INTERNAL COMMERCIAL STREETS AND THE CONSOLIDATION OF LARGE INFORMAL NEIGHBOURHOODS: the case of Zahedan, Iran

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Abstract
This paper studies the spatial distribution of commercial land use in the informal settlements of Zahedan. Hillier et al. (2000) argued that commercial activities can have an impact on the socio-economic circumstances of informal settlements. They expressed the extent of shops’ concentration on the settlement edges through the concept of ‘Edge Oriented Commercial Activities’. They infer that when these edge shops are privileged with spatially integrated streets, their benefit from the movement increases and this in turn contributes to the gradual self-improvement of the informal settlement. This paper suggests that this is not just the concentration of shops on highly integrated edge streets but the overall correspondence between commercial land use and syntactic factors that might facilitate consolidation. This process is even more likely to happen in a large informal settlement when its route network takes a ‘deformed wheel pattern’ with integrated internal streets. Evidences of such phenomenon will be studied by this paper in the city of Zahedan in south east Iran where internal commercial streets are evident within the settlements. A methodology is developed to quantify the commercial ratio of street segments and to compare it against their syntactic variables. One finding is that consolidated large informal neighbourhoods have their shops corresponding to the global scale of the street network. It suggests that inner streets of large settlements can act as media that integrate the local markets to their wider urban economy.

Introduction
An increasing appreciation of the spatial factors facilitating the consolidation of low-income housing is observable in the academic and decision-making sources (Mukhija, 2001; UNCHS, 2003). Consolidation in this context refers to the process of socio-economical and physical self-improvement of initially unserviced and legally unrecognized low-income settlements (Pacione, 1996). This recent trend in favour of spatial factors is in contrast with the conventional approach of highlighting and facilitating the rather non-spatial factors such as security of housing-tenure or access to credit as slum upgrading solutions (Pacione, 1996).
As UNCHS (2003) underlines, a ‘spatial’ advantage associated with the large size of an informal settlement, is the potential for hosting ‘internal markets’ that can contribute to the socio-economic improvement of the residences (Pacione, 1996: 70-90). However what are not discussed by this source and other non-space syntax sources is the micro-scale conditions, mainly the street network morphology, which might affect the benefits of such internal markets. Moreover, the peculiar characteristics assigned to the street network of large informal settlements, sometimes referred to as ‘organic’ (Hublin, 1996), are rarely examined in relation to their consolidation opportunities. For doing this an analytical tool is needed to study the seemingly irregular morphology of spontaneous informal settlements at the fine scale of their street network\(^iv\). In this regard, space syntax has a history of dealing with organic urban forms that are not easily described through the conventional geometrical language\(^v\).

In the case of large informal settlements, a fine-scale morphological analysis can assess the potential of street network to increase or impede presence and then efficiency of internal markets and hence consolidation opportunities arisen from that. It should be reminded that the effect of streets’ morphology on the economic gain of informal settlements of Santiago and their consolidation has been found by space syntax research before (Greene, 2003; Hillier et. al, 2000) but the 17 case studies are particular in that they are mostly small to average size\(^iv\) (average area of 4.83 hectare, with a mean population of about 962.9 person, Hillier et. al, 2000: 75). As a result of this small size, one would not expect to find internal market in the settlements while the later researches found the remarkable effect of commercial activites on the settlements’ edges where they interact with the city. They found that a higher proportion of shops on the outward faces of an informal settlement when interacts with spatially integrated streets increases the economic gain of that neighbourhood. In this way, the more economic benefit through ‘natural movement’ on the edges - called ‘Edge Oriented Economical Activity’ or ‘EOCA’ (Hillier et. al, 2000: 88) - enforces a faster socio-economic and physical consolidation.

This paper adopts the theoretical model underlying Hillier and others’ work (Hillier et. al, 2000) assuming that the efficiency of commercial activities through maximizing their concentration on integrated streets would contribute to the consolidation although with an added condition. The condition stems from the fact that when a settlement grows large, it might develop a ‘deformed wheel pattern’ (Hillier, 2001). If a large informal settlement that take such spatial form, the longer radial lines and the integration core of the wheel become more attractive for commercial activities. This can explain the formation of internal markets in the large informal areas while a hypothetic condition for the success of commercial activities (whether internal or on the edges) is their concentration on more integrated streets.

