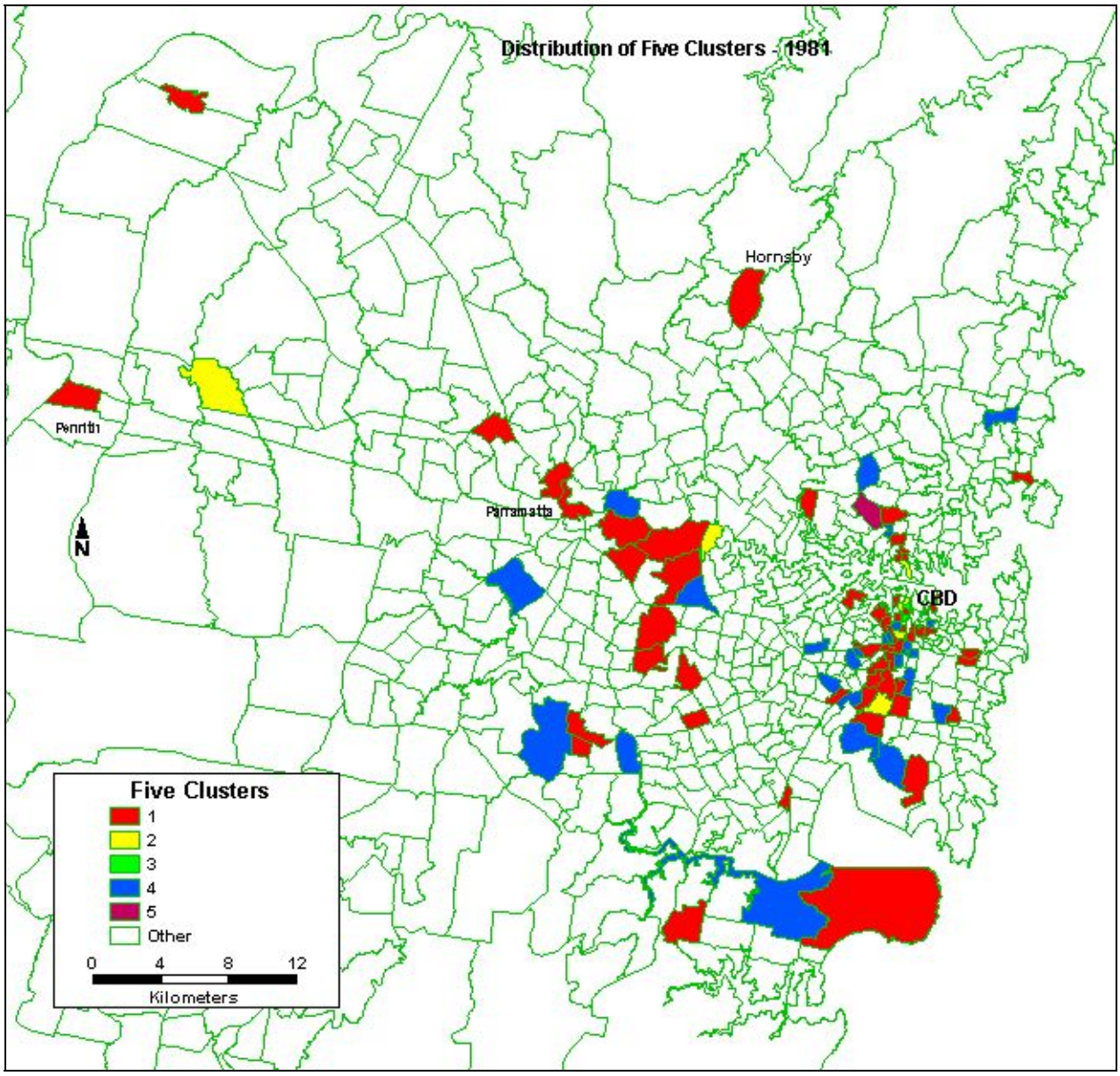
We used Ward's hierarchical clustering method with squared Euclidean distance as the dissimilarity measure. For 1981, the hierarchical analysis identified five homogenous groups of employment centres (Figure 5) and six for 1996 (Figure 6). Results are summarized in Table 5. Some key trends emerging from the cluster analysis are as follows. First, manufacturing industry continues to have a presence in traditional areas such as the Central Industrial Area, but in 1996 exhibits a more spatially concentrated pattern of location into fewer centres.

