Compensatory Urban Form

Configuration as means of expanding social equity in Belem, Brazil

54

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Abstract
This paper argues that urban form is a means, among others, for expanding social equity by providing compensation for disadvantages created by locational differences. Accessibility as a factor of social equity was measured by space syntax and combined with analysis of locational differences assessed according to infrastructure and public transport provision in the centre and on the periphery of Belem in Brazil. The findings from urban form assessment were appraised in the light of ideas from local urban planning. Conclusions are articulated at the end of the paper linking urban form findings and social equity.

Keywords
Social equity, urbanization, locational differences,

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Introduction

This paper articulates the idea that spatial analysis is to be integrated with other scales of analysis in the assessment of outcomes of urban planning and management. Commenting on Harvey's Social Justice and the City from 1973, the difficulty in the integration or synthesis needed was identified by Batty:

> Social processes are rarely, if ever, represented by models of spatial form and vice versa...the difficulty of synthesis...is that the various languages and styles used to develop ideas about social processes and spatial form are almost impossible to reconcile. Urban modelling demonstrates this dilemma in a direct fashion for the models [analysed in his book] have been concerned with spatial form rather than social processes.
>
> The difficulty of integrating these two approaches cannot be over-estimated. What seems to be required is a new type of calculus which is able to handle quantitative and qualitative ideas, micro and macro concepts, behavioural and statistical approaches and so on.
> (Batty, 1976:355.)

The analysis of relationships between urban form and policy is an extension of the socio-spatial debate from the 1970s, when urban modelling was a main tool for defining land use and occupation guidelines (Batty, ibid). As a method, space syntax was claimed at the end of the 1980s to assess in detail alterations in urban form and integrate them with social processes (Hillier, 1996). The use of space syntax is a means to assess results from the application of guidelines for territorial organisation provided by modelling. The representation of spaces by axial lines seems appropriate to show that movement is related to configuration and land uses, important elements for analysis of distribution of benefits within the city. It is proposed that topological relations between spaces rather than measures of alterations in zoning

and occupation, as done in modelling studies, will inform in more detail the consequences of relationships between socio-spatial segregation and distribution of benefits such as infrastructure and accessibility.

Space syntax was employed to analyse potential accessibility in Belem, Brazil. Syntactic measurements of global integration, local integration and intelligibility are correlated with socio-economic information - income, schooling and infrastructure provision, including public transport - to find the extent to which urban form compensated for locational disadvantages. This paper focuses on the possibilities that urban form, or different locations with certain urban configurations, can be used to assess urban policy effectiveness in achieving social equity.

Compensatory aspects of the definition of social equity

Social equity is used interchangeably with social justice to refer to justice or fairness in the distribution of benefits such as income and wealth, and consequently of opportunities to recipients (Campbell, 1988). Social equity means balancing distribution of benefits of urbanisation through urban form, and via infrastructure provision and housing to the benefit of less advantaged social groups (Rawls, 1972; Campbell, 1988). Rawls' ideas are relevant because of their nearness to urban reform demands in the recent democratisation of Brazil (Ribeiro and Azevedo, 1996). Decreasing inequalities between social groups is a prime goal in Brazil, because of the geographical proximity of living locations of better- and worst-off populations. Accepting Rawls' formulation, the difference between classes must be understood and reversed and compensated for, to create favourable conditions for disadvantaged dwellers.

Evident inequalities in Brazilian cities seem explained by assumptions that the status quo of class segregation is maintained by zoning and urban density regulations (Rolnik, 1997). Rawls' proposition that social and economic inequalities have to be identified and then compensated for is basic in assessing constraints imposed by urban form and the way it is managed. Compensatory urban form means that configuration potentially reduces negative impacts of locational disadvantages caused by socio-spatial segregation.

Accordingly, disadvantaged dwellers having constraints on receiving benefits might be compensated, receiving more benefits from state investment in infrastructure, including public transport. Infrastructure and service distribution might increase the capacity of urban form to minimise negative effects of inequalities, inherent to urban occupation. To understand these relationships, urban form's ability to facilitate or, if it is the case, to constrain dwellers to benefit from their living locations should be assessed. An understanding of existing conditions of residents and the extent to which dwellers are to be compensated for their inability to benefit from the overall city to improve living conditions must be established. The relationship between local order in urban form and global conditions should replace localised views of benefits commonly associated with facilities within a manageable distance, as in welfare policies. Urban form study should suggest a multi-level compensation for disadvantages, beyond local shelter and facilities; benefits to be brought about by the overall city configuration.