Doing a fine scale configurational analysis, the correspondence between commercial ratio of street segments and the syntactic measures of spatial centrality for those segments (Hillier and Iida, 2005) can be considered as an indicator of the commercial efficiency for a settlement. The hypothesis is that more concentration of commercial activities on the spatially integrated segments\(^iv\) would increase the benefit of shops and this in turn will contribute to the consolidation of that area. However, establishing a reliable ratio of commercial land use along the street segments is of some methodological difficulty and will be discussed in a separate section of this paper.
This paper studies the syntactic attributes of commercial activities of some large informal settlements in the scale of their street segments to shed light on their consolidation process. Knowing that this has not been done before in the field of space syntax, the scope of the study will be limited to this extent although the incorporation of other sorts of land use analyses combined with relevant socio-economic data seems to be a valid future enhancement.

The case studies of this paper are the large informal settlements of Zahedan, the capital of Sistan and Balochestan province in south-east Iran. In a context of a severe provincial poverty, informal low-income areas accommodate a considerable proportion of citizens there (at least 33%) with notable socio-economic variations amongst the settlements. The fact that these settlements are contiguous and mostly large makes them appropriate cases for this study in that the conventional factors such the distance from city centre can not completely explain their various degrees of consolidation. Moreover the variation in the commercial activities among these informal settlements is easily observable through the detailed land use data, at the building level, used for this study. Observations on site and secondary data sources are also used to assess the self-improvement degree of these areas expressed through consolidation ranks. The current urban poverty alleviation projects in Zahedan (IMHUD/WB, 2003) would get some benefits from this study while the methodology developed here is applicable to other urban contexts.

The paper is structured in the following way. First a literature review on the theme of large informal settlements and the effect of commercial activities on their consolidation will follow. The aim is to show a gap in the existing knowledge about the syntactic conditions for internal markets and their effect on the consolidation of the large informal settlements. The case study of Zahedan and its informal settlements comprise the next section. This section aims at putting the informal settlements in the context of the city overall growth while different socio-economic dynamics of these areas will be expressed through the ranks of consolidation. In the section on the research methodology the problem of measuring the ratio of an event to the basic units along the axial segments will be introduced. This problem is translated to measuring the ratio of commercial buildings over buildings for which some statistical and GIS solution will be suggested. Finally the developed method will be applied to four informal settlements to compare their extent of effective distribution of shops with regards to their configurations. It suggests that the spatial structure of each case in conjunction with the way that the shops are distributed in respect to it (both on the edges and within) have a possible impact on their long term gain. This hypothesis will be evidently supported by the existence of large internal markets in more consolidated large case studies.

**Theoretical Background: Consolidation of Large Informal Settlement and Configuration**

The fact that low-income informal areas can some times self-improve themselves to gradually overcome their initial unserviced and illegal situation is referred to as ‘consolidation’ (Pacione, 1996; Potter & Lloyds-Evans, 1998). More recently, some sources have underlined the consolidation opportunities associated with the spatial and morphological attributes of informal settlements (Mukhija, 2001; UNCHS, 2003). Subsequently, UNCHS (2003) suggests that amongst the spatial factor the size of a settlement would provide it with some consolidation opportunities (e.g. easier gain of legal recognition due to community solidification) while making it vulnerable to degradation in other ways (e.g. the need for independent urban infrastructure and...
services). Another improvement potential associated with the large size of a settlement is the ‘economy of scale’. It means that large informal settlements, due to their excessive access to cheap labour, can provide goods and services in low prices that sometimes can compete with the formal sector (UNCHS, 2003). The manifestation of this economical advantage is the formation of large internal markets that attracts even better-off citizens.

Up until this point, what has not been sufficiently addressed by the sources is how the peculiar morphology of informal settlements might play a role in their socio-economic dynamic. It should be mentioned that this morphological peculiarity sometimes expressed through the attributes of street network has been the subject of different non space syntax researches before (Payne, 1977, Hublin 1996, Steinberg, 1990). Space syntax research on the other hand adopts a different approach towards the issue of street network and socio-economic circumstances of informal settlements. Before, some brief introduction to the theory and methods of space syntax is necessary.

