Probing Different Centralities in City Regions: A space-syntactic approach [1]

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Abstract

This paper presents preliminary findings from the first attempt at extending the spatial-configurational analysis of individual cities' street network to the city-regional scale street network, hoping to capture simultaneously the inter- and intra-settlement spatio-functional dynamics that may explain different centralities – historically evolved centres, planned centres, emergent metropolitan centres at various spatial scales – in rapidly expanding city regions. This involves the analysis of aggregate space-syntactic properties, multiple-radii integration and choice measures of the complete spatial network of two rapidly developing, geo-morphologically varied, Malaysian city regions – Penang Island and Johor Bahru District. It is demonstrated that spatial network analysis is an effective tool for studying different centralities in mostly planned, spatially non-contiguous city regions. The spatial network approach aptly encapsulates city-regional morphological variations; gives effective spatial accounts of centres of different hierarchies and sizes at various spatial scales; identifies the presence of global and intermediate-scale spatial relations that may define centres' global significance and regional strength; depicts the nesting of local centres within larger centres as well as overlapping centralities across spatial scales; and accounts for the "alternative" global-oriented location pattern of emergent metropolitan centres in city regions. More specifically, it is found that historically evolved centrality tends to be more intelligible and synergetic than planned centrality; that higher ratio of planned centrality in city regions may possibly have aggregate weakening effects on their overall intelligibility and synergy levels; and that modern metropolitan shopping/commercial centres are spatially emergent under a different spatio-functional logic that is best captured by choice analysis. Within the paper's restricted analytical depth and specificity, it is asserted that spatial network analysis effectively describes inter-settlement centrality patterns and potentially complements economic geography and regional science's spatial interaction modelling of regional/urban centrality, with the crucial advantage of not losing sight of centres' internal spatial structure. However, more in-depth quantitative analyses and detailed micro-structure studies are necessary to substantiate this claim. The paper concludes by opening up more questions that need further addressing in future studies.

Keywords: spatial network analysis, different centralities, city regions, multiple-radii integration, choice, spatio-functional dynamics

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Traffic density serves to condition where the best commercial opportunities are located and increases the likelihood of substitution of commercial premises for dwellings. This 'density of traffic on a city street is not fortuitous or arbitrary but rather a direct consequence of its position in the city plan' and is less affected by the structures along it than those such as bridges, gates, and so on, that influence the flow of traffic. Traffic is a dynamic factor in the city, as is its focal point 'which is not something spatially fixed and unmoving'.
(Frisby, 2003, p.68; citing J. Stübben's (1890) "Der Städtebau", pp.32-33)

1.0 Introduction: towards city-regional spatial network analysis

Recent space syntax studies have demonstrated the potential of spatial network analysis for better understanding the socio-spatial dynamics that underlie centrality in cities (e.g. Hillier, 1999; Cutini, 2001; Kubat, 2001; Read 2001; Holanda et al, 2002; Azimzadeh, 2003; Greene 2003; Medeiros et al, 2003; Read and Budiarto, 2003; Romppanen and Ujam, 2004). Most studies either imply or discuss as a sideline the spatial aspects of urban centrality, often loosely relating axial integration cores to actual centres in cities. A few studies have nonetheless focused more in-depth on the spatio-functional understanding of centres and subcentres in individual cities, within largely contiguous urban forms (Cutini, 2001; Read, 2001; most notably, Hillier, 1999). Hillier (1999) offers by far the most complete account of the socio-spatial processes that underlie the emergence and evolution of a key centrality element – live centrality – across various spatial scales in cities. Based on studies of London and several British towns, it is shown that street network configuration, through its effects on streets' movement potential, generates a seamless field of high and low natural movement areas and "attraction inequalities" within a street network. This then influences the spatial distribution of centrality, particularly of live centres that seek high movement locations in cities. As street network configuration is non-static, centrality is concomitantly a dynamic factor in cities; their location shifts in response to global and local spatial-configurational changes. Internal-structurally, growing centres evolve a more intense local grid for functional efficiency. Therefore, insofar as it is allowed to emerge and evolve through time, centrality in cities may be identified with well defined global and local spatial relations as indexed by the global and local integration measures, and/or with distinct intensification of the local grid structure. The global position of a centre in a street network bears upon its global-functional importance while its local grid structure underpins its efficient functioning in terms of local spatial inter-accessibility that is essential to economically successful centres.

This seems to hold true as regards emergent and evolved centres and subcentres within gradually expanded and historically evolved, continuous, urban structures. However, in many rapidly urbanising countries, such as Malaysia, urban growth may take an entirely different form and scale. Rapidly developing metropolitan regions are characterised by numerous masterplanned, sprawling, spatially leapfrogging housing schemes or new townships which are loosely held together by expansive networks of highways/expressways. Dotted within these are some original settlements/towns that have been subsumed into the expanding city region as well as modern metropolitan shopping/commercial centres that emerge mainly along major traffic corridors or at key traffic intersections. While the spatial network approach has successfully contributed to better spatial understanding of centrality in individual cities with a largely continuous and evolved urban structure, how can the approach be adapted for analysing different centralities in city regions that comprise multiple spatially non-contiguous settlements, numerous planned centres and emergent metropolitan centres?

This paper presents a first attempt at extending the spatial network approach to analysing street network in individual cities to the analysis of the complete street network of multiple settlements in city regions. It is hoped that this exploratory exercise is able to spatial-configurationally capture city regions' different centralities – historically evolved centres, planned centres, emergent metropolitan centres at various spatial scales – and contribute to explicating the city-regional spatio-functional dynamics that underlie the observed centrality pattern. To that end, Penang Island (Penang) and Johor Bahru District (JBD), two rapidly expanding Malaysian city regions with similar socio-economic-functional characteristics but different spatial-morphological structure, have been selected as case studies.

2.0 Different Centralities in City Regions: Penang versus JBD

Penang and JBD make interesting comparative cases for the purpose of this paper because they possess many similar socio-economic and functional characteristics but simultaneously stark variations in geophysical aspects and morphological structure. This ideally permits a more precise evaluation of the effects of the spatial-morphological disparities between the city regions on their pattern of different centralities – hence the effectiveness of the spatial network approach adapted to city-regional analysis – while the macro socio-economic-functional aspects are held somewhat constant.

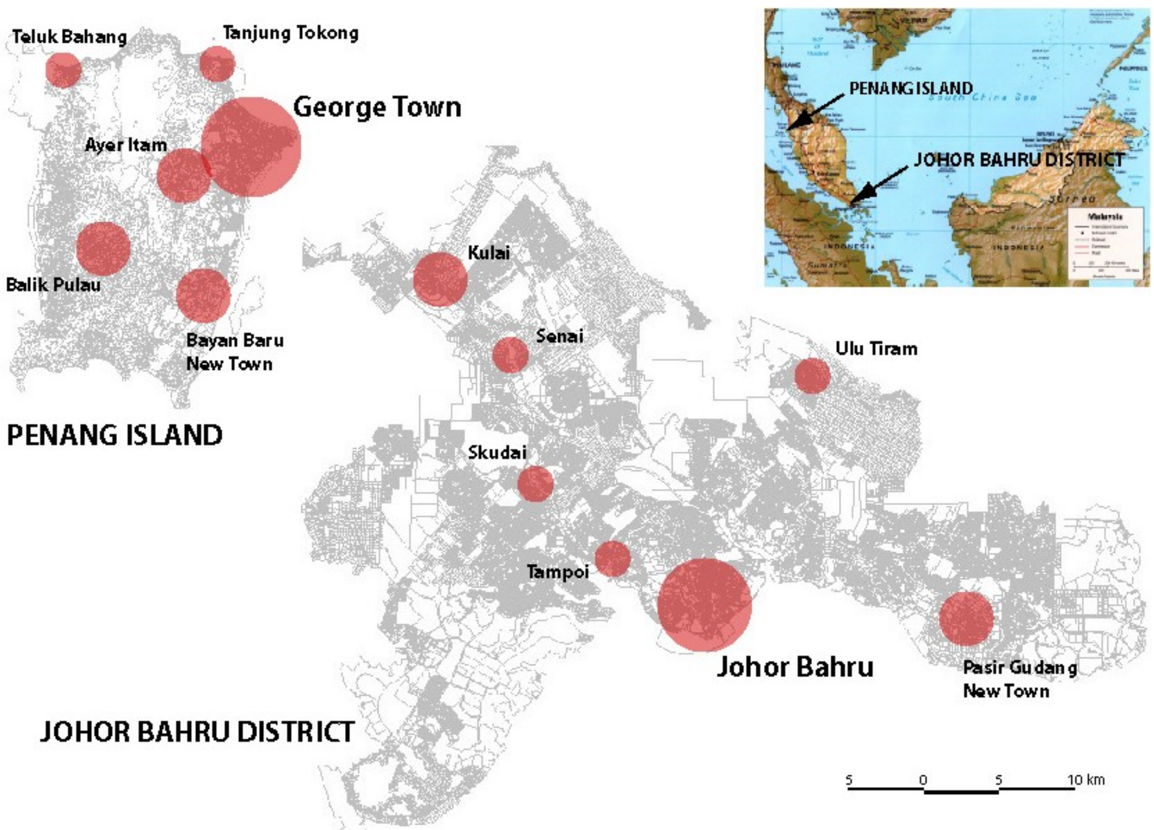
To begin with, George Town in Penang and Johor Bahru in JBD are the administrative capital and commercial and financial centre correspondingly for the States of Penang and Johor. They are the next largest cities after Kuala Lumpur, Malaysia's Federal Capital. Both cities serve an estimated regional population of over 2 million and function as the primary urban growth-pole respectively for the Northern and Southern Economic Regions in Peninsular Malaysia (Figure 1). Penang and JBD have been enjoying similar economic growth levels since the 1990s and are undergoing rapid economic and urban expansion. At the macro-regional level, Penang is designated the main centre for the Indonesia-Malaysia-Thailand Growth Triangle while Johor Bahru is one of the key economic centres in the Singapore-Johor-Riau Growth Triangle. Additionally, both city regions have an economically closely tied "companion city" separated by a narrow channel: Penang is connected to Butterworth on the mainland peninsula via a 3.3km vehicular and pedestrian ferry link, and a 13.5km bridge further south; JBD is connected to the island nation of Singapore at Woodlands through a 1.2km causeway and at Tuas by a 2.7km bridge much further west.

Despite the similarities, Penang and JBD are geo-physically and spatial-morphologically different. Penang is a small island of 299.65km^2 while JBD boasts a land area of 1,864km^2. With a resident population of 667,500, Penang's gross population density is 2,228 people per km^2 whereas JBD, housing 1.4 million people, has 751 people to every square-km. In fact, net population density is much higher in Penang due to the island's less forgiving physical-topography (40% land area 61m above sea-level). This has resulted in higher intensity, smaller-scale, compact development forms in Penang which concentrate along the island's eastern foreshore but larger-scale, self-contained and sprawling development forms in JBD, especially since the 1990s.

