“Livable Communities” Indicator Development and Its Application in a Borough of the Lisbon City

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Abstract
In the last decade studies have been developed concerning the implication of planning and transports on the quality of life of residential boroughs. Some of these studies are included under the name of “transit-friendly communities”, “transit-oriented development”, “traffic calming” and “livable communities”, these analyze urban issues with the goal of maximizing the quality of live of residential boroughs and minimize the externalities created by unwanted urban planning and transportation developments.

This article explores the concept of “livable communities”, it develops indicators of some relevant factors of urban planning and transports in a borough and analyzes them individually and in an aggregated fashion for a study area defined in the city of Lisbon (borough of Graça). The main elements selected to study were based on the State of the Art research and on the study of the area main characteristics: the accessibility to local equipments, the pedestrian comfort, the traffic congestion, the parking capacity and quality, the building degradation and the land use mixture.

The procedures involved included GIS analysis on a cell-by-cell basis (during the local conditions evaluation and for scenario development), and it also included GIS-CAD interaction (each time a proposal had to be set on a local basis for further project development). The proposed methodology described at this article can be used at different scales of analysis and included the possibility of adding new indicators that are considerate relevant for each specific case.

Some of the conclusions point to the importance of developing these kind of integrated analysis, not only for implementation and project development, but also as a useful decision making tool that will grant an understanding and easy acceptance of local citizens.

Keywords: Livable Communities; Parking, Traffic; Pedestrians; land use mixture;

Introduction
Nowadays, urban/regional planning and transport policies have a big influence on the quality of life of residential boroughs. During the last decades, several studies have been developed applying the concept of sustainability in order to face some of the problems we are facing (i.e. congestion, sprawl), from these innovative approaches new concepts have been proposed such as: “transit-friendly communities”, “transit-oriented development” and “traffic calming”, which can be included in the “livable communities” when applied to residential zones.

The understanding of the factors that contribute to the “livable communities” have been the main subject of these studies, trying to understand the repercussions over the mobility (i.e. reduction of commuters’ trips). The United States bibliography spans over these and other important subjects, mainly handbooks of how to build a livable community, presenting case-base experiences. Some cities have their own handbook; at these handbooks urban planners and transportation experts point out the main planning and mobility policies and instruments used at a borough scale. Most of the times, these manuals focus on the Central Business District (CBD) and some suburban zones that are essentially residential, but that should present a favorable land use mixture in order to grant a better quality of life to its inhabitants (County of Ventura Planning Division, 1997; Maine Development
These handbooks allowed to identify some relevant variables that affect the borough livability, that in its turn are used in this article as the main variables for the developed livability indicators (i.e. land use mixture).

To develop this methodology a borough was selected to work as the Case Study. The Case Study selected was a borough located in Lisbon’s city center that has a particular livability, due to its historic inheritance, its location inside the city and paisagistic value, and a particular sense of place between inhabitants and their borough. This borough is A Graça, which location inside Lisbon city and its organic urban design can be seen in Fig. 1.

In order to quantify and spatialize the livability of the borough selected for this study a group of indicators that reflected the concept essence were developed. The development of the indicators started by the definition of the main variables considered as responsible for the livability of a borough, trying that all of them had some relation with the borough mobility. Six spatializable variables related with livability were identified: walking accessibility to local equipments and public spaces, pedestrian comfort, traffic congestion, building degradation, parking capacity and quality, and land use mixture. Other variables could have been considered which have some influence in the livability of a borough, such as residents’ income, real estate price, etc.; these were not considered due to the lack of data with spatial referencing for the same land units used at this study area.

To spatialize the developed indicators, it was created a new spatial unit that would be similar to a block dimension. For that purpose, it was created a square cell grid that whose area was determined considering the smallest statistical spatial area available: the BGRI. The cell grid area was considered as the average of the study area’s BGRI, resulting in an 11,958,89 m² cell. The resulting grid for the study area was composed by 64 cells, from these base number, only 42 of them were analyzed due to the lack of information for some of the zones near the study area limits. This cell grid was created in CAD software and then imported to GIS software (Geomedia Professional 5.1 - Intergraph), where all the analysis were developed.

After the definition of a new spatial unit, it was necessary to develop a methodology to estimate the indicators from the available variables. This article describes the steps of the indicator development with the goal of assessing sustainable urban and mobility at the borough scale. The spatialization of the of the livability indicator’s results is not presented in this article, although it was done for all of them.