Space syntax theory is based on evidences suggesting that the spatial configuration of cities and buildings have an underlying social dimension which is in mutual interaction with the spatial nature of the social activities (Hillier and Hanson, 1984). Street network in space syntax is mostly represented as a set of linear elements called the ‘axial map’ and the simultaneous relation between each element and all others is expressed through measures of spatial configuration (Hillier and Hanson, 1984). In this relation, the ‘natural movement’ theory indicates that configurationally more integrated streets and urban spaces would carry more movement through themselves (Hillier et al., 1993). Consequently the theory of ‘movement economy’ indicates that the movement flows largely influenced by configuration would affect the distribution of land uses with ‘movement demanding’ activities tend to be found on more integrated streets (Hillier, 1996). This distribution of land uses is also observable in sufficiently large urban systems when a few long radial streets are connecting the settlement core and the bulk of shorter streets together and to the system’s edges (called ‘deformed wheel pattern’). As a result of this spatial pattern shops and public activities favour the integrated radial streets and the settlement integration core while residential areas would fill the rather spatially segregated interstices between the radials (Hillier, 2001).

With regards to the informal settlements, space syntax has shown that the configuration of street network plays a major role in their formation, organization of socio-economic activities and consolidation. The findings about the informal settlement of Santiago and the effect of edge shopping were already mentioned in the introduction (Hillier et al., 2000, Greene, 2003). In another study however, Mora (2003) examines the spatial logic of commercial activities in a relatively large informal settlement of Santiago. One of his findings was that the formation of a ‘deformed wheel’ and its consequent distribution of syntactic measures plays a significant role in the establishment of commercial activities. However, in contrast with the previous study, Mora does not deal with the overall consolidation and its case share any boundary with the city.

In the context of Jakarta, Budiarto (2003) suggests that the organization of activities in the informal settlements is largely influenced by the global properties of the urban grid as well as their local configurational variations arising from socio-cultural factors. In this regard, he uses the concept of ‘super-grid’ in two different levels, of which the first level corresponds to the city formal functioning in a global scale. The lower level super-grid, as he reports, interacts with
both the local and global movement and serves the informal economy especially within the informal settlements. However, as he reminds us, space syntax method is used in a conceptual level while he does not quantify the correspondence between informal commercial activities and syntactic variables.

This literature review revolved around the syntactic attributes of internal markets and their effect on the consolidation of large informal settlements. One key text in this regard is UNCHS (2003) which underlined the potential of internal markets for the consolidation of large informal settlements although without discussing the streets’ configurational matters. Some space syntax studies, on the other hand, show the effect of street network on the consolidation through EOCA but for not large settlements with the potential for internal markets. The other space syntax researches suggest the effect of street configuration on the internal markets of large informal settlements but neither relates it to the consolidation nor measure correspondence between commercial land use and syntactic values of the streets. Above all, no space syntax study has used the method of axial segment analysis to study the land use pattern of informal settlements and with regards to their consolidation. In order to address this gap, the paper will develop a methodology to measure the overall correspondence of commercial land uses with the syntactic values to evaluate the consolidation potentials for large informal settlements.

The Case Study, Zahedan

The History and Regional Strategic Status

The city of Zahedan is located in the south east Iran close to the border with Pakistan and Afghanistan. It is the capital of Sistan and Balochestan, one of the poorest provinces in the country. The harsh climate for agriculture and rural poverty in this province accounts for a population flow from villages and smaller cities to the larger cities in search of better living conditions. In addition to the in-migrants there have been Afghan refugees fleeing their country during the political conflicts of 1980s which deemed as illegal migrants. The above factors in conjunction with the natural population growth have pushed Zahedan from a city with 17,000 in 1950s to about 565,000 citizens in 2001 (IMHUD/WB, 2003).

The above growth in population however should be seen in the context of Zahedan’s strategic location which acted as the main reason for its initial formation. In 1918-1919 the creation of a railway by British India Company connected Zahedan, a small village called ‘Dozdab’ at that time, to the Indian subcontinent increased the interests of the central government. As a result of this interest and the need for establishing an administrative and official centre in the region, during 1930s the place became the official capital of its province while its name was officially changed to Zahedan. As a result the city received some investments and groups of governmental employees (Piran, 2000). Since then, the city has kept its prominent status in the province while with the increase of its population there has always been an increasing inequity between governmental affiliated people and the rest of the city, mostly low-skilled people working in the informal sector (IMHUD/WB, 2003).