In terms of urban growth, Penang has a considerably longer history than JBD. George Town has mostly grown not under any overall planning scheme for almost 200 years since 1786, when the first formal settlement was set up on the island's north-eastern tip. The town became a key trading outpost to the British-India Company east of India and continuously expanded in three narrow bands north-westwards, westwards (up to the central mountain range) and southwards.

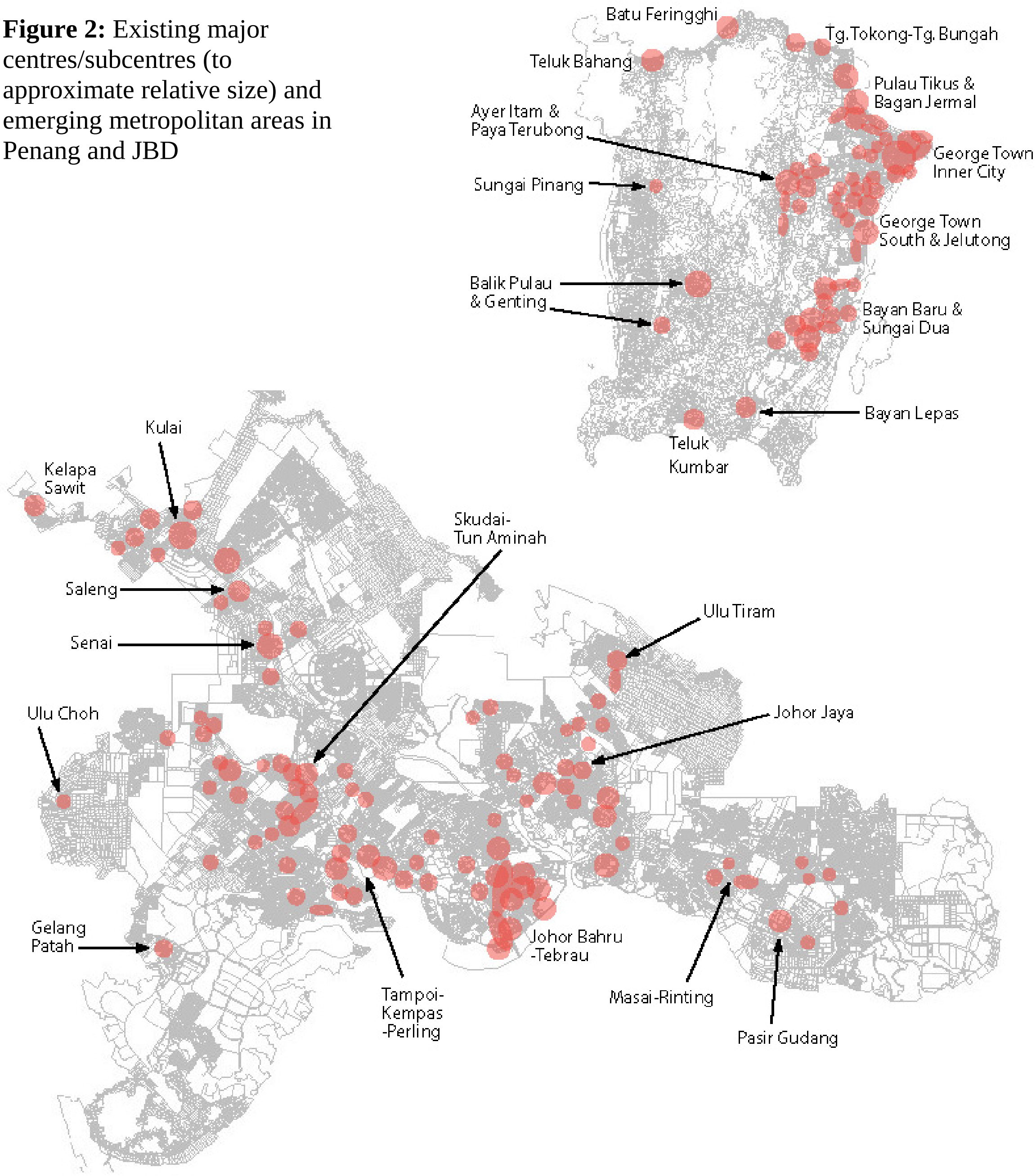
Rapid urban expansion began in late 1960s, gained pace in mid-1980s and persists till today. Consequently, Penang has a sizeable historically evolved urban core with distinct centres/subcentres from which the larger city extended outwards and merged with several outlying towns without overall planning. Planned and regulated growth which gained pace in the 1980s has been characterised by relatively small scale, high intensity individual development schemes as stated above. The few masterplanned new towns in Penang are of much smaller spatial scales, though higher densities, than most planned housing schemes in JBD. Since the 1990s, several metropolitan-scale modern shopping/commercial centres have emerged within quite distinct emergent metropolitan areas.

Figure 1: Penang and JBD and their major centres to relative scale



In contrast, Johor Bahru has a modest historical core of fewer than 15 urban blocks which began to take shape in the 1920s, though the original estuarine trading centre dated back to 1855. There was not much spatial expansion until the 1920s which saw the completion of the causeway (1924) linking the town with Singapore. The town grew gradually until the 1980s, when very rapid development began to take place partly due to economic-overspill from Singapore. In a span of two decades since, Johor Bahru has grown into a sprawling metropolis where numerous large-scale, masterplanned self-contained housing schemes/new towns fan out from the compact historical core along three primary transport corridors – the northwest JB-Kulai corridor, northeast JB-Ulu Tiram corridor and east-west Pasir Gudang corridor. In the process, several outlying towns have been incorporated into the expanding city. Modern shopping centres have also sprouted within emergent metropolitan areas that correspond to the major transport corridors. Figure 2 indicates existing major centres/subcentres and emerging metropolitan areas in Penang and JBD.

Figure 2: Existing major centres/subcentres (to approximate relative size) and emerging metropolitan areas in Penang and JBD



From the above, coupled with the observation of various centres in Penang and JBD, centralities in the two city regions may be generally differentiated according to the following morphological types:

- Primarily historically evolved centres
- Original centres with some "sporadic" planned growths
- Original centres with large-scale planned extension
- Planned centres in masterplanned housing schemes or new townships
- Emergent metropolitan shopping/commercial centres

Of interest now are: how will each kind of centre figure space-syntactically when analysed in relation to one another within the spatial network of the two city regions? How will city regions with different make-ups of each kind of centres overall vary from each other in syntactic terms? Will each city region's aggregate syntactic descriptions reflect its geo-morphological and socio-economic characteristics as described above?

3.0 Space-syntactic Profile of Penang and JBD

With a view to ascertaining the extent to which the city-regional spatial network is capable of encapsulating the geo-morphological variations between the two city regions as previously described, it is instructive to begin by exploring and comparing between Penang and JBD's overall geographic and space-syntactic properties (Table 1). The syntactic size of JBD, defined in terms of total axial line number and total axial line length is respectively 3.5 and 4.7 times that of Penang, despite JBD's population being only 2.1 times that of Penang. Concurrently, population density per axial line is 1.8 times as high in Penang as in JBD while population density per axial-km in Penang is 2.3 times that of JBD, with axial lines in JBD being averagely 1.3 times longer. This reinforces earlier observations that development in Penang tends to be denser but smaller in spatial scale than that in JBD. Nevertheless, the maximum and mean step-depths for both city regions, despite their considerable size difference, are quite similar, with JBD's maximum depth (114-deep) just three steps deeper than Penang's (111-deep), while their mean step-depths from their respective most integrated street (17 and 16 respectively) vary only by one-deep. This implies that axial lines in JBD are on the whole better connected than those in Penang, which is confirmed by mean connectivity in JBD being 17% higher. The marginal variation in Penang and JBD's depth properties may be attributable to "globalising rules" (see Hillier et al, 1993) operating in JBD's growth process, resulting in the up-scaling of axial properties and consequential conservation of shallowness of its spatial network. For the same reason, mean global integration for Penang and JBD are nearly invariant (less than 2% difference), though their mean local integration differs more significantly, with JBD's mean local integration 18% higher. Therefore, while the two city regions appear to have similar level of global integration, JBD tends to have overall stronger local spatial structures, which may be an indicator of dispersed local centres in the city region. However, this may be the effect of the introduction of numerous side/back-lanes in modern planned housing schemes/new towns as required under planning regulations. A cursory inspection of Penang and particularly JBD's local integration maps quickly reveals non-central, locally highly integrated lines in several planned housing schemes. These "non-realistic" red/orange lines are a product of their 2-step structural importance in being lines that hold large numbers of 1- and 2-deep lines together, but which do not yield any coherent local grid structure.

Turning to second order syntactic measures of intelligibility and synergy, albeit both city regions register low values (Table 1), Penang has over four times the intelligibility and 3.4 times the synergy of JBD. While this may be an effect of size disparity (intelligibility is especially known to decrease with increasing syntactic size), it is proposed that it may be more a consequence of morphological variations between the city regions. It is suggested that JBD's significantly lower intelligibility and synergy are a result of higher proportion of planned development schemes that feature more regularised street layouts. This has the effect of regularising the distribution of local integration across the spatial network while global integration always falls towards the network's edges. Therefore there is less correlation between global and local integrations in JBD, hence its lower intelligibility and synergy.

Table 1: Comparative geographic and space-syntactic properties of Penang and JBD

Geographic/Space-syntactic Properties	Penang	JBD	JBD:Penang Ratio
Total land area (km^2)	299.65	1864	6.22
Total population	667,500	1,400,000	2.0974
Population density per km^2	2228	751	0.3371 (2.9665)
Total axial line number	7,054	24,721	3.5045
Population density per axial line	94.6272	56.6320	0.5985 (1.7590)
Total axial line length (km)	1,546.0075	7,210.7762	4.6641
Population density per axial length (km)	431.7573	195.1539	0.4320 (2.3148)
Mean axial line length (m)	219.1673	291.6861	1.3309
Maximum step-depth	111	114	1.0270
Mean step-depth (from the most integrated street)	16.4105	17.4465	1.0631
Mean connectivity	3.3782	3.9543	1.1705
Mean global integration (rad-n)	0.4700	0.4613	0.9815 (1.0188)
Mean local integration (rad-3)	1.9783	2.3267	1.1761
Intelligibility	0.0457	0.0111	0.2429 (4.1169)
Synergy	0.0827	0.0241	0.2914 (3.4317)

Note: *numbers in brackets show inverse ratio*

The proposition that planned centrality may impair city regions' intelligibility and synergy is bolstered by the examination of whether centres of different morphological types are space-syntactically different from one another and how this differentiation, if any, impacts on the overall syntactic properties of the city regions. Table 2 shows the aggregate key space-syntactic properties of centres by morphological type for Penang and JBD. It is obvious, at least for Penang and JBD, that historically evolved centrality tends to have higher intelligibility and synergy compared to planned settlements of similar syntactic sizes. Also, as the proportion of planned centrality increases, the less intelligible and synergetic the entire city-regional spatial network becomes, though average connectivity tends to rise. Both intelligibility and synergy generally decrease as we go from primarily historically evolved (the least planned) centres, through original centres with sporadic planned growths, to original centres with large-scale planned extension, particularly in JBD. The most revealing comparison to substantiate this is to scrutinise the size and second order measures for historically evolved centres and planned centres side-by-side. Bearing in mind the tendency that second order configurational measures decrease with increasing network size, George Town (GT) presents a remarkable case of historically evolved centrality; consisting of 899 axial lines, it has much higher intelligibility (0.3987) and synergy (0.6118) than any much smaller masterplanned centres in Penang and JBD (Table 2). Johor Bahru (JB), with 336 lines, similarly has higher intelligibility (0.3680) and synergy (0.5791) than averagely smaller planned centres. Finally, emergent metropolitan areas, which are essentially amalgamations of mainly masterplanned settlements and possibly a few original centres, give the lowest intelligibility and synergy values among all morphological types.