The city of Belem

The city of Belem, the capital of Parα State, lies on the fringe of the Amazon region, and is the largest capital city of the Brazilian Amazon, with an area of 13,000 hectares at the intersection of the Parα (a tributary of the great Amazon River) and Guamα rivers, on a bay called Guajarα. It includes the city centre of the municipality of Belem and those of its immediate surroundings located in the Primeira Lιgua Patrimonial (First Delimitation of Municipal land), and its periphery, also referred to as Belem's expansion area. The population of Belem was in 1995 1,144,312; 1,435,727 are estimated for 2010 (IBGE, 1997).

In the beginning of the 20th Century, exports of Amazon rubber brought prosperity to the city; since the 1960s, the local economy in the North region of Brazil has put constraints on Belem's development. At the end of the 1990s, the city economy relied almost entirely on tertiary sector activities provided by businesses and state administration in the city. The negative consequences of economic decline are evident in unemployment and housing shortage, shown in different types of peripheral occupation since the 1950s. First land was allocated for public institutions along the two main routes along which the city was supposed to grow: army, navy and research institutions owned land in the 'Institutional Belt' of the city. The nature of this land use (i.e. defence) created large areas with access restrictions. In those areas, later occupied in part by conjuntos habitacionais (social housing developments built by central government), illegal land invasions by the poor occurred since the 1970s in areas owned mainly by the private sector and by institutions. This happened after high density occupation inside the boundaries of Primeira Lιgua Patrimonial, on the 'first' periphery of the city, called baixadas (Figure 1). In the centre and on the periphery they are the alternative sites for housing the poor, wanting shelter near work and within reach of the facilities in the city centre.

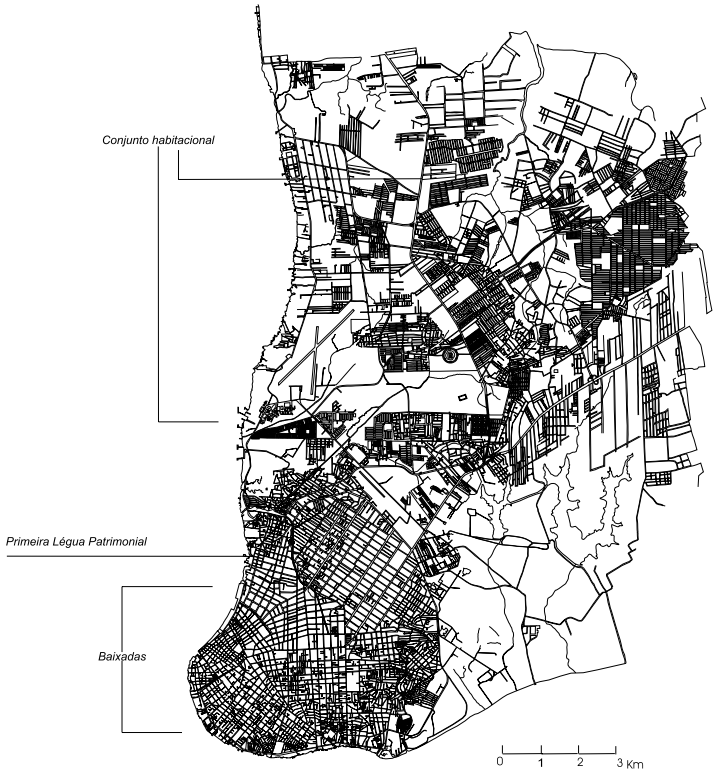

Figure 1. Map of Belιm in 1997, based on official maps showing the city main core and part of its periphery. Sources: CODEM (1997; 1986) and aerial photos taken in 1995 (CELPA, 1998)

Urban planning in Belem has been subject to comprehensive plans drawn up by co-operation between central and local governments (PMB, 1993). The objectives in policies set out before 1988 was functionally-differentiated urban structure, characterised by compatibility between land use and accessibility through a decentralised concentration model of urban occupation and expansion of the urban fabric. Peripheral expansion was a means of implementing the objectives of plans and regulations by provision of infrastructure and release of land for housing along transport axes. After 1988, the same ideas were advocated, to which were added other socially-fair principles; the envisaged urban structure had to fulfil social as well as functional principles.

Assessing Locational Differences in the Urban Form

To measure to what extent these objectives and connected manipulation of urban form have been effective in improving social equity, implicit in the plans before 1988 and explicit later, socio-economic and spatial measurements were devised to assess existing locational differences in the Belem's urban form. The measurements take into account the distribution of social groups in the city and other factors related to changes in the urban patterns inherent to policies, creating locational advantages and disadvantages in the centre and on the periphery.