The Spatial Structure of Zahedan

The city was originally built according to a plan consisting of four main orthogonal streets. During the past the main spines of the city have always preserved their north-south and east-west dominance. By the time being, Zahedan is structured around the two formal spines of the
University street (north-south) and Imam Khomeini (east-west) that are the longest and most connected alignments with a few major streets running close and parallel to them. These two orthogonal spines and a few parallel streets literally make a large deformed wheel pattern with most of the official buildings and formal commercial activities around its spokes (figure 1, right).

An initial observation is that the two main spines of the city do not extend into the informal areas except of Shirabad and Babaeyan neighbourhoods. However, the informal settlements are peculiar in having a relatively clear local structure especially in places like Karimabad and Babaeyan where the long internal streets are well-connected to the main spines of the city and organizing linear clusters of shops around themselves. Figure 2 shows the logarithmic of segment choice in two different local and global radii for the southern part of Babaeyan area. It shows a striking pattern in which the commercial buildings are highly concentrated on locally and globally integrated internal segments, although there are clusters of shops on the southern edges of Babaeyan as well. This issue will be discussed furthermore in the next sections but it suggest that informal settlements are benefiting from a more local urban grid that although overlap with the city main spines at some points is functioning independently.

The Urban Poverty and Informal Settlement in Zahedan

A manifestation of Zahedan polarized socio-economic circumstances is the formation of relatively large areas of informal settlements stretching from north-west to the north-east. These informal areas are now accommodating large proportion of the less well-off citizens (at least 33% of Zahedan population in 2002) where there is a higher population density (Table 1) and lower rates of socio-economic indicators such as literacy ratio (figure 2, right).

Table 1: Demographic comparison between Zahedan and its informal settlements (extracted from IMHUD/WB, 2003)

<table>
<thead>
<tr>
<th></th>
<th>Population</th>
<th>Population Density</th>
<th>Household size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zahedan</td>
<td>700,000</td>
<td>137 person/hectare</td>
<td>5.95</td>
</tr>
<tr>
<td>Informal Settlements</td>
<td>235,000</td>
<td>200-300 person/hectare</td>
<td>8.0 and more</td>
</tr>
</tbody>
</table>

Figure 1: The spatial structure of Zahedan in 2001, the line thickness corresponds to the higher value of reciprocal mean depth $R_{metric} = n$ (left). The GIS representation of literacy ratio with darker colours for lower rates (right).
In terms of socio-economic circumstances, the dwellers of low-income settlements in Zahedan are facing high rates of underemployment and addiction which enforce each other (IMHUD/WB, 2003). This problem however should be seen from a broader view, where the attractiveness of tertiary sector as the dominant job market for immigrants causes a quick increase in the Zahedan low-income population. Because of the weak economical structure, this population can not find job in the formal sector and hence evolve in low-skilled informal and sometimes illegal activities. The resulted job insecurity and low earnings in general leave the urban poor with no choice of affordable shelter except informal housing which push them into a vicious circle of poverty.

**Informal Settlements’ Dynamism Over Time: Consolidation**

Zahedan informal settlements vary in their ages and origins as well as their ethnic mix-up (e.g. Baluchis, Persians and Afghans). Most of these areas are the result of illegal subdivision and selling of the agricultural lands but some others, like Shirabad, have rural nuclei that have been growing over time and were subsequently absorbed by the city (Piran, 2000). A general categorization suggested by IMHUD/WB report divides the Zahedan informal settlements into two major groups of the ones within municipal boundaries and ones outside it (Table 2). The former is group consists of older settlements that although deemed formal by officials, have been dealing with insufficient infrastructure and public services. The later group (located outside the municipal boundary) are in a harsher condition as they rarely have had access to basic services such as water pipeline network and other infrastructure. Moreover in Table 2 the informal settlements are divided to five main consolidation ranks with lower ranks for more improved settlements. This ranking is done by the author and according to an extensive examination of the existing reports, GIS maps and site observation. 