**Indicators description**

**Accessibility to local equipments indicator**

For the definition of the Accessibility to local equipments indicator, public spaces and equipments of the study area as well as their walking accessibility were initially identified as main indicators to be built. The local equipments were classified in eight types: health care centers, day care centers, nurseries, elementary schools, high schools, garden, leisure spaces and kindergartens. These equipments and public spaces localization in the study area are presented in Fig. 2. Using Geomedia Professional 5.1 GIS software, the geographic projected coordinates of all the equipments and public spaces were determined using the Hayford-Gauss Datum73 (Lisbon) coordinate system.
To calculate the distance of buildings contained by each cell grid defined for the study area, it was necessary to admit that the center point of each cell represents the distance of the equipments and public spaces to the buildings contained by them. This consideration is reasonable because of the reduced dimension of each cell (approximately 100 meters square side cell).

The distance of the center point of each cell to each type of equipments was calculated using Cartesian distances, considering for the variable value only the minimum value of each type of equipment or public space. The time walking distance was then calculated considering that the walking speed was 3 km/h, data that was obtained through the Highway Capacity Manual (HCM) 2000 in Chapter 18, where, for a population with a 40% of elderly people the walking speed value is 3 km/h. Considering this data, it was obtained the walking time distance of each cell center point to each type of equipment or public space in minutes.

To obtain a global indicator for the study area, it was weighted the importance of each accessibility previously calculated. To weight the importance of each equipment or public space accessibility, it was estimated the possible population that could use each of them. These results are presented in Table 1.

Table 1: Captive population of each equipment and public space of the borough

<table>
<thead>
<tr>
<th>Health Care Centers</th>
<th>Day Care Centers</th>
<th>Nurseries</th>
<th>Elementary school</th>
<th>High school</th>
<th>Garden</th>
<th>Leisure space</th>
<th>Kindergarten</th>
</tr>
</thead>
<tbody>
<tr>
<td>More than 65 years</td>
<td>More than 65 years</td>
<td>0 to 4 years</td>
<td>5 to 13 years</td>
<td>14 to 19 years</td>
<td>50% of the population</td>
<td>30% of the population</td>
<td>5 to 13 years</td>
</tr>
</tbody>
</table>

The resulting population of the sum of each type captive population is greater than the total population in the study area. As result of this, the weight of each equipment or public space accessibility was calculated through formula (1).

$$ P_i = \left( \frac{\sum_j \% \text{ captive population of each equipment and public space}}{\sum_j \% \text{ captive population of each equipment and public space}} \right) \cdot 1 $$

The developed indicator is a weighted walking time (in minutes) of each cell to existing equipments and public spaces in the study area. In order to allow a later integrated analysis of all the indicators, this indicator had to be standardized. For this standardization it was used the function presented in the Fig. 3, that retrieves 1 when the accessibility is lower than 2 minutes, and retrieves 0 when the accessibility is greater than 10 minutes.
Pedestrians comfort indicator

To create a Pedestrians comfort indicator, it was used the concept of level of service for pedestrians. The methodology used to determine the level of service was once again obtained from the HCM 2000. To apply this methodology, it had to be estimated the usable sidewalk width, which was considered 80% of total sidewalk width. Initially, the minimum sidewalk width was identified for each cell of the study area, and then the minimum usable sidewalk width for each cell was calculated.

The pedestrian flow was measured only for streets with higher commercial use, some important equipment or a point of interest that could create an important tourists flow. From this initial data, the pedestrian flow of each cell was estimated as the maximum flow of the roads that are inside or cross the cell.

From the estimated data for each cell, it was developed the pedestrians comfort indicator calculating the pedestrians flow most unfavorable per minute and meter of sidewalk width. This indicator of flow for each cell was standardized considering a function that develops value between 0 and 1. This standardization function is presented if Fig. 4. The value of 23 pedestrians per minute and per meter of sidewalk width was estimated from the value required by the HCM 2000 to have a level of service A, because this level of service methodology does not penalize very low sidewalk widths that are very common in this particular borough.

Traffic congestion indicator

This indicator was developed in order to measure the impact created by traffic congestion in the residential zones. For this purpose, it was necessary to measure the car flows in the study area. Like it was made in the pedestrians comfort indicator, the car flows were only measured in the principal roads, where traffic congestion could be a problem. The flows in the smaller streets were estimated as being a percentage (5% to 20%) of the flows measured in the principal roads depending on the road hierarchy established for the study area.