Table 2: Aggregated Space-syntactic Properties of Centres of Different Morphological Type for Penang and JBD (see **Appendices** for complete data of individual centres)

Centres by Morphological Type	Mean Line Number		Mean Connectivity		Mean Intelligibility		Mean Synergy	
	Penang	JBD	Penang	JBD	Penang	JBD	Penang	JBD
Primarily historically evolved	293	173.38	3.15	3.72	0.3265	0.2824	0.4718	0.3971
Main city centre	899 (GT)	336 (JB)	3.62 (GT)	3.67 (JB)	0.3987 (GT)	0.3680 (JB)	0.6118 (GT)	0.5791 (JB)
Other centres	141.5	150.14	3.04	3.72	0.3085	0.2702	0.4368	0.3711
Original centres with some sporadic planned growths	323.25	680.67	3.38	3.97	0.2289	0.1938	0.3459	0.3008
Original centres with large-scale planned extension	NA	1,100.4	NA	4.13	NA	0.0958	NA	0.1385
Masterplanned developments	286.67	317	3.96	4.22	0.2698	0.2007	0.3509	0.2728
Emergent metropolitan areas	1,987.57	5,858.6	3.55	4.18	0.1364	0.0327	0.2285	0.0588
Complete city region	7,054	24,721	3.38	3.95	0.0457	0.0111	0.0827	0.0241

Even at this crude level of syntactic profile analysis, it is revealing that the regional spatial network is able to capture geo-morphological variations between Penang and JBD. This is achieved, it is proposed, because the city regions' geo-morphology is to a high degree intrinsic in the way the city regions develop and, thus, in their spatial form and structure, which are then internalised into the city regions' axial network. On the whole, it is shown that Penang and JBD are space-syntactically inherently different; the spatial variation may be attributable to the city regions' different make-ups of historically evolved and planned centralities, and their density and scale variations that respond to geophysical constraints. How does this figure in the total centrality pattern of the city regions? In what follows, the city regions' total centrality pattern is spatially checked against multiple-radii integration and choice measures.

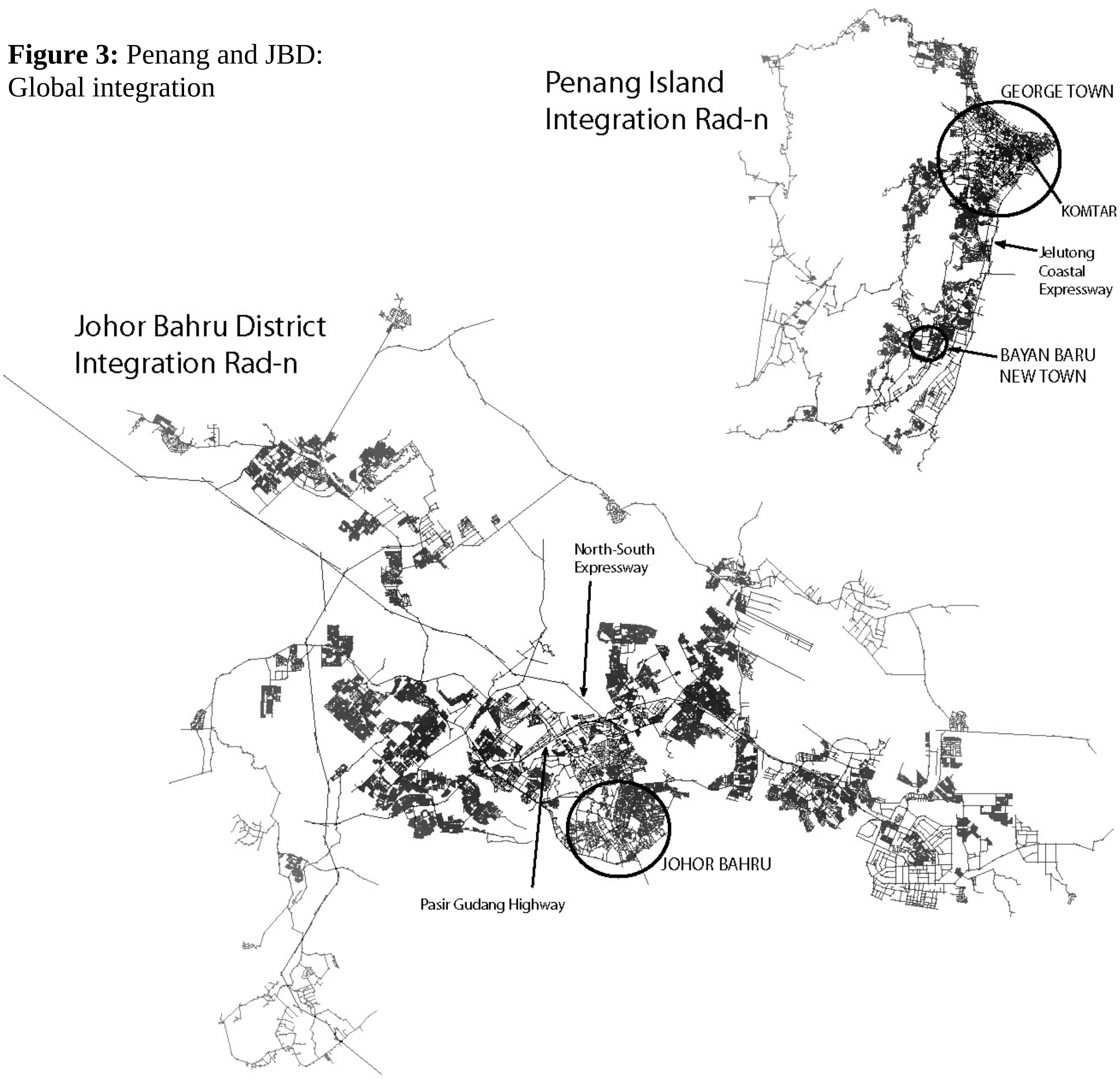
4.0 Multiple-radii Integration Analysis: a diagnostic approach

Apart from radius-n and radius-3, integration analysis for both Penang and JBD has been run at radii beginning with radius-4, through radius-radius, up to the radius where the global integration structure begins to emerge (radius-28 for both Penang and JBD). The rationale behind multiple-radii analysis is the presumption that different radii integration may identify multiple settlements' different-sized, lumpy, spatial structures. In this paper, only global integration (radius-n), radius-radius integration, and radii 6-8 integrations which effectively pick out Penang and JBD's major centres/subcentres are discussed. Discussion at this juncture is general and based mainly on visual inspection of the axial maps pending detailed quantitative and area-specific analyses that are currently underway.

4.1 Global Integration Analysis

Global integration analysis indicates the primary space-syntactic core of a spatial network, which should ideally correspond to the city regions' main live centre. However, for Penang and especially JBD, the global space-syntactic core does not denote their respective main live centre. For both city regions, the global syntactic core highlights spatially more central sections of inter-settlement highways that comprise quasi-linear sequences of long, shallow-angle lines which stretch across significant lengths of the city regions (Figure 3). These are functionally non-central spaces but part of the major global-scale movement network. While globally the shallowest, they lack any local grid structure that has been found to be fundamental to the germination and efficient functioning of live centres. Nevertheless, the shape of the global syntactic core in the two city regions varies considerably. Due to its longer morphological history, hence its large syntactic size, George Town has evolved a tighter, robust spatial structure that possesses the spatial inertia to retain the syntactic core within the city, though shifted slightly inland and southwards (along the Jelutong Coastal Expressway) towards Bayan Baru New Town, Penang's second largest settlement. Within the city grid, the syntactic core appears more convex, well distributed over a dense local grid. Part of the core penetrates the edge of the historical inner city where Penang's largest shopping, commercial and government centres (KOMTAR comprehensive redevelopment scheme) are located.

Figure 3: Penang and JBD: Global integration



In JBD, hasty suburbanisation to the northwest, northeast and east has drawn the syntactic core approximately 10km north of Johor Bahru, JBD's main city centre with dominant shopping, commercial and government functions. The syntactic core, centring on the Pasir Gudang Highway and North-South Expressway, arches over a third of JBD's east-west dimension, forming a sparse, large-scale grid that is far from having any distinct centre-like characters on the ground. Global integration analysis effectively confirms the general feeling among local people that Johor Bahru seems to be located on the "other end" of the city and appears to be imposing longer-than-necessary travel distances to the city centre, which may have implications on the city's social, environmental and economic sustainability. The fact that Johor Bahru is thriving while located so much off the syntactic centre is a special case of having a large "global attractor" – Singapore – to its south. Singapore is an indispensable factor underlying the socio-economic vitality of Johor Bahru, which functions as the "gateway" for the daily tens of thousands of commuters, tourists/visitors and shoppers crossing between them (Johor Bahru is a shopping and gourmet paradise for Singaporeans while Singapore is an attractive employment centre to the JBD population; both due to foreign exchange advantages).