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*Figure 2:*

Segment map of Babaeyan along with commercial buildings. The measures of logarithmic choice in two metric radii of infinity (right) and 1200 meter (left) is shown through segment thicknesses. The highlighted internal market corresponds to high values of local and global choice.
The Economical Activities in the City and its Informal Settlements

Regarding the perceived landscape of urban poverty and in a rather in-depth commentary, Piran claims that the amount of capital accumulation in Zahedan is not low at all. The reasons for poverty, he concludes, are the investment of this capital in non-productive activities or its departure towards the larger cities: "...The existence of extended border trade, drug trafficking and an available urban market for goods and services are other indicators of large capital accumulation." (Piran, 2000: 32). This ‘available urban market for goods’ is distinctly appear and prevalent in Zahedan. It manifest itself through the dense commercial streets in the city centre that offer from electronic imported products to garment shops and groceries. The author’s observation in the informal areas also show a variety of commercial activities ranging from rather specialized shops and services especially in places such as Babaeyan, or daily bazaars such as the ‘Common Market’ in the ‘Posht-e Garage’ informal settlement to the small vending kiosks built from temporary materials (figure3).

Table 2:
Urban services and environmental conditions of Zahedan informal settlements with regards to the overall city average (Source: IMHUD/WB, 2003). The last column (Ranking) is calculated by the author in which lower value means more consolidation

<table>
<thead>
<tr>
<th>Location</th>
<th>Settlement</th>
<th>Age</th>
<th>Access Roads</th>
<th>Water-Pipe Network</th>
<th>Electricity Network</th>
<th>Public Services</th>
<th>Environmental Pollution</th>
<th>Consolidation Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside the municipal boundary</td>
<td>Darreh-ye Panjshir</td>
<td>25</td>
<td>-</td>
<td>existing</td>
<td>existing</td>
<td>-</td>
<td>Medium</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Gharibabad</td>
<td>25</td>
<td>-</td>
<td>existing</td>
<td>existing</td>
<td>-</td>
<td>High</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Chaliabad</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>existing</td>
<td>-</td>
<td>High</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Nukabad</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>existing</td>
<td>-</td>
<td>High</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Qasemabad</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>existing</td>
<td>-</td>
<td>High</td>
<td>4</td>
</tr>
<tr>
<td>Within the municipal boundary</td>
<td>Babaiyan</td>
<td>40</td>
<td>2</td>
<td>existing</td>
<td>existing</td>
<td>2</td>
<td>Medium</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Karimabad</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sikhsuzi</td>
<td>30</td>
<td>2</td>
<td>existing</td>
<td>existing</td>
<td>1</td>
<td>High</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Moradqoli</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Posht-e Garage</td>
<td>20</td>
<td>2</td>
<td>existing</td>
<td>existing</td>
<td>1</td>
<td>High</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Karkhaneh-ye Namak</td>
<td>30</td>
<td>2</td>
<td>existing</td>
<td>existing</td>
<td>1</td>
<td>High</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Shirabad</td>
<td>20</td>
<td>1</td>
<td>existing</td>
<td>existing</td>
<td>1</td>
<td>High</td>
<td>4</td>
</tr>
</tbody>
</table>

Figure 3:
Commercial activities on the formal (left) and informal parts (right) of the city

A remarkable point is that a great deal of these informal commercial activities is occurring within the informal settlements. The coincidence
of informal activities on spatially integrated streets shown in figure 2 is observable all over informal settlements although with varying degree. The same observation is done for three more settlements in figure 4 (Moradqoli, Karimabad, Shirabad) using measure of choice in local (R=1200m) and global (R=n) levels. As can be noticed, the internal markets of Moradqoli settlement relates to both the local and global radii while the later case (i.e. Karimabad) has a more scattered pattern of shops. In other words, it seems that shops do not fully take advantage of locally and globally strategic street segments in it. Moreover, the deformed wheel pattern noticeable in Babaeyan, supposedly, has contributed to its effective location of shops by synchronizing between local and global scales and hence making it easier to access from outside. This is in contrast with the rather even distribution of commercial activities in Shirabad that does not fully follow the syntactic values.

These observations, when compared to the consolidation indices of different areas lead to the conjecture that commercial activities might have played a role. Although shops on outward edge of the informal settlements can still be found, it is hard to explain the degree of self-improvement through them. Table 3 illustrates the measure of EOCA for five settlements with varying consolidation rates. Interestingly, EOCA seems to relate with the lower consolidation ratios but not higher ones. The reason, as this paper conjectured before, is the contribution of internal markets to the consolidation of large informal settlements. As a result, a method is required to quantify the overall correlation between the distribution of shops on street segments and the syntactic values of those segments as a measure of shops’ distribution efficiency.