After the estimation of car flows for each road, the car flow of each street had to be associated with the analysis cell grid. For each cell, due to having several roads crossing it, it was necessary to weight the contribution of each road to the cell flow coefficient. The variable considered for the weighting of each road for cell coefficient was the length of road inside the cell as is presented in (2).

\[
\text{Estimated flow}_i = \frac{\sum \text{car flow}_n \cdot \text{length inside each cell}_i}{\sum \text{length inside each cell}_i}
\]  

(2)

As result of the simplifications made, the indicator of traffic congestion in cars per hour was obtained. Like the others indicators this had to be standardized. The standardization function is presented in Fig. 5, where the function returns the value 1 when there is no flow and value 0 when car flows are greater than 200 cars per hour.
Parking capacity and quality indicator

Car parking quantity and quality has also an important role in livability of a borough, because its deficit or disorganization can provoke an important degradation of the surrounding space. The parking indicator was developed with two components: the relationship of parking capacity with parking demand, and also parking quality or organization measured by the percentage of illegal parking in each cell.

To calculate the first component of the indicator, the available parking spaces of each road were associated to their containing cell. If the road was contained for more that one cell, parking capacity was split accordingly to the length of road contained by each cell (considering a uniform parking distribution along the road). Private parking facilities were also taken into account for the indicator, adding their capacity to the resulting road parking capacity of the cell that contains them.

In order to estimate the relationship of parking capacity with parking demand for each cell, it was necessary to estimate the residents parking demand. Parking demand was estimated considering the quantity of apartments contained by each cell. With the available data, this component of the indicator was calculated through the quantity of parking places for each apartment. To standardize this component of the indicator the standardization function presented in Fig. 6 was used, witch returns 0 for values lower than 0,2 parking places per apartment, and returns 1 for values greater than 1 parking place per apartment. This low value considered for the upper bound of the function can be explained by the study area urban design and the buildings age which is not very favorable and prepared for car parking.

The other indicator’s component is the percentage of illegal parking places of the total capacity of parking places. To standardize this component of the indicator it was used the standardization function presented in the Fig. 7, witch returns 0 for values greater than 50 % of illegal parking capacity, and returns 1 for the cells with no illegal parking.

To transform the two components in a single indicator it was made its average for each cell, considering the same importance of each component.

Building degradation indicator

The royal estate conservation of a borough is an important component of its community livability, because if buildings are in bad shape, this zone will not be attractive to new residents and will incentive their actual residents to leave the borough. To estimate this indicator, it was necessary to locate all degraded buildings of the study area, which were found by field trip to the area and by consulting the municipality internet warehouse for degraded buildings.

After the localization of the degraded buildings in the study area, they were coupled in the cells that contain them. The indicator was then calculated as the percentage of degraded building in the total building quantity for each cell. Like for the other indicators, this one’s values were also standardized considering the function presented in the
Fig. 8, where the function returns 1 when there is no degraded buildings in a cell, and returns 0 when the percentage of degraded buildings is greater than 10%.

Fig. 8 – Building degradation indicator standardization function.

Land use mixture indicator

Land use mixture in a borough is a fundamental factor for the existence of favorable community livability. Nowadays a borough must have a good land use mixture to be attractive for residents and also to reduce the need of car trips for daily shop. From this concept, it was developed an indicator with two components: a first that measures the land use mixture inside each cell, and a second that measures the intensity of residential use.

To estimate the first component related with land mixture, it was necessary to locate every land use of the study area and associate them with the analysis cell grid. Five types of land use were identified in the study area: shopping stores, offices and services, restaurants/bars, residential apartments and education institutions. For this analysis only the first four land uses were considered due to the great area of this kind of equipments that could bias the results. The area of each land use was estimated through the surface area of the building were the use is contained.

The land use mixture component was then estimated through variation coefficient of the non residential uses. This variation coefficient, resulting from the division of the non residential area average and its standard deviation, reflect for each cell the dispersion of the obtained values. In order to standardize this component, it was used a composite function that is presented in Fig. 9.

The residential intensity use component was calculated through the percentage of the built area of each cell dedicated to residential use. This value was calculated for each cell by subtracting to the total built area (obtained by the multiplication of the surface area of each building for its number of floors) the area of the non residential uses. To standardize this component, it was used, again, a composite function that is presented in the Fig. 10.

Fig. 9 – Land use mixture standardization function.

Fig. 10 – Residential intensity standardization function.

After the calculation of the two components of this indicator, its aggregated value was calculated through the average of both components, considering that these two components have the same importance for this indicator.

Indicators integrated evaluation

After the determination of all the indicators considered as relevant for the livability of the borough, it was developed an integrated evaluation and analysis of this indicators in order to determine the borough zones that have better and worse results on the global indicator.

Before starting this evaluation, the correlation between all the indicators was calculated. The results are presented in Table 2, where can be clearly concluded that the correlation between the indicators is very low, only presenting four values considered significant (presented in red at the table). These results point out that the
indicators were well selected and that the information given by one of them can not be explained by another indicator.