Accessibility to services in the city varies with social differences and is the outcome of political processes (Hay, 1995; Curtis, 1989; Harvey, 1973). Accessibility as a practical measure of social equity in relation to the urban form takes into consideration relationships between society and space. Studies of relationships between urban residential structure and accessibility claim that physical proximity to facilities contributes to people's welfare in a number of ways: apart from anything else, it offers opportunity. Some studies are based on descriptions of residential areas and calculate indexes of accessibility between residential areas and facilities (Smith, 1987). Others relate overall accessibility to individuals' needs for trips across the city. These studies show various accessibility aspects in terms of time, money available to spend on transport and other indicators (Vickerman, 1974; Knox, 1982).

Expanding the assumptions of the relationships between social equity and space in geographical studies, social equity in the city may reflect the degree of physical mobility and perceived accessibility possible for individuals, given the city's layout. This study avoids assessment of accessibility between two points in space, commonly applied in land use and transport planning models. Space syntax measurements are instead used to refer to overall access from any one location to any other in the city.

Syntactic measurements aim to evaluate how the configuration of the urban structure contributes to accessibility and how accessibility is associated with locational differentiation of social groups. Accessibility depends on the overall spatial characteristics of the urban structure and ease of access rather than length of journey (i.e. available transport, configuration and distance - not just distance). Space syntax is also justified by the city's form shaped formed historically through planned and spontaneous forces and infrastructure provision, including public transport, and influenced by priorities in government policies and expenditure. It is assumed that public transport uses the existing road network to operate, and reinforces the spatial distribution of land uses and social groups in the city.

The measurement of accessibility due to configuration, using space syntax, takes into account that intended sub-centres and decentralisation of non-residential land use from the city centre create locational advantages associated with social interactions and with opportuni-

ties for commercial and services land use to be created. The bus network is meant to provide dwellers with higher mobility and thus achieve benefits for social equity in the decentralised concentration model devised by masterplans (Prefeitura de Belem, 1993).

Rejecting the simplistic 'A to B' models of accessibility, space syntax measurements - connectivity, local and global integration as well as intelligibility - provide indexes of accessibility dependent on the configuration of three parts of the city (Figure 2). First, part of the Centre, second Entroncamento around the main junction linking the centre and the periphery of Belem and, third Augusto Montenegro peripheral area were selected for closer study because of their key positions in the overall arrangement of the different parts of the city. That part of the city called centre is the extension of Primeira Lgua Patrimonial formally (i.e. not informally) occupied at the beginning of the 20th century. The city centre and portions of the periphery were seParately investigated through axial maps.

