TÉCNICO LISBOA

# The potential of rehabilitation in urban centers using green roofs.

## Application to the city of Lisbon.

Maria João Pires Antunes

**Extended Abstract**

Supervisors: Maria Cristina de Oliveira Matos Silva, PhD, Professor

Inês dos Santos Flores Barbosa Colen, PhD, Professor

July 2015

# 1. Introduction

The high building density and low green spaces density in big cities have bad consequences in air quality and in the inhabitants' life. As verified by Oliveira, et al. (2011), the green spaces in the middle of a dense city have a significant influence in local temperature, even if having reduced dimensions which lead to conclude the necessity of increasing their number in the urban area. One solution for that is greens roofs implementation. This implementation is already common in countries like Canada, United States of America (USA), Switzerland, Germany and Japan (Lawlor, et al., 2006), among others. Although there are some examples of green roofs in Lisbon they are not enough.

Green roofs are building roofs whose coating is a layer soil with vegetation. As main advantages of green roofs implementation, there are (i) the reduction of greenhouse gases emission (Kumar, et al., 2014), (ii) urban heat island, common in urban areas (Kosareo & Ries, 2007, Lawlor, et al., 2006, Shepard, 2010 and Bowler, et al., 2010), (iii) the increasing of $CO_2$ absorption (Shepard, 2010) and (iv) the air quality improvement (Kumar, et al., 2014, Kosareo & Ries, 2007, Lawlor, et al., 2006 and Shepard, 2010). As disadvantage, there is the installation cost associated to green roofs, higher than traditional roofs (Correia Pinto, 2014).

This study proposes a methodology to analyze urban areas keeping in mind the following objectives:

- the choice of indexes to characterize the buildings and their surrounding, with focus on possibilities and need of green roofs implementation, respectively;
- the definition of normalized scale for all the indexes;
- the definition of a ponderation analysis of the indexes in terms of building possibilities and surrounding needs of green roofs implementation;
- the application of the previous two points methodology to the city of Lisbon.

# 2. Evaluation methodology proposal

## 2.1. Adequate indexes to evaluate the green roofs potential

To develop this methodology, it is necessary to think about what are the most important characteristics to evaluate. In this case, the objective is to know the possibility of buildings to support green roofs and the surrounding needs to receive that kind of roof solutions. The city areas where there are higher possibilities and needs are the ones that have higher potential for green roofs implementation. The evaluation has to be objective, so the number of indexes to choose have to be limited and to describe the most important characteristics.

To describe the building characteristics, it is necessary to use the building age ($I_c$), used by Theodoridou, et al. (2012) and Zhang, et al. (2012) to know the construction features, and roof slope

(S), defined by Filogamo, et al. (2014) and Stevanovic (2010) and used to know if special fixation measures are needed. For the surrounding evaluation, three indexes were chosen: coverage index ($I_{cob}$), the ratio between building covered area and the total area of the city area (in percentage), that was defined by Maurer (2013) and Izquierdo, et al. (2008), the green suface index ($I_{sv}$), used by Maurer (2013) and described as the ratio between green area and total area of the city area (in percentage), and the street trees density index ($AA_a$), that corresponds to the ratio between the number of street trees and the total city area size (in units per unit area). There is a relationship between $I_{cob}$ and $I_{sv}$, when one of them is higher the other is lower, although this is not a directly proportional relationship.

## 2.2. Normalized scale definition

The definition of a normalized scale is due to the fact of selected indexes have different types of values that have to be compared. In this way, a scale with five levels is defined and was described on Table 1. The option to associate the lowest potential to the lowest level is based on an existent scale created by Gedge (2010) in which the lowest values correspond to the lowest load capacities.

Table 1 – Normalized scale

| Level | Needs/possibilities |
|---|---|
| 1 | Significantly low |
| 2 | Low |
| 3 | Intermediate |
| 4 | High |
| 5 | Significantly high |

Table 2 presents a proposal of a normalized scale for some of the considered indexes. For $I_c$, the association of younger buildings to the highest possibilities for green roof implementation due to the higher structural capability, and to the roof characteristics provide best conditions for that implementation. The definition of the three lowest levels is made later because it depends on the growth of urban area. This also happens with $AA_a$ because it depends on the dimensions variation of the city areas.

At the index S, the border between sloped and flat roofs (15% (8,5º) (Stevanovic, 2010)) is a reference to define the intervals, so on the intermediate level the interval is from 8,5 to 11º. The lowest slopes are associated to the highest levels due to having best conditions to receive green roofs because special fixation measures are not necessary.