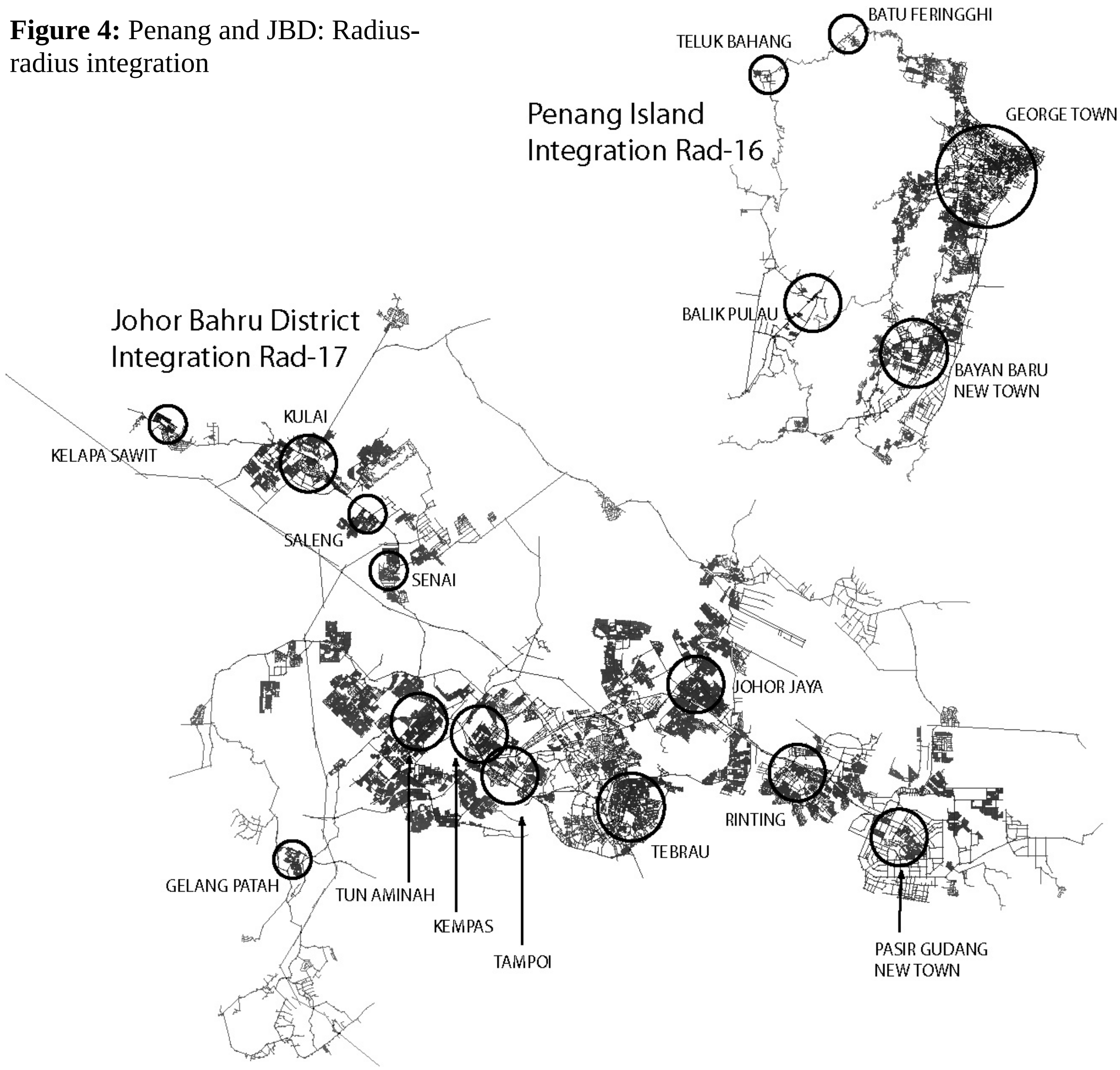
4.2 Radius-radius Integration Analysis

Radius-radius integration is computed by setting the radius to the mean step-depth from the network's globally most integrated line. This yields a global integration pattern while minimising edge effects on lines located on the edges of the network. It is found that for city regions with leapfrogging growth and non-continuous spatial forms, radius-radius integration is effective in identifying space-syntactic subsystems that correspond to major settlements and their central spaces within the spatial network (Figure 4). For Penang, radius-radius integration (radius-16) picks out three main sub-regional systems: George Town; Bayan Baru; and most markedly, Balik Pulau, the main town on the western side of the island (though a much smaller centre, Balik Pulau is to the west coast what George Town is to the island's eastern foreshore). It also aptly highlights Teluk Bahang and Batu Feringghi as smaller but significant centres on Penang's northwest coast. For JBD, except for the rapidly emerging Kelapa Sawit-Kulai-Saleng-Senai metropolitan area which is most strikingly highlighted, regional subsystems appear more diffused and less clearly depicted by radius-radius integration (radius-17). This pertinently illustrates the sprawling, regularised – spatially less differentiated – planned growth pattern in JBD as earlier described. Nonetheless, Tebrau (which has the greatest concentration of modern shopping centres in JBD); Tampoi; Kempas; Tun Aminah; Johor Jaya; Rinting; Pasir Gudang and Gelang Patah are moderately picked out. It is worth emphasising that for most of the centres, radius-radius integration pinpoints precisely down to their main shopping/commercial streets.

The centres are not only apparent in axial maps, but also strongly depicted in the synergy scattergram between radius-radius integration and global integration (Figure 5). Of interest here is not the regression value, which is bound to be high due to the nearness between radius-radius and radius-n, but the relationship between the two spatial scales that are being correlated. Taking Penang as example, the radius-radius/radius-n scattergram clearly identifies five distinct groups of centres where the largest group seems to encompass several centres, which is consistent with Penang's actual distribution of major centres; viz.:

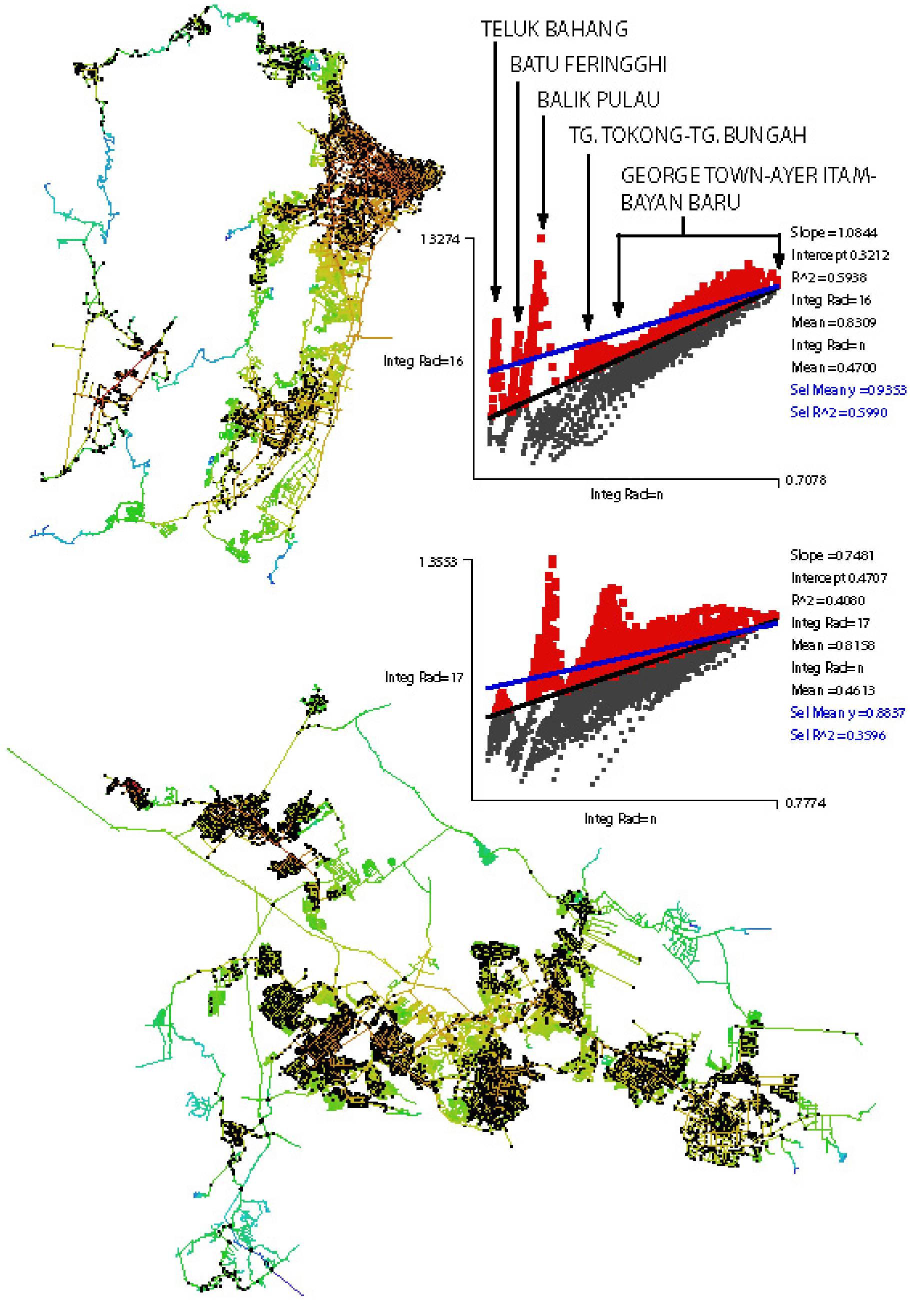
- George Town, Bayan Baru, Ayer Itam metropolitan centres;
- Tanjung Tokong-Tanjung Bungah;
- Balik Pulau;
- Batu Ferringhi; and
- Teluk Bahang.

Figure 4: Penang and JBD: Radius-radius integration



Aside from alluding to centre distribution, the scattergrams also clearly reveal inter-settlement routes linking and passing through various centres. The routes are distinguished by increasing radius-radius integration on lines approaching a centre, peaking on the centre-line, and decreasing on lines leaving the centre on the other side (cf. Hillier's (1999) "transect method"). Another notable aspect of the synergy scattergram is that when points representing axial lines whose radius-radius integration outperforms global integration (points above the regression line) are selected, they appear to phenomenally highlight most actual centres on the urban surface, though some non-central spaces in planned development and around smaller centres are also picked out (Figure 5) (but see next section). Conversely, points laying below the regression line, though some are globally highly integrated, pick out spaces that are in no way central (e.g. highways; major arterial routes). This works consistently for Penang and JBD, indicating that the kind of global-local spatial relations that define centralities in individual cities may similarly be present at the city-regional level; though, "local" in this respect means radius-radius instead of radius-3. Thus, global integration hints at centres' global-functional significance while radius-radius integration may be indicative of their "strength" of centrality. Further analysis is necessary to bear this out, especially considering that smaller centres are picked out more strongly than larger centres for both city regions.