Table 5 Employment clusters and sector specialization in 1981 and 1996

Clusters 1981	**Sector specializations where location quotient exceeds 1.25 (in order of declining importance)**
1: Mixed industrial	Manufacturing, wholesale, transport, govt. administration, education, personal services, electrical, property, finance
2: Mixed services	Transport, finance, property, communication, education, mining
3: Specialised services	Communications, finance, property
4: Specialised manufacturing	Manufacturing, wholesale, personal services
5: Specialised producer services	Health, administration, wholesale
Clusters 1996	**Sector specializations where location quotient exceeds 1.25 (in order of declining importance)**
1: Mixed industrial	Manufacturing, Govt administration, wholesale, education, personal services, accommodation, property, finance
2: Mixed services - CBD	Mining, manufacturing, electrical, wholesale
3: Specialised Services – Suburbs	Education, property, accommodation
4: Specialised Wholesaling – CBD	Wholesaling
5: Specialised services	Govt. admin, property, education
6: Specialised manufacturing	Manufacturing, wholesaling, construction, cultural, education

At the same time, there has emerged centres with manufacturing specialization in the western suburbs of Sydney, especially the Wetherill Park-Smithfield industrial areas and the industrial estates of Ingleburn in the southwest. Also note that manufacturing

Figure 5 Five clusters of centre specialization 1981

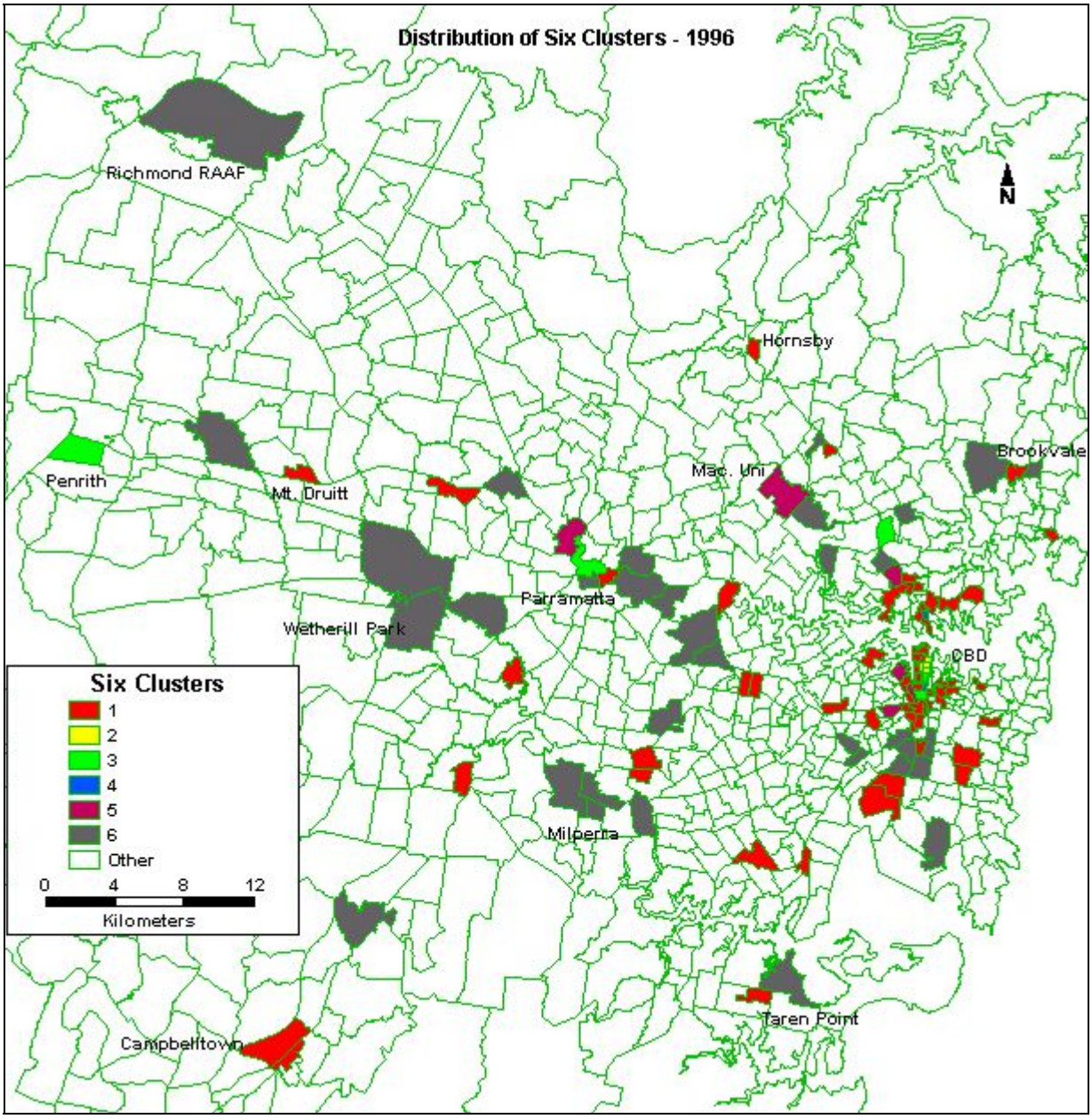


specialization on the North Shore appears more fragmented in 1996, and concentrated on the Flemington-Silverwater-Rydalmere corridor appears to have thinned out as well.

Second, mixed industrial centres show a clear trend toward concentrated dispersal in suburban locations in 1996 (Figure 6) and locations at some of the nominated

planning centres such as Campbelltown, Liverpool, Hornsby and other smaller pockets on the North Shore. Noticeable also is the emergence of Fairfield and Mt. Druitt in mixed industrial specializations.

Figure 6 Six clusters of centre specialization 1996