![Figure 4: The distribution of commercial land uses within the three informal settlements. The axial segment thicknesses in the above images correspond to the measure of logarithmic choice R = n and in the lower row to the logarithm of choice R = 1200m.](image-url)
The Research Strategy and Methodology

The aim of this method is to measure how concentrated the commercial land uses are on the street segments with particular syntactic attributes. However establishing a ratio of commercial land use on the street segments is not as easy as it might seems at first glance. Hillier and Sahbaz (2005) faced the same problem in gaining a ‘true ratio’ of burglary occurrence on street segments in their crime study. The problem is that if one just focuses on the average occurrence of an event (say burglary) along segments, as the number of basic units (i.e. residences) increases the average occurrence ratio of the event increases as well. As a result it will seem that street segments with more residences have higher average ratio of burglary while it is an unreal effect resulted from the increase in basic units. In other words, more basic units increase the probability of that event’s occurrence. The solution for this unreal increase as Hillier and Sahbaz (2005) suggest is to ‘band’ segments with regards to the number of basic units along these and then calculate the aggregated ratio of the event in each band to gain a ‘true’ ratio. This paper adapts the same solution but in this case the basic units are buildings and the main event is the occurrence of a certain land use (mainly ‘commercial’ in this study) in that building.

The GIS Procedure for Weighting the Segments with Land Use Data

Before linking the land use data to axial segments, an important attribute of the data at hand should be reminded: the land use is assigned to more than 107.000 buildings and not to the plots. The sheer size of this system does not let the use of Place Syntax Tools (Stahle et al., 2005) which can handle less number of buildings. On the other hand the entrances for these buildings are not known but instead the limit of the larger urban block that surrounds them is available. For reckoning the entrance location, a least distance criterion is used that assumes the entrance is the closest point on the urban block border to the building baseline.

For connecting these entrances (either doors on walls or facades) to the axial segments, they are intersected with the metric buffer of linear segments. The problems that would happen if a constant buffer radius is used are: 1- overextending the buffers to include and connect a non adjacent entrance and 2- faulty connections on the junctions. Each one of these issues can be eased to a great extent. The first problem can be solved by buffering the axial segment proportional to road-widths. Looking into a sample of 800 points suggest that road widths have some correlation (R-square 0.45) with the measure of angular segment choice R=1600 meter which is fair enough for estimating a maximum buffering radius.

To solve the second problem (i.e. junctions) also a directional criterion was introduced. This criterion connects the entrance to the axial segments if they are almost parallel. After doing all these steps, still each entrance (or façade) can be linked to an arbitrary number of segments which can distort the results of building count amongst those segments. This is making it necessary to connect each entrance to a single axial segment but how to prioritize amongst multiple
targets? For this purpose a set of criteria can be used, first of all the segments that are ‘parallel’ are in priority. If there are many of these ‘parallel’ segments, the priority is given to the segment that its host axial line has got the highest building count when ‘multiple connections’ is allowed and so on. The outcome of this procedure is a set of ‘selectively weighted’ axial segments in which the linearity of commercial clusters is well captured by the axial segments lines.

**The Banding Method and its Application to the City**

After applying the above GIS method, the total number of buildings and commercial buildings along each axial segment is counted and assigned to it. The axial segments of the whole city then are put into different bands in a way that the number of segments in each band is more or less remains steady. Table 4 shows the banding scheme applied to the segment map of Zahedan. The True Commercial Ratio (TCR) for each band is the aggregated number of commercial buildings divided by the total number of building in for all axial segments of that band. As can be seen in figure 7, the true commercial ratio for each band falls for the whole city while the average number of commercial buildings increases which is an untrue affect arisen from the increase of buildings along segments.