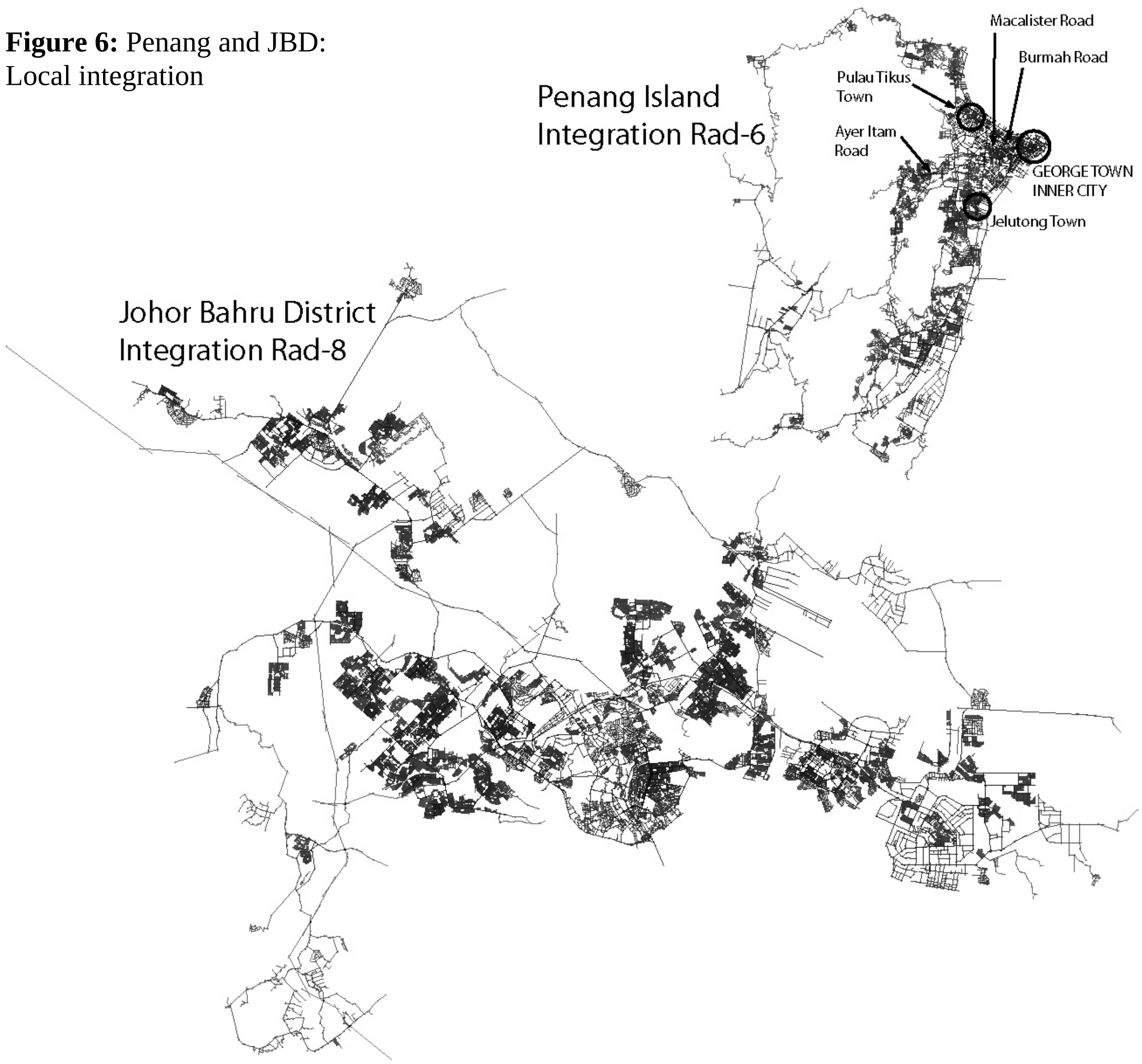
Figure 5: "Radius-radius integration/ global integration" scattergrams for Penang and JBD, with axial maps indicating lines that correspond to points-selection in the scattergrams



4.3 Local Integration Analysis

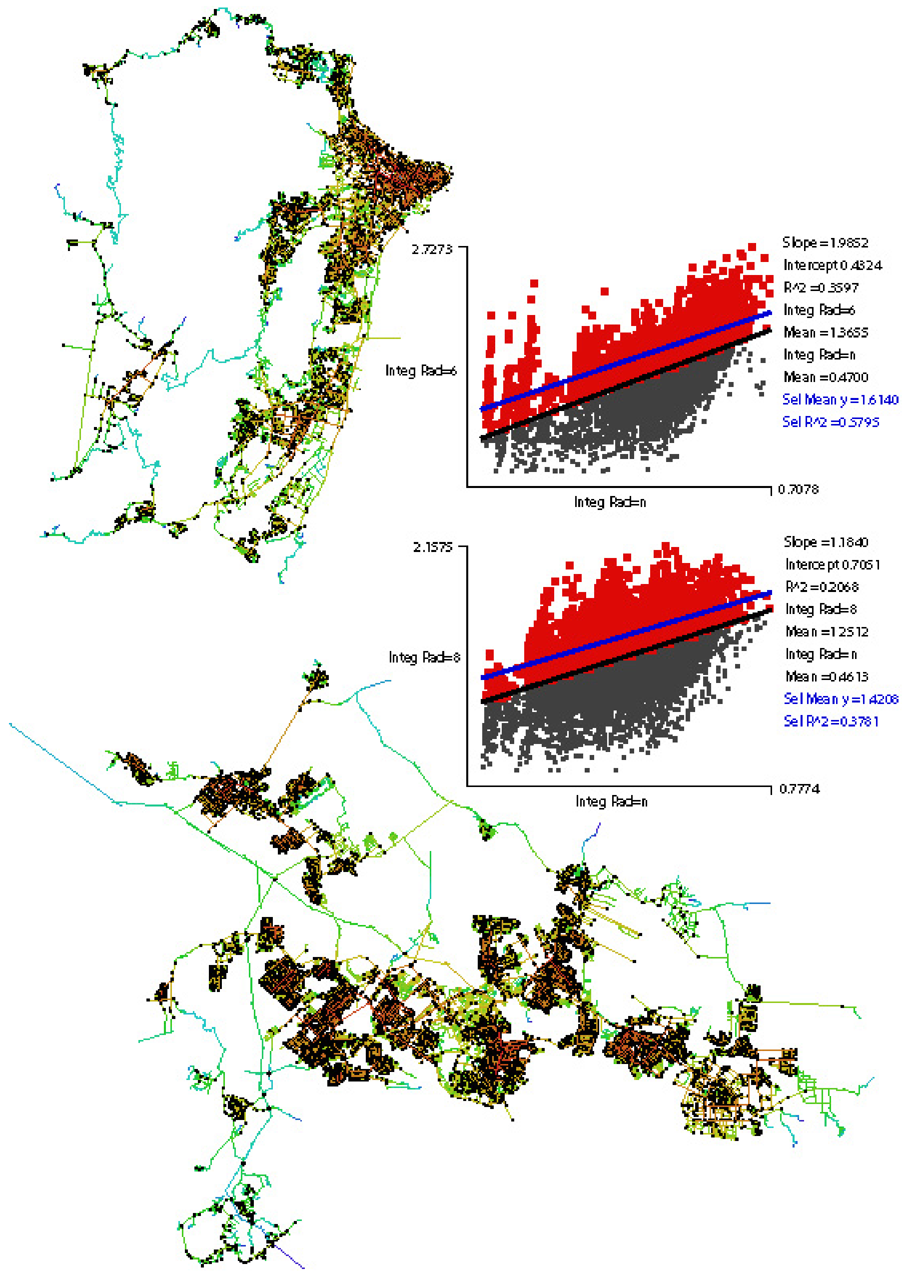
As noted before, integration radius-3 tends to highlight "non-realistic" locally highly integrated lines in Penang and JBD's planned settlements and is not a suitable descriptor for their local centrality. Radius-6 integration is found to best illustrate Penang's overall local centrality pattern while radius-8 integration best describes JBD's local centres (Figure 6). This implies larger service areas of local centres in JBD and reaffirms earlier remarks about JBD's larger development scales. Factoring in the city regions' mean axial length, Penang's local centres have a mean metric radius of about 1.3km vis-à-vis JBD's 2.3km, which unexpectedly matches the scale of JBD's major planned, self-contained housing schemes/new towns (e.g. Taman Universiti; Tun Aminah; Johor Jaya; Rinting; Tebrau). Furthermore, the respective local radius for Penang and JBD not only pinpoints larger numbers of local centres down to specific main streets but most interestingly, also suggests the nesting of lower-hierarchy centres within larger centres when checked against the radius-radius integration map. For instance, Penang's radius-6 axial map picks out George Town's inner city; Macalister Road; Burmah Road; Pulau Tikus; Jelutong; and Ayer Itam Road which clearly overlap George Town's radius-radius integration core (compare Figure 6 to Figure 4). In JBD, some radius-radius integration centres stand out more strongly as radius-8 centres, suggesting that they potentially function as both higher- and lower-hierarchy centres. Thus, the spatial network approach to city-regional analysis, through multiple-radii integration, is capable of capturing overlapping centralities across spatial scales.

Figure 6: Penang and JBD: Local integration



Turning to synergy, the respective scattergram for Penang (radius-6/radius-n) and JBD (radius-8/radius-n) depicts larger numbers of distinct centre groups (Figure 7) than the radius-radius/radius-n scattergram. This realistically reflects the urban centrality phenomenon where urban systems are composed of numerous lower-hierarchy centres but fewer higher-hierarchy centres. Repeating the procedure of selecting points whose local integration surpasses global integration, the selection faithfully detects most local centres, though again several non-central spaces in some planned development and around smaller centres are also highlighted. However, it is argued that this is reasonable because at the city-regional scale what network analysis seems to do is aggregating settlements as individual centres within larger city regions. More detailed, area-specific analysis should potentially bring to light more precise local centrality patterns in each settlement. This further supports the idea that spatial network analysis is effective across various spatial scales and presents an effective tool for regional-scale study of centrality.

Figure 7: "Local integration/global integration" scattergrams for Penang and JBD, with axial maps indicating lines that correspond to points-selection in the scattergrams