Third, the map for 1996 confirms earlier findings of increased specialization of sectors in centres located outside the inner core of Sydney. More of the key employment centres in western Sydney carry additional specializations in industry sectors in 1996 as compared to 1981 indicating that agglomeration forces exist for many types of activities in diverse locations. In may ways, the increased sector

specializations now evident in western Sydney reflect profiles similar to centres closer to the inner city – they are becoming just like the rest of Sydney. However, they are still differentiated from inner city centres as regards higher order services provision and, above all, employment densities. Some of these centres (e.g. Fairfield) also have very low employment-population ratios, indicative of their mixed residential-commercial-industrial nature.

CONCLUSION

Using an alternative approach to the identification of employment centres we identified 28 major concentrations in 1981 and 41 in 1996 –reflective of substantial changes in the spatial organization of employment in Sydney over this time period. Our preliminary investigations of the changing location and economic roles of these concentrations highlights the trends of increased specialization and dispersal of centres, and of increased complexity in the space economy of Sydney. It is clear from our treatment of the data, albeit with limitations, that their appear to exist a typology of centres and concentrations in particular which are, in turn, differentiated from the characteristics of the inner core of Sydney where the pull of density remains a strong force for organization. However, more detailed analysis is required for a better understanding of the effects of distance, and other factors, on why particular sectors occupy which centres and on the extent of specialization or diversification of centres.

Of interest to us is also the impacts of the growth of employment centres on the configuration of centre labour sheds and from where they draw their labour. In this context we also intend to investigate how well connected these centres are, and to what extent travel for the journey to work is by public transport or highway modes.

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