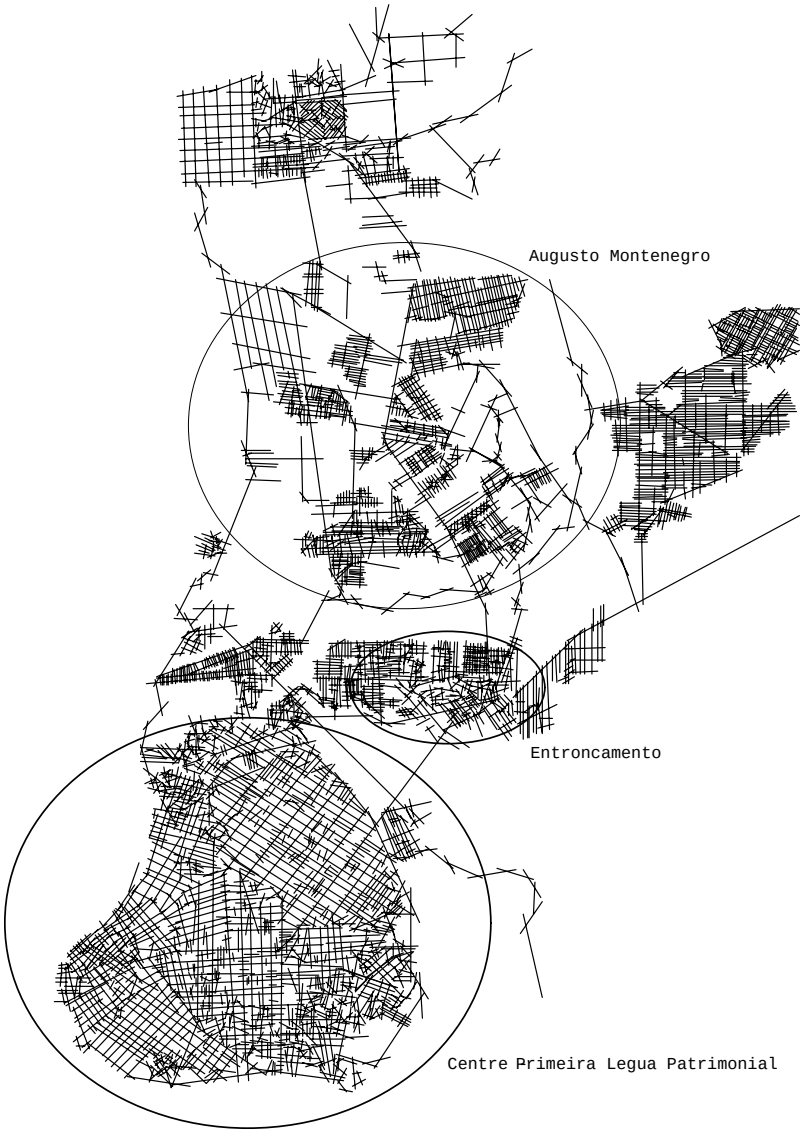

Figure 2. Axial map of Belem in 1995 showing hte case studies: Center (part of Primeira Legua Patrimonial), the main traffic junction (Entroncamento), A. Montenegro periperal area. Sources: CODEM, 1977; 1986 and CELPA, 1998

Analysis of accessibility in the urban form of Belem

Urban evolution of Belem took place through an aggregation of various types of layout. The regular grid of the city centre created a high level of intra-centre accessibility by long links from the main core towards the periphery. In the city, these long roads form the global integration core (10% most integrated lines). Most spaces of the centre are articulated in the same core (Figure 3).

The global integration core is made up of a few spaces or lines directly connected to the main link, where it is straightest. There are no major differences in the syntactic values of housing developments and spontaneous occupation in terms of global integration. Local integration measurements of connectivity and control in Entroncamento show that the road

Figure 3. axial maps of Belem city center showing syntactic measurements Global integration (left top), Local integration (right top), connectivity (left bottom) and control (right bottom). Sources: drawn from: CODEM, 1977; 1986 and CELPA, 1998

system creates a high degree of segregation between neighbouring spaces (Figure 4). Considering spaces accessible in three steps from each other, the road system shows few lines forming cores easily accessible by pedestrians.

Syntactic measurements in the A. Montenegro periphery show that accessibility depends directly on long axial lines, not well connected to surrounding spaces (Figure 5). Local syntactic measurements show each line or space has few connections to neighbouring spaces. The measurement of connectivity shows only limited relationships between spaces forming housing developments and spontaneous occupations responsible for 'cells' in the system (Figure 5, left bottom map). In the A. Montenegro area, global integration is more significant than

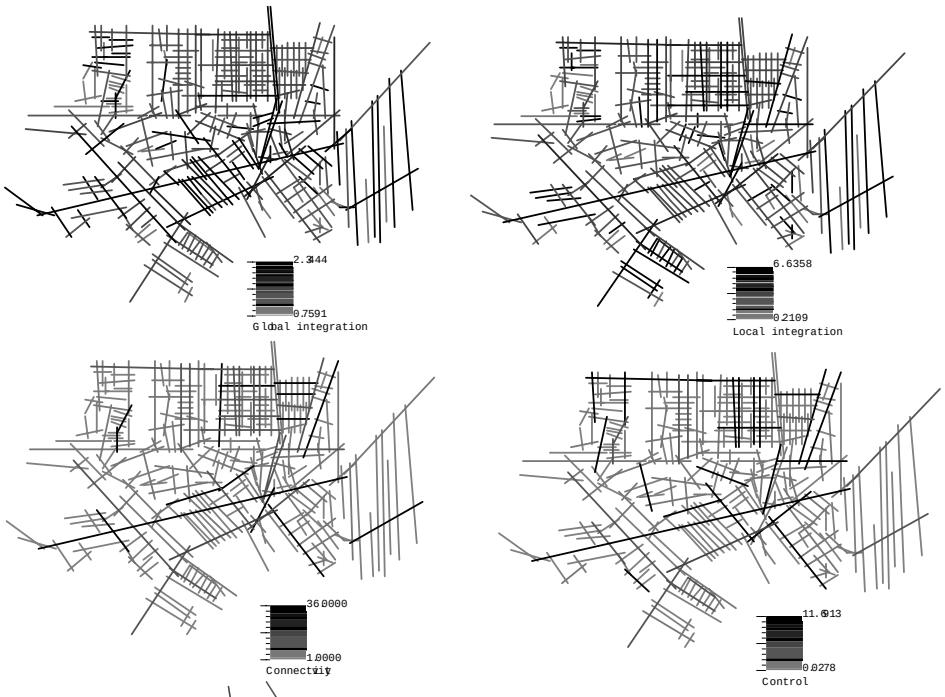

Figure 4. Axial maps of Entroncamento showing syntactic measurements. Global integration (left top), Local integration (right top), connectivity (left bottom) and control (right bottom). Sources: CODEM, 1977; 1986 and CELPA, 1998