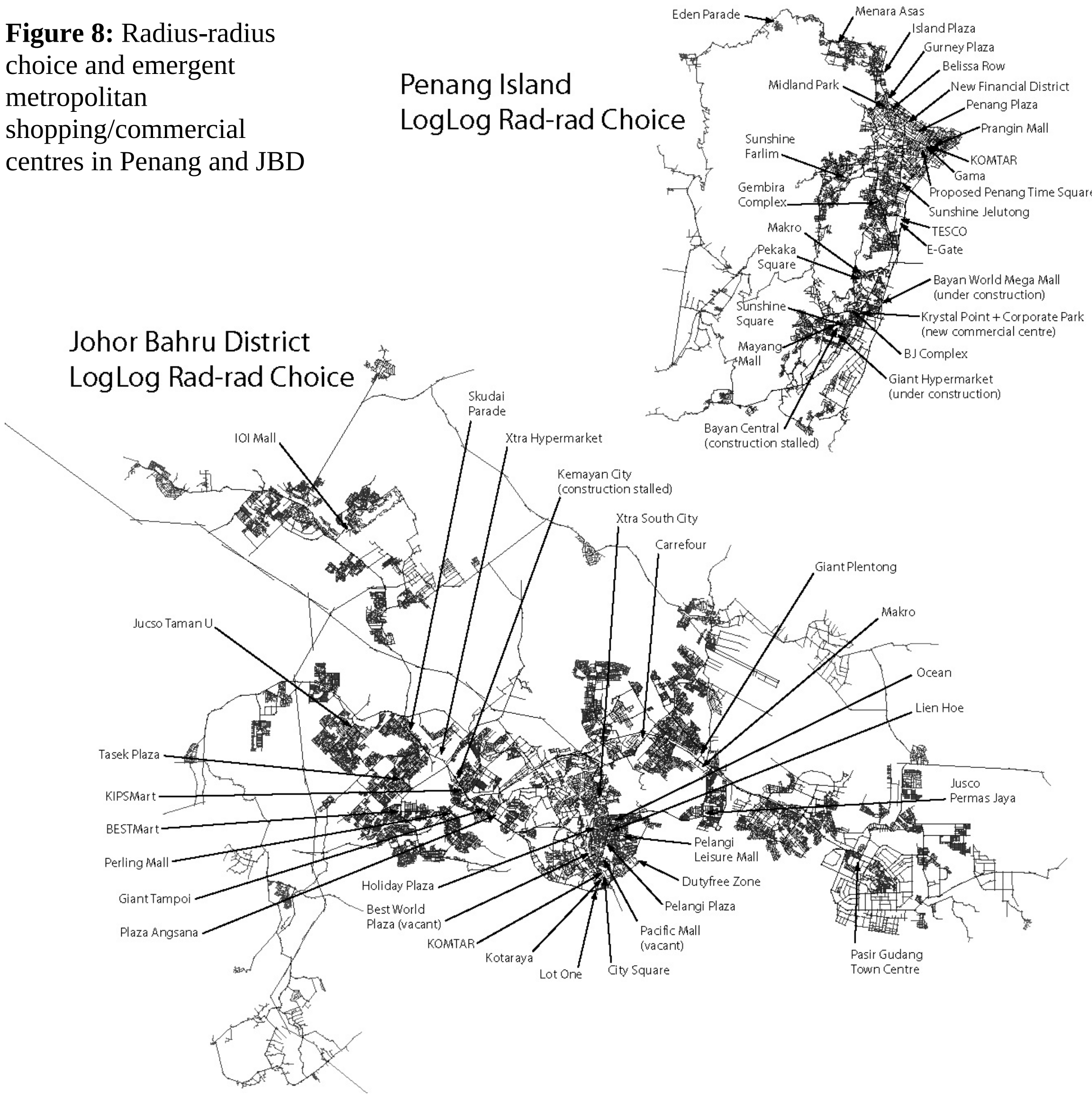


5.0 Choice Analysis: exposing emergent metropolitan centrality

One shortcoming of multiple radii integration analyses is their inability to all at once account for the distribution of modern shopping/commercial centres that sprouted in emergent metropolitan areas in Penang and JBD since the 1990s. Global and radius-radius integrations fail to account for outlying metropolitan centres while local integration does not justify the centres' global-orientedness. We need a global measure that is able to explain these centres' collective location pattern. Stemming from observations that modern shopping/commercial centres are vehicular oriented, this paper experiments with the global choice and radius-radius choice measures. "Choice" computes the likelihood that each space in a spatial network is traversed for all potential movements on topologically simplest routes between all possible pairs of origin and destination spaces within the network. Choice, therefore, is an index of the potential of space for "through movement", as opposed to "to-movement" which is indicated by the integration measure (Hillier et al, 1987; Peponis et al, 1989).

For Penang and JBD, radius-radius choice picks out the complete primary traffic network and best articulates the distribution of emergent metropolitan shopping/commercial centres in the city regions (Figure 8). It is observed that these centres are always located abutting, or up to maximally 2-deep off (due to service/slip roads off highways) primary radius-radius choice lines, often at key traffic intersections among established housing schemes/new towns. Johor Bahru again poses an extraordinary case where the city centres' largest shopping complexes do not associate with any strong choice lines; this is again explainable by the earlier alluded to "Singapore factor". These results, though preliminary, is instructive of the spatio-functional logic underpinning the distribution of these emergent metropolitan centres. Metropolitan shopping/commercial centres do not serve any particular locale and are therefore not so much central destinations for any specific localities which require high-integration locations at the radius appropriate to the localities. These centres thrive on high passing traffic volume and do best when they achieve maximum exposure to the entire city-regional populace. They globalise their existence through locations that are topologically shallow and directly visible from primary global through-movement routes which are space-syntactically indexed by global/radius-radius choice. As such, metropolitan shopping/commercial centres are also spatially emergent, but they operate on a different spatio-functional logic vis-à-vis historically evolved centres, seeking high global/radius-radius choice locations rather than high-integration locations in the spatial network. This seems tenable, so far, based on the crude "eyeball method" of visually correlating centres' location with the choice core pattern at the city-regional scale. More in-depth analyses are necessary to verify whether global/radius-radius choice is the principal spatial factor influencing the location of emergent metropolitan centres, or do local spatial properties also play a role? More quantitative exploration of the choice measure (e.g. correlating choice rank with centre size) is also warranted in view of its under-usage in space syntax research so far.

Figure 8: Radius-radius choice and emergent metropolitan shopping/commercial centres in Penang and JBD



6.0 Discussion: what next?

The paper's findings open up two possible realms of discussion. The first relates to the methodological question initially raised about the effectiveness of the spatial network approach to analysing city-regional street networks in order to bring to light different centralities in two morphologically varied city regions. The second concerns more specific questions about Penang and JBD's different centralities, which have been severally raised and discussed along the way in the preceding sections. Therefore, the discussion herein focuses on generally evaluating the methodological effectiveness of the spatial network approach.

This paper has successfully demonstrated that spatial network analysis, which has been primarily applied to the analysis of individual cities' evolved, continuous street network, is an effective analytical tool for studying different centralities in mostly planned, spatially non-contiguous city regions. The network modelling of Penang and JBD's complete linear spatial structure, even at the aggregate syntactic-profile level, is capable of encapsulating geo-morphological variations and invariants between the city regions, which the network model has been able to internalise. Moreover, syntactic-profile analysis of centres according to morphological type is able to show that historically evolved centrality and planned centrality are inherently different: the former tends to be more intelligible and synergetic than the latter. Multiple-radii integration analysis of entire city regions then gives effective spatial accounts of centres of different hierarchies and sizes at various spatial scales and identifies the presence of global and intermediate-scale spatial relations that may define centres' global significance and regional strength, though this requires verification by more in-depth analyses. The technique also suggestively depicts the nesting of local centres within larger centres as well as overlapping centralities across spatial scales. Choice analysis then completes the picture by illuminating the "alternative" global-oriented location pattern of emergent metropolitan centres that multiple-radii integration inadequately illustrates, thus implying a different spatio-functional logic underlying the centres' emergence.

Spatial network analysis of city regions, it seems, is effective in describing inter-settlement centrality patterns – hitherto an exclusive subject area in economic geography and regional science – but without losing sight of the centres' internal spatial structure which economic geography and regional science's spatial modelling techniques tend to miss (see Rihll and Wilson, 1987, 1991; Carter, 1995; Fujita et al, 1999; Wilson, 2000; McCann, 2001). Questions arise, however, as to whether the spatial network approach, which hinges on a different spatial paradigm vis-à-vis economic geography and regional science, may better quantitatively model inter-settlement functional relationships. An interesting possibility will be to correlate various space-syntactic measures with centres' economic-geographic functional indices, which is the next phase of this research.

The exploratory nature of this paper in experimenting with city-regional scale spatial network analysis on two rapidly expanding city regions necessarily restricts its analytical depth and specificity. At this stage, no spatial distinction has been made with respect to centres' different morphological types as the spatial network approach appears to satisfactorily capture all historically evolved, planned, and emergent metropolitan centralities; though the former two may be amply distinguished from the last one. Therefore, while the approach proves effective in portraying city regions' total centrality pattern, more detailed, area-specific analysis is necessary to ascertain the extent to which different morphological centres may be variedly picked out. Much remains to be done to examine the internal structure and micro-spatial properties of these different centralities in order to detect any micro-structural variation among them. Of interest include: how different are the local spatial structure of each kind of centrality from the other? Are planned centres and emergent metropolitan shopping centres also necessarily characterised by intense local grid structure? How does the up-scaling of axial properties (see Section 3.0) in growing city regions impact on the shape, scale and internal structure of different kinds of centres?

Finally, there remain a few open questions that need to be addressed in future studies:

- That higher ratio of planned centrality vis-à-vis historically evolved centrality in city regions may weaken the city regions' overall intelligibility and synergy; how true is this, or is it more an effect of city regions' larger syntactic size? Does this then apply generally to most city regions?
- That lower intelligibility and synergy may imply higher degree of subcentrality (non-concordance between local and global spatial properties may indicate tendency of subcentre formation beyond the main syntactic centre); is this more pertinent to historically evolved settlements than masterplanned ones (whose low intelligibility and synergy may be attributable to "non-realistic" locally highly integrated lines)?

- That "more local" spatial properties may be more crucial to the germination and long-term efficient functioning of centres compared to global spatial properties that mainly bears upon the centres' overall functional importance; does this apply equally to planned centrality and emergent metropolitan centrality?
- That large global attractor which spatially distorts city regions' centrality pattern, resulting in large centres located in non-spatially integrated locations, thus imposing higher expenditure of resources and effort to overcome space, may have implications on cities' long-term social, environmental and economic sustainability; how can space-syntactic variables be correlated with appropriate urban sustainability indicators in order to substantiate this?

Acknowledgement

The author owes the idea behind city-regional spatial network analysis to his supervisor, Professor Bill Hillier (University College London) through a weekend telephone conversation.

Bibliography

Azimzadeh, M., 2003, "Survival of bazaars: global spatial impact and local self-organising processes", *Proceedings, 4th International Space Syntax Symposium*, London, pp.77.1-77.18

Carter, H., 1995, *The Study of Urban Geography*, 4th ed., London, Arnold

Cutini, V., 2001, "Configuration and centrality: some evidence from two Italian case studies", *Proceedings, 3rd International Space Syntax Symposium*, Atlanta, pp.32.1-32.11

Frisby, D., 2003, "Straight or crooked streets?: The contested rational spirit of the modern metropolis", in Whyte, I.B. (ed.), *Modernism and the Spirit of the City*, London, Routledge

Fujita, M.; Krugman, P.; Venables, A.J., 1999, *The Spatial Economy: Cities, Regions, and International Trade*, Cambridge, Mass., The MIT Press

Greene, M., 2003, "Housing and community consolidation in informal settlements: a case study of movement economy", *Proceedings, 4th International Space Syntax Symposium*, London, pp.38.1-38.24

Heitor, T.; Kruger, M.; Muchagato, J.; Ramos, T.; Tostes, A., 2000, "Breaking of the mediaeval space: the emergence of a new city of enlightenment", *Urban Design International*, 5, pp.199-208

Hillier, B., 1999, "Centrality as a process: accounting for attraction inequalities in deformed grids", *Urban Design International*, 4(3&4), pp.107-127

Hillier, B.; Burdett, R.; Peponis, J.; Penn, A., 1987, "Creating life: or, does architecture determine anything?", *Architecture and Behaviour*, 3(3), pp.233-250

Hillier, B.; Penn, A.; Hanson, J.; Grajewski, T.; Xu, J., 1993, "Natural Movement: or, configuration and attraction in urban pedestrian movement", *Environment and Planning B: Planning and Design*, 20, pp.29-66

Holanda, F.; Passos Mota, A.M.; Cavalcante Leite, A.A.; Bello Soares, L.R.S.; Garcia, P.M., 2002, “Eccentric Brasilia”, *Urban Design International*, 7, pp.19-28

Karimi, K., 1997, “The Spatial Logic of Organic Cities in Iran and the United Kingdom”, *Proceedings, Space Syntax First International Symposium*, London, pp.05.1-05.17