For the creation of a global indicator that integrates all the others indicators, it was necessary to develop a methodology to calculate the different contributions or weights of each indicator to the global outcome. After several attempts, it was established that the weights should be chosen in order to maximize the values dispersion (higher standard deviation of the values). This methodology considered that the weight of each indicator was directly proportional to the standard deviation of each indicator.

The results obtained for this weighting methodology are presented in Fig. 11. In this figure, it can be seen that the cells that have worse values of the global indicator are those located near the road with higher traffic hierarchy (i.e. Rua da Graça located along the central part of the borough). The cells with best values for this indicator are located in the East and West side of the borough, were traffic congestion is low, and the equipments and public spaces accessibility have good values. These cells do not have the best values in any of the livability indicators, but they have a very regular behavior for all of then, resulting in a better global indicator.

Table 2 – Correlations matrix of the developed indicators.

<table>
<thead>
<tr>
<th>Correlation matrix</th>
<th>Equipments accessibility</th>
<th>Traffic congestion</th>
<th>Pedestrians comfort</th>
<th>Building degradation</th>
<th>Parking quantity and quality</th>
<th>Land use mixture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipments accessibility</td>
<td>1,00</td>
<td>0,08</td>
<td>-0,25</td>
<td>-0,13</td>
<td>-0,05</td>
<td>0,05</td>
</tr>
<tr>
<td>Traffic congestion</td>
<td>0,08</td>
<td>1,00</td>
<td>0,43</td>
<td>-0,01</td>
<td>-0,22</td>
<td>-0,21</td>
</tr>
<tr>
<td>Pedestrians comfort</td>
<td>-0,25</td>
<td>0,43</td>
<td>1,00</td>
<td>-0,03</td>
<td>-0,23</td>
<td>-0,54</td>
</tr>
<tr>
<td>Building degradation</td>
<td>-0,13</td>
<td>-0,01</td>
<td>-0,03</td>
<td>1,00</td>
<td>-0,16</td>
<td>0,12</td>
</tr>
<tr>
<td>Parking quantity and quality</td>
<td>-0,05</td>
<td>-0,22</td>
<td>-0,23</td>
<td>-0,16</td>
<td>1,00</td>
<td>0,12</td>
</tr>
<tr>
<td>Land use mixture</td>
<td>0,05</td>
<td>-0,21</td>
<td>-0,54</td>
<td>0,12</td>
<td>0,12</td>
<td>1,00</td>
</tr>
</tbody>
</table>

Although this global indicator analysis gives some valuable information, it was developed a clusters analysis to reinforce the obtained results and to achieve further information from livability indicators.

Fig. 11 – Global indicator results spatialization.

Clusters analysis

After the creation of a global livability indicator, where the behavior of the different indicators was analyzed, it was developed a clusters analysis. The theoretical approach of the clusters analysis is not presented in this article, although different methodologies to measure distance and aggregation criteria were tested.

Only the logical values obtained for the tree analysis were tested as number of cluster groups. The most significant of the number of groups that were tested was three groups, due to the easiness of understanding of the geographical structure results. The results of this analysis are presented in Fig. 12. The zones placed next to roads of a greater traffic hierarchy belong to the same cluster, which is the cluster with lower average results. Another resulting cluster is located in the East and West zone of the borough, having the
best result, due to the higher value obtained in the traffic congestion indicator, pedestrian comfort indicator and accessibility to equipments and leisure spaces indicator. The third cluster represents all intermediate zones that have good values in some indicators and bad values in other indicators, or have a very regular behavior for all of them.

![Fig. 12 – Spatialization of the clusters analysis of the livability indicators for k=3.]

Conclusions

After the developed analysis, some conclusion can be undertaken for the study area:

- The East and West zones of the borough, have better values for the developed indicators than the other zones;
- The zones that are crossed by a higher traffic hierarchy road present worse values for the majority of the indicator, with an exception in the land use mixture indicator.

Due to the low correlation between all the developed indicators, the results obtained for each cell in the different indicators, allow compensation of the low values with other high values. This can be corrected with some different weighting methods for the global indicator, using non linear approach to the problem.

The indicators developed in this study can be used as a decision making tool that will grant an easier acceptance of local citizens, due to its analysis scale and ability to detect local problems that other instruments cannot identify. This kind of indicator should be used previously to a project development (i.e. parking lot implementation) in order to detect the real local impact, and as a monitorization instrument to evaluate the real impact of some equipments or infrastructures.

This methodology should be used also for other city areas after a calibration of the standardization functions for each indicator, which can have some different attributes of the study area used for this article, and develop a integrated analysis as an instrument to solve local problems that can have some impact at the city scale (i.e. reduction of leisure trips using the car).

References

County of Ventura, Planning Division. Livable Communities Program. 1997.