Figure 5. axial maps of A. Montenegro periphery showing syntactic measurements. Global integration (left top), Local integration (right top), connectivity (left bottom) and control (right bottom). Sources: CODEM, 1977; a986 and CELPA, 1998

local integration, the consequence of road improvements linking the main core of the city to the rest of the municipality. The periphery is characterised by the location of housing developments without a coherent layout, featuring fragmentation and isolation of peripheral cells.

Table 1shows a comparison between mean values of syntactic measurements in three case study areas of Belem. It compares syntactic measurements and their relationships through correlations between global integration and local integration called, in space syntax, intelligibility. Intelligibility is defined as the correlation of a local and a global variable (the local is more readily available to experience and correlation implies that the more easily experimential is an index of the more abstract). In earlier works, intelligibility was explored by the relationship between connectivity and global integration (Integration Rn). More recently, intelligibility has been explored by relationships between local integration (or Integration R 3) and global integration (Hillier, 1996), as did this study to assess accessibility.

Mean global integration in the Centre is higher than on the periphery. The location and size of the global integration core of the Centre (defined here by the 10% more integrated lines) provides endorsement of explanations given by space syntax. The better performance of the centre providing accessibility to different social groups mixed in the centre is explained by coincidence between location and size of the global integration core and the areas with commerce and services. The historic centre of Belem lies at the southwest corner within the Primeira Lıgua Patrimonial. As the city expanded, the commercial and service centre shifted to closer to the geographic centre of the Primeira Lıgua Patrimonial, shown in the map in Figure 3. Its position and size coincide with the global integration core spanning over most of Primeira Lıgua Patrimonial.

Table 1. Mean values of syntactic measurements in the case study areas" Source: Axial map drawn on official maps of Belım (CODEM, 1986; CELPA 1998)" Obs.:N is the number of axial lines

Case studies	Mean global integration	Mean local integration	Mean connectivity	Global integration / local integration	Global integration / connectivity
Centre (N=518)	1.78	2.03	5.52	0.54	0.34
Entroncamento (N=373)	1.32	2.43	4.07	0.52	0.24
A. Montenegro (N=316)	1.27	2.63	4.72	0.29	0.17

Spaces on the periphery present a higher mean value than the centre; locally, their formation on the periphery are better articulated by three changes of direction from each in turn. In the centre, local integration is less important, also shown by the mean value of connectivity in the same table. In the centre, mean connectivity is higher than on the periphery; the Centre presents a shallower and more connected structure than the periphery.

In Belem, intelligibility decreases with the fragmentation and deformation in the original grid of the main core. In the centre, intelligibility is higher than on the periphery; the centre's intelligibility correlation is 0.54. In Entroncamento, intelligibility drops to 0.36 and in A. Montenegro to only 0.29. Analysis of intelligibility shows two important aspects of the configuration of the periphery in contrast to the centre. The first is that the coefficients in the regressions are the result of overall layout rather than of the configuration of specific patterns and their locations. The second is that these fragmented conditions mean that the layout of

social housing makes accessibility difficult within the periphery and between the periphery and the main core of the city. Low intelligibility on the periphery explains the pattern of poor intra-periphery accessibility. The location of social housing schemes and condominiums without secondary links, restricts intra-periphery accessibility.

Accessibility due to the public transport network

The importance of public transport to accessibility is because buses constitute the most popular means of transport in the city for poor people. The map on Figure 6 shows the distribution of bus routes in 1995, obtained from the local government department responsible for planning and management of public transport in Belem.

Syntactic measurements were obtained from the analysis of information about bus routes in the city (CTBEL, 1998). The number of bus routes in each axial line was compared with measurements all roads of the city network. It shows how availability of bus services is related to choice in terms of accessibility, used in each case study area reported before.

The distribution of bus routes shows a lack of balance between the centre and the periphery. As observable in the city, the high percentage of bus routes penetrating central areas causes congestion in the main roads of Primeira Lıgua Patrimonial. The consequences of the configuration of the bus network for accessibility are evident in the relationships between syntactic measurements and the number of bus routes in each axial line. Globally, bus routes are better articulated in the centre than on the periphery. Table 2 shows that mean global integration of roads with buses in the centre is higher than the mean of the city (1.912 against 1.627).