Kubat, A.S., 2001, “Istanbul: A configurational model for a metropolis”, *Proceedings, 3rd International Space Syntax Symposium*, Atlanta, pp.62.1-62.7

McCann, P., 2001, *Urban and Regional Economics*, Oxford, Oxford University Press

Medeiros, V.A.S.; Holanda, F.R.B.; Trigueiro, E.B.F., 2003, “From compact colonial villages to sparse metropolis: investigating grid integration, compactness and form of the integration core in Brazilian cities”, *Proceedings, 4th International Space Syntax Symposium*, London, pp.12.1-12.16

Peponis, J.; Hadjinikolaou, E.; Livieratos, C.; Fatouros, D.A., 1989, “The spatial core of urban culture”, *Ekistics*, double issue on space syntax, 56(334/335), pp.43-55

Read, S., 2001, “‘Thick’ Urban Space: shape, scale and the articulation of ‘the urban’ in an inner-city neighbourhood of Amsterdam”, *Proceedings, 3rd International Space Syntax Symposium*, Atlanta, pp.18.1-18.12

Read, S. and Budiarto, L., 2003, “Human scales: understanding places of centring and de-centring”, *Proceedings, 4th International Space Syntax Symposium*, London; pp.13.1-13.16

Rihll, T.E. and Wilson, A.G., 1987, “Model base approaches to the analysis of regional settlement structures: the case of Ancient Greece”, in Denley, P. and Hopkin, D. (eds.), *History and Computing*, Manchester, Manchester University Press

Rihll, T.E. and Wilson, A.G., 1991, “Modelling settlement structures in Ancient Greece: new approaches to the polis”, in Rich, J. and Wallace-Hadrill, A. (eds.), *City and Country in the Ancient World*, London, Routledge

Romppanen, M. and Ujam, F., 2004, “Monitoring the Physical Structure of the Helsinki Metropolitan Area”, *Journal of Urban Design*, 9(3), pp.367-377

Wilson, A.G., 2000, *Complex Spatial Systems: The Modelling Foundations of Urban and Regional Analysis*, Harlow, England, Prentice Hall

Appendix 1: Spatial configurational properties of centres by morphological type in Penang Island

Centres by Morphological Type	Total Line Number	Total Length(m)	Max Length(m)	Mean Length(m)	Std Dev	Max Conn	Mean Conn	Std Dev	Max Intg-n	Mean Intg-n	Std Dev	Max Intg-3	Mean Intg-3	Std Dev	Intell	Syngy	Max Depth	Mean Depth	System Radius	Max Intg-r	Mean Intg-r	Std Dev
Primarily Historically Evolved																						
George Town Inner City	899	143958.459	2310.073	160.132	188.254	28	3.6151	3.391	2.5850	1.4865	0.271	5.8413	2.1255	1.077	0.3987	0.6118	14	4.7964	5	3.2732	1.8472	0.474
Ayer Itam Town	135	19655.730	663.305	145.598	108.150	18	2.7259	1.842	1.7949	0.9413	0.249	5.1783	1.6617	0.775	0.2356	0.5246	17	4.5111	5	2.5973	1.2469	0.405
Jelutong Town	130	27741.247	861.050	213.394	160.844	19	3.6000	2.523	2.8055	1.3305	0.357	5.0444	2.0626	0.901	0.4392	0.5619	13	3.5846	4	3.5442	1.7158	0.531
Balik Pulau	243	82461.740	6020.670	339.349	523.714	22	2.8477	2.326	1.7588	0.9121	0.233	15.6692	1.8452	1.401	0.1416	0.1244	20	5.0412	5	2.7123	1.3198	0.458
Teluk Bahang	58	14414.547	993.151	248.527	203.668	9	2.9655	1.675	2.0825	1.0963	0.281	3.7920	1.7762	0.735	0.4173	0.5362	11	3.5862	4	2.4235	1.4519	0.422
Mean	293	57646.345	2169.650	221.400	236.926	19.2	3.1508	2.351	2.2053	1.1533	0.278	7.1050	1.8942	0.978	0.3265	0.4718	15	4.3039	4.6	2.9101	1.5163	0.458
Original Centres with some "Sporadic" Planned Growths																						
Ayer Itam Road	371	60573.937	1434.579	163.272	139.276	25	3.2615	2.369	1.9433	1.0144	0.244	5.6001	1.9741	0.891	0.1172	0.2090	20	5.0647	5	2.8810	1.4807	0.394
Pulau Tikus	438	95311.667	1819.559	217.607	219.403	19	3.5616	2.522	1.9338	1.1990	0.250	5.0518	2.0801	0.887	0.3174	0.4544	16	5.2032	5	2.8166	1.5892	0.410
Tanjung Tokong	318	55625.563	1476.165	174.923	152.797	12	3.3711	2.062	1.6083	0.9917	0.194	4.2050	1.9531	0.828	0.2991	0.4253	20	5.5660	6	2.1755	1.3131	0.284
Tanjung Bungah	350	65969.397	1080.857	188.484	151.486	13	3.0229	1.918	0.9768	0.6741	0.163	4.5046	1.7414	0.819	0.2091	0.3634	38	8.0143	8	1.6185	1.0116	0.257
Paya Terubong	176	38069.727	1135.172	216.305	171.396	13	3.3864	2.159	1.5362	0.8759	0.228	4.3569	1.9154	0.873	0.3700	0.5793	24	5.1818	5	2.6618	1.3397	0.425
Gelugor	237	49757.657	1251.617	209.948	152.650	17	3.5190	2.273	1.7344	1.0217	0.209	5.2289	2.0854	0.822	0.2599	0.4290	15	5.0633	5	2.4941	1.5070	0.354
Sungai Dua-Sungai Nibong	539	118455.809	3490.137	219.770	231.308	15	3.6067	2.250	1.7056	0.9603	0.179	4.9793	2.0928	0.842	0.2113	0.2830	20	5.8071	6	2.2507	1.3274	0.296
Teluk Kumbar	157	33581.688	1423.563	213.896	184.274	11	3.3503	1.977	1.0309	0.6524	0.118	7.8461	2.0318	0.974	0.0474	0.0240	17	6.5860	7	1.9042	1.1467	0.237
Mean	323.25	64668.181	1638.956	200.526	175.324	15.625	3.3849	2.191	1.5587	0.9237	0.198	5.2216	1.9843	0.867	0.2289	0.3459	21.25	5.8108	5.875	2.3503	1.3394	0.332
Original Centres with Large-Scale Planned Extension																						
NIL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mean	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Masterplanned Centres																						
Greenlane	324	68154.072	1353.843	210.352	181.588	17	4.3330	2.592	1.9086	1.1310	0.224	4.8427	2.4198	0.817	0.2490	0.3621	16	5.0185	5	2.8408	1.6777	0.355
Ayer Itam New Town+Farlim	168	40003.792	1079.602	238.118	173.727	10	3.5714	1.987	1.7604	1.0265	0.227	4.2767	2.0932	0.746	0.2930	0.3901	13	4.7381	5	2.3134	1.4451	0.316
Bayan Baru New Town	368	94422.683	2918.232	256.583	305.758	18	3.9728	2.546	2.2432	1.1819	0.250	4.9544	2.2904	0.876	0.2675	0.3005	15	4.6495	5	2.7574	1.5819	0.351
Mean	286.6667	67526.849	1783.892	235.018	220.358	15	3.9591	2.375	1.9707	1.1131	0.234	4.6913	2.2678	0.813	0.2698	0.3509	14.6667	4.8020	5	2.6372	1.5682	0.340
Emergent Metropolitan Centres																						
Tjg Tokong-Tjg Bungah	676	122353.898	1476.165	180.997	149.547	13	3.1805	1.983	0.9538	0.6176	0.117	4.5046	1.8365	0.825	0.1376	0.2430	44	9.1509	9	1.6053	1.0208	0.225
Jelutong-Batu Lanchang	331	66032.015	1172.524	199.492	165.104	29	3.7039	2.740	2.3604	1.2828	0.271	6.2671	2.1622	0.911	0.2804	0.4487	13	4.4532	4	3.5964	1.8008	0.551
Greenlane-Jelutong	651	132057.404	1353.843	202.853	169.524	29	4.0307	2.700	1.9704	1.1046	0.199	6.2671	2.2968	0.879	0.1698	0.2706	18	5.4332	5	2.8369	1.6590	0.378
Ayer Itam+New Town+Paya Trbg	885	158854.225	1434.933	179.496	140.074	25	3.3514	2.266	1.2926	0.8269	0.158	5.5657	1.9782	0.861	0.1070	0.2102	34	7.5763	8	1.9812	1.1620	0.242
Bayan Baru+Surrounding	1501	343791.009	3561.925	229.041	239.275	18	3.4777	2.180	1.3821	0.8140	0.163	4.9793	2.0242	0.850	0.1391	0.1975	37	7.7655	8	1.8319	1.1395	0.227
George Town	3309	644971.212	2315.052	194.914	197.014	32	3.6283	2.826	1.3599	0.8705	0.152	6.2374	2.1229	0.949	0.0748	0.1361	34	8.6978	9	2.2068	1.3110	0.242
George Town Metropolitan	6560	1354175.479	3608.004	206.429	209.434	32	3.4976	2.517	0.9241	0.5920	0.119	6.2374	2.0434	0.904	0.0459	0.0935	77	12.9242	13	1.5336	0.9897	0.190
Mean	1987.5714	403176.463	2131.778	199.032	181.425	25.4286	3.5529	2.459	1.4633	0.8726	0.168	5.7227	2.0663	0.883	0.1364	0.2285	36.7143	8.0002	8	2.2274	1.2975	0.293

Appendix 2: Spatial configurational properties of centres by morphological type in Johor Bahru District