<table>
<thead>
<tr>
<th>Segment band</th>
<th>Building count on segment</th>
<th>Number of segments in band</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1295</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>1038</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>814</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>680</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>605</td>
</tr>
<tr>
<td>6</td>
<td>6-7</td>
<td>1060</td>
</tr>
<tr>
<td>7</td>
<td>8-9</td>
<td>855</td>
</tr>
<tr>
<td>8</td>
<td>10-11</td>
<td>694</td>
</tr>
<tr>
<td>9</td>
<td>12-14</td>
<td>794</td>
</tr>
<tr>
<td>10</td>
<td>15-17</td>
<td>611</td>
</tr>
<tr>
<td>11</td>
<td>18-21</td>
<td>670</td>
</tr>
<tr>
<td>12</td>
<td>22-27</td>
<td>551</td>
</tr>
<tr>
<td>13</td>
<td>27 and more</td>
<td>739</td>
</tr>
</tbody>
</table>

Figure 6 shows the comparison of true commercial ratios against the average global and local choice measures in each band. As it is illustrated in this graph, the true commercial ratio in a global radius shows bifurcation which suggest two different trends for smaller bands and larger ones. For the former the more global choice (R = 10,000m) means more shops on smaller segments while for the longer segments, more commercial ratio again corresponds to more choice.
value but for more populated segments. The local choice however shows a more linear trend (RSquare 0.79) which indicates there is an underlying interplay between the local and global factors influencing the distribution of commercial activities in the city.

This corresponds to of movement economy and also suggests that commercial activities tend to concentrate on more fragmented small segments as the process of centrality occurs (Hillier, 1999). One conjecture based on it is that the informal settlements as urban subcomponents would follow the same trend but how the socio-economic variation amongst these might be influenced by the syntactic efficiency of their commercial activities. This question will be answered in the next section.

The Results and Discussion

The above method is applicable to the individual informal settlements as well. However two points should be born in mind. First, it is important to have more or less the same number of segment bands for each settlement to be able to compare the correlation coefficient amongst those settlements. Second, in respect to various sizes of the cases, it would be more accurate to relativize the commercial ratio for each band comparing to the expected number of shops in that band\textsuperscript{xviii}. By calculating the relativized ratio in each settlement it is possible then to compare the four selected informal settlements (Table 3) because the commercial ratios are now expressed for each band independently and proportional to the expected number of shops on its segments\textsuperscript{xix}.

Figure 8 shows such comparison with regards to the measure of Choice with a metric radius of 5000 meters which is a fairly district-wide measure. It can be realized that in all cases, the segments with less number off buildings (lower band numbers on the scatterplot

\textbf{Figure 6:}

\textit{The True Commercial Ratio of segment bands for all Zahedan against their average global choice }\textsuperscript{R=10000m (top left), average global mean depth }\textsuperscript{R=5000m (lower left), average local choice }\textsuperscript{R=1200m (top right) and average local mean depth }\textsuperscript{R=1200m (lower right)
dots) have more than expected commercial activity (positive RTCR). Moreover, Babaeyan and Moradqoli have a steeper regression line although R square for Babaeyan for this metric radius is not noticeable. By looking into figure 7, R-square values and the slope of regression lines seems to have some relations with the consolidation rankings of the settlements. In Babaeyan and Moradqoli the smaller segments have a quicker pace of increase in their commercial ratio which means shops are more concentrated on globally integrated street segments.

With regard to the above spatial variations amongst the settlements it is crucial to understand how the concentration of shops might relate to the street configuration from local to the global scales for each case. Figure 8 shows such an attempt, by plotting each settlement’s trend in terms of its R-square of correlation between RTCR and angular segment choice in different metric radii. For comparison purpose, a new residential development in the west (Qods district) is also included. It can be seen that although Babaeyan has a low local correspondence between shops concentration and choice values in a local scale, it ends up with a relatively high R-square in 1000m radius. Also Moradqoli keeps a relatively steady and high correspondence all over the radii which is different with the two less consolidated settlements of Shirabad and Karimabad. In a sense the two later cases (especially Shirabad) are similar to the Qods official housing area in which the shops are more distributed according to the local choice factor but there is a weak correspondence. However, care should be taken not to just focus on the R-square values but to an extent the strength of correlation can show how effective the commercial buildings are located with respect to the local and global syntactic factors.