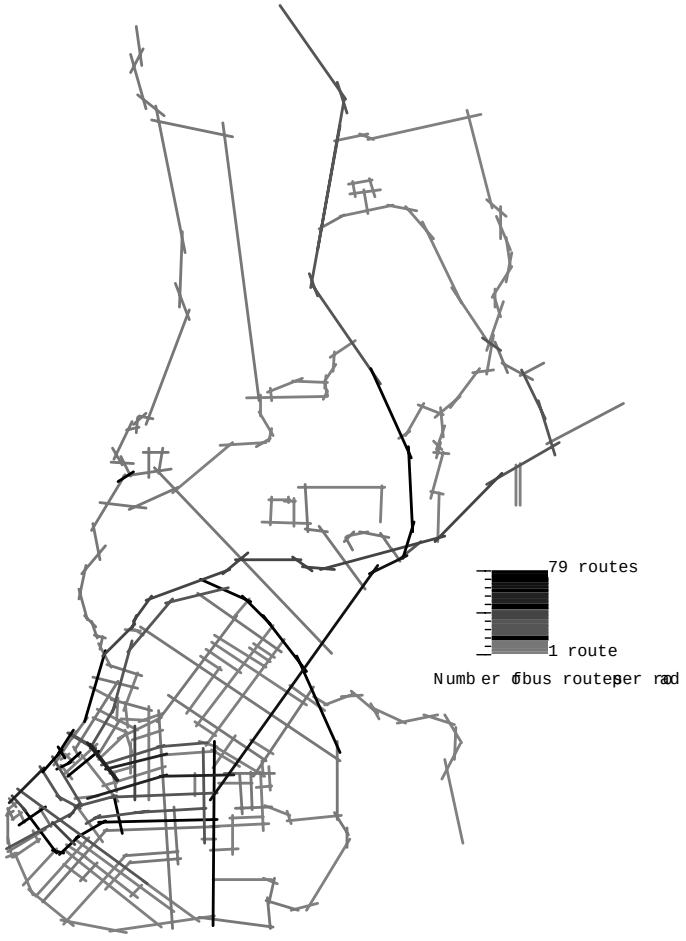

Figure 6. Map of public transport network in 1995 showing bus routes. Roads in grey are those without but routes. Sources: map from CODEM, 1977; CELPA, 1998 and bus routes description from CTBEL, 1998.

Mean local integration values show that the bus network is more accessible within three changes of direction in the centre than on the periphery. In addition, on the periphery, accessibility to bus routes is also compromised by a limited number of routes. Considering connectivity of roads with bus routes to immediate neighbouring roads, the centre also has the highest values in Belem. A. Montenegro area has almost half the connectivity values of the centre, suggesting that configuration plays an important role in the efficiency of the bus network, at least in the centre. Connectivity in the grid is important if urban layout is to increase social equity through public transport. It governs whether public transport will or will not be accessible, thus financially viable and efficient.

Figure 7 shows that intelligibility in areas with roads with bus routes is higher in the centre than on the periphery. The importance of the bus network to mobility in the centre is also seen in the local integration cores in the centre. Comparison of the map of bus routes (Figure 6) with maps of the centre (Figure 3) shows that the integration core in the city centre coincides with the concentration of roads with more buses. The distribution of bus routes

Table 2. Mean values of syntactic measurements in roads with bus routes in the case study area 1998 Source: Axial maps drawn on official maps of Belem from PMB, 1998; CODEM, 1986; and CELPA 1998. Obs.: N is the number of axial lines with bus routes

Case studies	Mean global integration of roads with bus routes	Mean local integration of roads with bus routes	Mean connectivity of roads with bus routes
Belem (N=56)	1.627	3.15	6.905
Centre (N=29)	1.912	3.543	8.438
Entroncamento (N=9)	1.308	2.516	4.553
A. Montenegro (N=18)	1.329	2.834	5.611

in relation to syntactic measurements shows that for urban form to have an effect on social equity, feasibility and coverage by public transport needs to be well integrated with the pattern of accessibility provided by urban form.