Centres by Morphological Type	Total Line Number	Total Length(m)	Max Length(m)	Mean Length(m)	Std Dev	Max Conn	Mean Conn	Std Dev	Max Intg-n	Mean Intg-n	Std Dev	Max Intg-3	Mean Intg-3	Std Dev	Intell	Syngy	Max Depth	Mean Depth	System Radius	Max intg-r	Mean Intg-r	Std Dev
Primarily Historically Evolved																						
JB Central District	336	99088.170	1966.598	294.905	294.195	18	3.6726	2.663	1.8137	1.1055	0.222	5.1085	2.1194	0.936	0.3680	0.5791	15	5.2054	5	2.5497	1.5749	0.409
Skudai Town	88	24481.238	1182.588	278.196	221.495	12	3.6136	1.890	1.5890	0.9575	0.231	4.3208	2.1084	0.708	0.2295	0.2720	13	4.4545	4	2.8049	1.6476	0.403
Masai Town	151	37431.016	801.685	247.888	160.831	13	4.2252	2.551	1.9252	1.1912	0.250	4.7979	2.3597	0.824	0.3787	0.5063	14	4.4238	4	3.2021	1.8851	0.488
Kelapa Sawit	256	79494.171	1571.630	310.524	269.478	32	3.6875	3.178	1.7226	0.9886	0.217	6.9149	2.2433	0.979	0.1965	0.4501	17	5.1481	5	3.2772	1.6337	0.477
Kangkar Pulai	175	51274.948	2045.674	293.000	303.000	13	3.6000	1.829	2.0369	1.0509	0.221	4.4718	2.0528	0.721	0.1707	0.2319	12	4.3943	4	3.0890	1.6464	0.433
Ulu Choh	67	21119.913	1279.764	315.223	268.796	12	3.3731	1.857	2.3018	1.2630	0.303	4.2209	1.9798	0.715	0.5473	0.6873	9	3.5224	4	2.9382	1.6216	0.434
Lima Kedai	102	18347.416	765.082	179.877	136.332	14	3.8235	2.664	1.9572	1.1874	0.249	4.8969	2.2750	0.801	0.2409	0.3040	11	4.0980	4	3.0303	1.8407	0.455
Gelang Patah	212	55632.950	1549.607	262.420	234.758	17	3.7453	1.903	1.5455	0.9370	0.170	4.9449	2.2136	0.719	0.1276	0.1459	14	5.3349	5	2.8146	1.4674	0.331
Mean	173.375	48358.728	1395.329	272.754	236.111	16.375	3.7176	2.317	1.8615	1.0851	0.233	4.9596	2.1690	0.800	0.2824	0.3971	13.125	4.5727	4.375	2.9633	1.6647	0.429
Original Centres with some "Sporadic" Planned Growths																						
Ulu Tiram	656	146868.054	2054.414	223.884	197.555	21	3.8171	2.774	1.4054	0.8678	0.163	5.5951	2.2349	0.881	0.1497	0.2376	25	6.8216	7	2.1173	1.3156	0.273
Tampoi	259	70329.821	3244.531	271.544	328.807	19	3.6988	2.884	2.2608	1.2025	0.265	5.4623	2.2418	0.923	0.2173	0.3093	13	4.4054	4	3.3975	1.8535	0.513
Tebrau-Pelangi	1127	317490.523	2598.435	281.713	259.428	28	4.4028	3.371	2.3631	1.2562	0.226	6.7490	2.5150	0.937	0.2144	0.3554	19	5.1970	5	3.0477	1.7902	0.394
Mean	680.6667	178229.466	2632.460	259.047	261.930	22.6667	3.9729	3.010	2.0098	1.1088	0.218	5.9355	2.3306	0.914	0.1938	0.3008	19	5.4747	5.3333	2.8542	1.6531	0.394
Original Centres with Large- Scale Planned Extension																						
Kulai	1457	382786.774	4221.568	262.723	260.121	30	4.2320	2.995	1.8949	1.0571	0.197	9.6712	2.4683	0.920	0.0989	0.1403	22	6.1826	6	2.5423	1.5558	0.286
Kulai + Bandar Putra	2077	547152.313	4221.568	263.434	243.612	30	4.2475	2.982	1.3888	0.8249	0.152	9.6712	2.4549	0.920	0.0516	0.0911	32	8.0746	8	2.0773	1.2863	0.238
Senai	931	230358.468	1835.249	247.431	222.854	22	3.8883	2.717	1.1508	0.7117	0.117	18.1856	2.3784	1.141	0.0556	0.0103	27	8.3265	8	1.8962	1.2316	0.189
Saleng	413	93487.946	1894.735	226.363	210.671	26	4.2518	3.425	2.5003	1.3079	0.290	6.9520	2.5295	0.911	0.1612	0.2732	15	4.4431	4	4.0910	2.0591	0.501
Tampoi + BBU	624	165460.584	5099.626	265.161	195.464	22	4.0449	2.969	2.0821	1.1382	0.223	5.4623	2.3701	0.899	0.1116	0.1778	15	5.2196	5	2.9127	1.7101	0.367
Mean	1100.4	283849.217	3454.549	253.022	226.544	26	4.1329	3.018	1.8034	1.0080	0.196	9.9885	2.4402	0.958	0.0958	0.1385	22.2	6.4493	6.2	2.7039	1.5686	0.316
Masterplanned Centres																						
Pasir Gudang Town Centre	559	141305.209	3244.628	252.782	318.919	20	4.0751	2.903	1.4960	0.9585	0.152	6.5315	2.3579	0.869	0.0991	0.1435	17	6.3757	6	2.2008	1.4681	0.269
Taman Pasir Puteh (Psr Gdg)	258	73503.394	2339.163	284.897	258.832	16	4.1163	2.517	1.6713	1.0201	0.208	5.7525	2.4034	0.751	0.1520	0.2006	15	5.2519	5	2.7283	1.6254	0.289
Taman Sri Pulai	177	42982.090	1254.040	242.837	189.098	21	4.5198	3.042	2.5684	1.4477	0.321	6.1388	2.5805	0.804	0.2628	0.3243	11	3.9040	4	3.5563	2.0619	0.446
Taman Teratai	227	43616.710	999.328	192.144	125.971	16	4.1850	2.533	1.6813	0.9825	0.220	6.9062	2.4576	0.783	0.1100	0.0936	16	5.1233	5	2.9354	1.6360	0.319
Taman Pulai Perdana	188	44621.055	1601.001	237.346	185.166	15	4.1064	2.172	1.3777	0.9178	0.153	5.5013	2.3425	0.731	0.0978	0.1102	13	5.6170	6	2.1824	1.4175	0.245
Taman Universiti	797	208782.162	3131.991	261.960	216.173	34	4.8080	4.007	2.3018	1.2800	0.227	20.7911	2.8060	1.090	0.0805	0.0782	15	5.0652	5	3.3435	1.9372	0.349
Taman Pulai Utama	192	48637.052	2007.836	253.318	190.767	13	3.8958	2.395	2.4843	1.2012	0.257	5.0949	2.3214	0.803	0.1745	0.1687	11	4.0156	4	3.6589	1.8238	0.421
Taman Mutiara Rini	357	83135.798	1685.623	232.873	192.350	25	3.8431	3.000	1.4169	0.9123	0.153	14.6356	2.4005	1.080	0.0620	0.0581	19	6.1653	6	3.6680	1.6165	0.377
Taman Sri Skudai	201	49816.400	1871.349	247.843	238.038	29	4.1791	3.808	2.8552	1.5942	0.340	7.7383	2.5776	1.013	0.3544	0.4805	11	3.7761	4	3.9001	2.0875	0.512
Taman Sri Putri	137	28431.270	1049.066	207.528	151.720	18	3.7956	2.377	2.2220	1.1979	0.276	6.9370	2.2745	0.894	0.3226	0.4016	13	4.0365	4	3.3876	1.7868	0.459
Taman Skudai Baru	171	40104.030	966.984	234.526	178.005	23	4.4094	3.215	2.7134	1.5515	0.319	5.5279	2.5899	0.810	0.2838	0.4189	10	3.7836	4	3.4161	2.1034	0.415
Taman Ungku Tun Aminah	665	176114.512	2648.904	264.834	255.207	39	4.3098	3.700	2.4826	1.3838	0.254	9.0928	2.6196	0.110	0.1661	0.2321	15	4.7368	5	3.1140	1.8138	0.382
Taman JB	184	43913.859	1836.757	238.662	219.587	45	4.4565	5.333	3.5372	1.7603	0.414	13.9039	2.9079	1.326	0.2820	0.3274	10	3.3967	3	13.9039	2.9079	1.326
Taman Sri Orkid	68	19115.401	1220.637	281.109	221.859	14	4.2941	2.876	2.2619	1.2682	0.287	5.3777	2.5014	0.845	0.3961	0.4117	9	3.5588	4	3.6388	1.9799	0.447
Taman Selesa Jaya	327	81344.406	2132.181	248.760	242.067	35	4.0000	2.457	2.2475	1.2249	0.271	7.1062	2.4474	0.913	0.1476	0.3718	14	4.5688	5	2.9154	1.7292	0.406
Taman Perling	419	134417.090	1860.186	320.805	284.496	25	4.7733	3.337	1.8065	1.1373	0.203	6.2943	2.6852	0.833	0.1579	0.2559	15	5.3938	5	2.5605	1.8394	0.297
Taman Sutera	201	50350.387	1224.196	250.449	163.482	28	3.9204	3.086	2.0122	1.1872	0.235	6.2391	2.4953	0.815	0.0832	0.3405	12	4.5224	5	2.9195	1.7226	0.356
Taman Tampoi Indah/Utama	176	39958.859	2033.516	227.039	224.568	15	3.7727	2.121	1.7806	1.0316	0.252	5.2231	2.1593	0.806	0.3249	0.4003	16	4.7443	5	2.4918	1.4692	0.362
Bandar Baru UDA (BBU)	268	73304.164	2294.436	273.523	238.966	22	4.3582	2.985	2.2350	1.2624	0.246	5.3463	2.4584	0.863	0.3169	0.4379	12	4.4552	4	3.4933	1.9663	0.489
Permas Jaya New Town	768	188987.639	1770.445	246.078	210.983	24	4.4922	3.098	1.7921	1.0379	0.178	8.0666	2.5495	0.898	0.1391	0.2004	17	5.9076	6	2.5064	1.5556	0.255
Mean	317	80622.074	1858.613	249.966	215.313	23.85	4.2155	3.048	2.1472	1.2179	0.248	7.9103	2.4968	0.852	0.2007	0.2728	13.55	4.7199	4.75	3.6261	1.8274	0.421
Emergent Metropolitan Centres																						
JB (within Psr Gdg Highway)	3651	996143.915	5099.626	272.841	262.284	28	3.8789	2.876	1.1957	0.7774	0.117	13.2707	2.2600	0.944	0.0787	0.1167	29	9.7362	10	1.9251	1.1603	0.180
Skudai West Corridor	6011	1556509.981	3266.181	258.944	232.390	45	4.4086	3.424	1.0679	0.6745	0.112	29.3919	2.5899	1.045	0.0111	0.0241	42	11.3356	11	1.6357	1.1274	0.152
Skudai-JB Corridor	8636	2311580.141	5279.711	267.688	264.620	45	4.2202	3.307	1.1052	0.6706	0.125	29.3919	2.4905	1.055	0.0170	0.0405	46	11.4927	11	1.6355	1.1133	0.154
Tebrau East Corridor	7248	2025190.482	4941.440	279.414	265.328	37	4.2740	3.161	0.9874	0.6112	0.104	13.2707	2.4484	0.930	0.0227	0.0503	53	12.3695	12	1.7804	1.0491	0.152
Kulai-Senai Corridor	3747	994927.873	4221.231	265.527	253.817	32	4.1068	2.976	1.1201	0.6639	0.132	18.1856	2.4210	0.979	0.0341	0.0474	45	10.2914	10	1.7894	1.1220	0.185
Mean	5858.6	1576870.478	4561.638	268.883	255.688	37.4	4.1777	3.149	1.0953	0.6795	0.118	20.7022	2.4420	0.990	0.0327	0.0558	43	11.0451	10.8	1.7532	1.1144	0.164