Figure 7:
Correlation between ‘Relativized True Commercial Ratio’ and segment angular choice (R5000m) for Karimabad (top left), Babaeyan (top right), Moradqoli (lower left) and Shirabad (lower right). Each dot is labelled with the segment band for that settlement.
This study developed a methodology to quantify the concentration of shops on the street segments. This gives an indication of how the commercial activities might effectively locate themselves to maximize their benefit from syntactically more strategic locations. The initial results suggest that socio-economic variations amongst the informal settlements of Zahedan are related to this interplay between commercial land use locations and street network attributes. The large informal settlement with higher degrees of consolidation seems to maximize their economical benefit not only through shops on their outward edges but also accommodating internal markets which links its local economy to the wider urban context. However, the way that consolidation rates are calculated are relatively rough which necessitates the use of a more rigorous framework in future including more elaborate socio-economic data and site surveys. The methodology is also extendable to the other categories of land use to assess the degree of each settlement’s syntactic efficiency in terms of that specific land use. It then can inform the current upgrading policies in terms of ‘where’ to locate the new amenities in contrast with the conventional question of ‘how much’ to invest.

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References


i. The term ‘fine-scale’ here refers to the segments analysis in which the spatial elements are the segments of axial lines between junctions. The term ‘fine-scale network analysis’ was first used by Hillier and Sahbaz (2005) in this sense but the basics and theoretical fundamentals are presented in Hillier and Iida (2005).

ii. See Karimi (1997) for the debate on organic urban forms.

iii. There is no objective criterion, as UNCHS (2003) indicates, to identify an informal settlement as ‘large’. It is, as this source proposes, rather relative to the size of the wider city by exemplifying cases between 400,000 to 140,000 people as large (UNCHS, 2003: 90). However, in the same urban context of Santiago another research by Mora (2003) studies large internal markets for a low-income settlement of 120,000 persons.

iv. Instead of ‘spatially integrated’ it can also be said ‘spatially central’ which embraces the concepts of betweenness and ‘closeness’ expressed as measures of ‘angular choice’ and ‘angular mean depth’ respectively (Iida and Hillier, 2005).

v. It is an estimation done by the author simply by adding up the informal settlements’ population mentioned in the official reports, i.e. 235,000 people, to the maximum estimation of Zahedan population that is 700,000 people.

vi. Because Budiarto uses the concepts of ‘socio-cultural’ and ‘micro-economic’ forces to explain the emergence of super-grid, one can logically find its similarities with the ‘deformed wheel’ concept. As a result his argument can be translated to the connection of a settlements’ structure (either called ‘deformed wheel’ or ‘second level super-grid’) to the larger city.

vii. Without official estimations of 700,000 with 150,000 Afghan refugees is also mentioned in the same source.

viii. This can be generally related to the official policies in the past to discourage the growth of informal settlements by excluding these from official amenities while directing the city growth towards south and east axes to avoid encountering informal settlements (IMHUD/WB, 2003). This trend has been changed recently and as a part of the Ministry of Housing and Urbanism action plan to improve the situation of low-income areas in the country (IMHUD, 2004).

ix. This is in line with Budiarto’s concept of a ‘second-level super grid’ reviewed before. This local network supports the informal economy while the ‘first level super grid’ comprised of the main spines of the city.

x. This socio-economic contrast in a geographical sense was first reported by IMHUD/WB through their GIS studies of Zahedan.

xi. The same as 12

xii. In this ranking the main factor is how despite the age, a settlement has failed to self-improve or have been excluded from infrastructure and services. The other factors have been the proportion of areas with critical building condition, household size, employment and social pathology from the IMHUD/WB report.

xiii. These three cases along with Babaeyan are selected due to their closeness to each other their distinct variations in consolidation ratios also observed by the author at their sites.

xiv. It is based on the formula indicated by Hillier et. al (2000, Page 88): EOCA = 10 (shops/plots) + 10 (edge shops/plots) + (edge shops/shops)

xv. If the building actually has a shared border with the urban block line, it is assumed that it has an active façade that acts as its entrance.

xvi. The third criterion is the number of building count on the segment itself if the ‘multiple connection’ is allowed.

xvii. For more on the statistical bases of the banding method see Hillier and Sahbaz, 2005

xviii. The expected number of shops in each band is proportional to its total number of buildings. In other words, it is like assuming that each segment band will have a share of the total shops in a settlement proportional to its share of the total buildings of that settlement. Now it is possible to see how much difference there is between the actual (Ac) and expected (Ec) number of shops relative to the expected number of shops in that band. In effect, Relativized True Commercial Ratio (RTCT) is calculated as follow: (RTCT) = (Ac – Ec) / Ec

xix. This solution however is similar to the recent work of Ortiz and Figuirerdo on land use pattern matching in which the distribution of a certain land use is compared to a hypothetically random distribution of those.