The analysis of the bus network within the road network of Belem shows that the bus network in the centre improves accessibility; intelligibility of roads of the city network with bus routes on them is higher than on the periphery. There, intelligibility of roads with bus routes shows that the bus network does improve intra-periphery accessibility (Figure 7). This is also suggested by a comparison between the total number of axial lines in the centre and on the periphery and those on which buses run. The centre has 1294 axial lines or spaces and

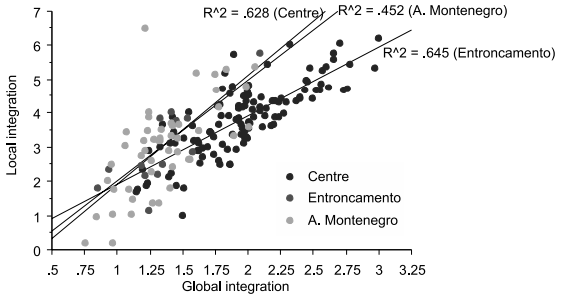

Figure 7. Scatterplots of intelligibility in areas with bus routes in Belem. Sources: Axial map drawn on official maps of Belem from PMB, 1998; CODEM, 1986: and CELPA 1998.

bus routes on 518 of them, while on the periphery, of 1097, 128 roads have bus routes. Intelligibility of roads carrying bus network is higher than intelligibility of roads without buses, both in the city centre and on the periphery. These figures reveal a negative aspect of public transport provision.

Locational differences assessed by relationships between syntactic measurements and socio-economic indicators as predictors of accessibility

The indicators obtained from census data and axial graphs were organised into a single data set. Census data referring to household and dwelling units were aggregated into groups of census sectors and average syntactic measures of axial lines within each group of census sectors. The seParation of social groups within the city has been described by socio-economic indicators for the three study areas. Scatter plots in Figure 8 and Figure 9 show intelligibility correlations of census sectors with households and dwelling unit characteristics according to income and amount of living space. The selection of income intervals (seen in Figure 8) was made in order to investigate different social groups, high income (earning more than 10 LMW) and low income (earning less than 5 LMW).

The correlation of syntactic measurements - intelligibility from global and local integration - with income in the centre shows that social status associated with location of different social groups can predict accessibility. Comparison of the two scatter plots of Figure 8 shows that intelligibility in areas where higher-income groups live is higher than in areas with a lower-income population. In the centre, higher income areas have a coefficient of intelligibility (R^2) of 0.893 whereas this coefficient in lower income areas, also in the centre, is only 0.235. These coefficients show that accessibility is an advantage offered to higher income groups in the centre (and not on the periphery). Intelligibility on the periphery shows that accessibility has a high value for those who can choose their living space (condominiums), but not in social housing developments, mainly as a consequence of the pattern of road and buses, assessed in terms of frontage values (Lima, 2000). Examining these findings in the light of global and local integration measurement of the centre and the periphery, accessibility seems better predicted by higher income in the centre than on the periphery, explicable by greater reliability for space syntax inputs; the grid is more consolidated in the centre than on the periphery, where there is a hierarchical and fragmented urban form.

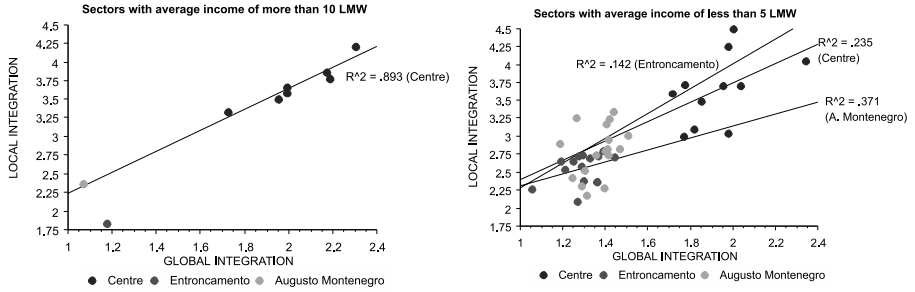

Figure 8. Scatter of intelligibility in study areas according to selected income intervals. Sources: IBGE, 1992 and SEFIN, 1991a.

Investigation of intelligibility in locations according to the number of people per dwelling provides further evidence of how form features relate to socio-spatial segregation (Figure 9). Census sectors with a low number of people per dwelling are characterised by higher social status groups; in the centre there are nine sectors with an average number of people per dwelling less than 4.5, and in A. Montenegro there are 13 such sectors. In the centre, intelligibility of these locations is higher ($R^2 = 0.907$) than intelligibility of sectors with the same average number of dwellers per unit on the periphery ($R^2 = 0.079$). These differences of intelligibility confirm that on the periphery, socio-spatial segregation by amount of living space is less associated with locational advantages.

An examination of locations with an average of more than 4.5 dwellers per unit shows that low social status groups in the centre and in Entroncamento also encounter lower intelligibility (R^2 = 0.291 and R^2 = 0.304) than do residents of the same status in A. Montenegro. Paradoxically, there, intelligibility of locations of high social status groups is lower than is intelligibility of locations of low social status groups: R^2 = 0.079 against R^2 = 0.604. Nevertheless, locational disadvantages do not affect high status residents of condominiums on the periphery, once they rely on private transport to overcome it. For residents of the social housing developments, the level of intelligibility can not be considered an advantage because of deficiency of public transport. It can, therefore be inferred that in the centre, intelligibility is positively associated with the social status of groups, while on the periphery this is not so.

High intelligibility in A. Montenegro is accompanied by low levels of global and local integration, showing that socio-spatial segregation of the periphery depends upon layouts of the developments. Global and local integration on the periphery, compared with those in the centre, show the effects of fragmentation in the layout. On the periphery, access to neighbouring spaces is restricted; there is no consideration of accessibility in the whole road system. Figure 8 shows also, that, in choosing their place of living, among other reasons, accessibility seems to be valued by high income groups in the centre. Highly significant

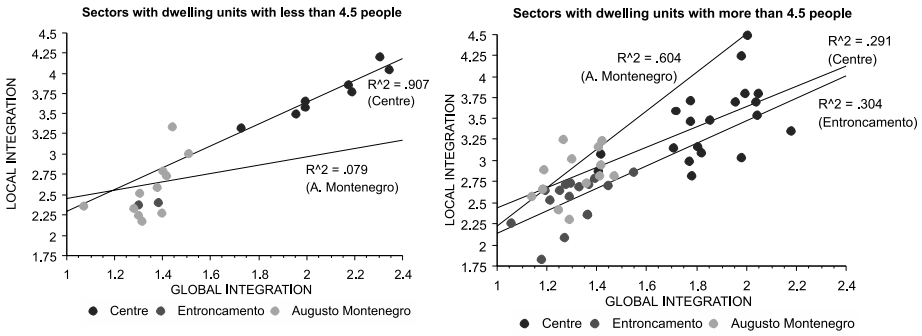

Figure 9. Scatter plots of intelligibility (global and local integration measurements) in study areas and selected number of people per dwelling, left with less than 4.5 people per unit and right with more than 4.5 people per unit. Source: IBGE, 1991 and axial graphs. Source: IBGE, 1992 and SEFIN, 1991a.

positive intelligibility exists there, where indicators of amount of living space show their desire to be located in spaces having the best global and local accessibility in the whole system. In the same scatter plot, low intelligibility in the location of units with lower occupation density, characteristic of the condominiums on the periphery, shows their self-chosen segregation accompanied by low intelligibility. This is the result, in part, of developments not being well connected with their surroundings and, in part, of their internal form. So, better space standards on the periphery are not accompanied by better accessibility.

Findings and Conclusion

Exploration of relationships between spatial measurements and socio-economic indicators, especially the spatial distribution of social groups according to income and amount of living space, suggests a fine-grain socio-spatial segregation in the centre, stemming from differentiation of social status. This segregation is a result in part of the centre's dense and compact configuration, and in part of how social groups take advantage of locational aspects of the distribution of infrastructure, especially provision of public transport, made possible by the central road network. The differences of accessibility in the centre and on the periphery are that the centre grid has a 'global order arising from the way local parts are defined' (Hillier, 1989:20). On the periphery, on the contrary, global order is lost by the way the cells were formed.

The co-existence of different social groups in the centre means that the same high standard of infrastructure and the configuration of the grid deliver mobility to different social groups. The importance of the grid in the centre is demonstrated by local integration measurements showing integrated cores and the importance of routes linking them. The correlation of integration with amount of living space shows the effects of infrastructure provision on the character of the road layout. The first is largely political and is related to the distribution of infrastructure, showing that service providers do not consider that patterns of distribution cause locational advantages for specific locations. Benefits are spread and used by different groups as a consequence of the configuration of the centre.

According to the concept of social equity, compensation in distribution is needed to ameliorate negative consequences of locational disadvantages. The analyses show that coherent urban form in the centre is potentially more compensatory than on the fragmented periphery. This is not because of configuration per se; socio-spatial segregation exists in both, as seen in the analysis. But a combination of different factors makes the difference. 'Compensatory' accessibility is generated by the combination of urban form, the bus network and the mix of social groups located within the configuration of the city.

This paper contributes to urban policies because it elucidates a sort of accumulative compensation that can operate in cities through urban form. Due to the common practice of governments not providing a clear rationale for priorities in implementing changes in urban form, compensation for disadvantages in Brazil seems a 'hidden' assumption, and does not justify emphasis on improving the living location of elites. The paper shows that effective policies should take into account the extent to which disadvantages arising from local disorder in living spaces need to be compensated in order to gain globally improved living conditions.

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