$I_{cob}$ and $I_{sv}$ are indexes with results in percentages, so they are divided in five intervals of 20%. However, once the city areas with major needs of green roof implementation are those which have major building covered area and minor green areas, the highest levels correspond to the highest percentages of $I_{cob}$ and the lowest percentages of $I_{sv}$.

Table 2 – Indexes normalization

| Indexes | | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 |
|---|---|---|---|---|---|---|
| Applicable to the building | $I_c$ (ano) | Depends on the urban area | Depends on the urban area | Depends on the urban area | 1930 – 1960 | > 1960 |
| | S (º) | > 30 | 11 - 30 | 8,5 – 11 | 3 - 8,5 | ≤ 3 |
| Applicable do the surrounding | $I_{cob}$ (%) | ≤ 20 | 20 – 40 | 40 – 60 | 60 – 80 | > 80 |
| | $I_{sv}$ (%) | > 80 | 60 – 80 | 40 – 60 | 20 – 40 | ≤ 20 |
| | $AA_a$ (un/km$^2$) | Depends on the urban area | Depends on the urban area | Depends on the urban area | Depends on the urban area | Depends on the urban area |
| $I_c$ – Building age<br>S – Roof slope | | | $I_{cob}$ – Coverage index<br>$I_{sv}$ – Green surface index<br>$AA_a$ – Street trees density index | | | |

## 2.3. Grouping city areas

It forecasts that the urban area can be divided in a significant number of city areas whose characteristics can be similar between them, affording to create only one major city area. In this way, it joins all the city areas that have three or more indexes with the same level of classification, with exception for special cases. It admits the possibility of two city areas (A and B) that are not adjacent can be joined if they are compatible by the previous criteria and there is another city area (C) between them and compatible with both that joins in that group. Considering the low probability of existing city areas with all the indexes with the same classification, the determination of the other values is made according to the Expression 1:

$$NF = \frac{\sum_{i=1}^{n} A_i \times NI_i}{\sum_{i=1}^{n} A_i} \quad (1)$$

where:

$NF$ – Final level of the city area;

$A_i$ – Area of the initial city area $i$;

$NI_i$ – Initial level city area $i$;

$n$ – Number of initial city areas to join.

## 2.4. Indexes ponderation

The indexes ponderation involves the consideration of several criteria that conducts to the final conclusion. Because of that it is possible to say the analysis method used is similar to Multi-criteria Analysis but in a simpler way because a limited number of combinations is used. This ponderation has two steps, the first one evaluating possibilities of green roof implementation and the second one evaluating needs. The final result is the area with highest potential for the implementation of these roofs.

### 2.4.1. Possibilities poderation in terms of the building

First of all, three ponderation tests are applied and defined on Table 3, considering the indexes $I_c$ and S. After the application of the tests to the several defined city areas, each one is associated to a level per test. Whenever this level is 3 or higher, it considers the city area as selected by the test. Each test can not select more than a defined maximum percentage of urban area. If it selects, it will be excluded. This percentage is defined for each urban area according to the objectives. After that, the city areas with more possibilities to green roof implementation are chosen, considering a city area as selected when 50%, or more, of not excluded tests selects it.

Table 3 – Possibilities weighing tests

| Tests | Weights (%) | |
|---|---|---|
| | $I_c$ | S |
| A | 50 | 50 |
| B | 25 | 75 |
| C | 75 | 25 |

$I_c$ – Building age
S – Roof slope

### 2.4.2. Needs ponderation in terms of surrounding

This ponderation process is similar to the previous one, but there are some small differences. First, the tests application area is the selected area on the previous step instead of the total area. Second, the maximum percentage of selected area by each test should be lower in this step. Considering the indexes $I_{cob}$, $I_{sv}$ and $AA_a$, seven tests with different weight combinations were defined. The tests considered are presented on Table 4.

Table 4 – Needs ponderation tests

| Tests | Weights (%) | | |
|---|---|---|---|
| | $I_{cob}$ | $I_{sv}$ | $AA_a$ |
| A | 33,3 | 33,3 | 33,3 |
| B | 60 | 20 | 20 |
| C | 20 | 60 | 20 |
| D | 20 | 20 | 60 |
| E | 40 | 40 | 20 |
| F | 20 | 40 | 40 |
| G | 40 | 20 | 40 |

$I_{cob}$ – Coverage index
$I_{sv}$ – Green surface index
$AA_a$ – Street trees density index

One more time, it considers a city area as selected when it presents a level of 3 or higher. After the elimination of the tests with a percentage of selected area higher that the defined, it chooses the city areas with highest needs to receive green roofs. It selects a city area when 50%, or more, of not excluded tests select it. The resultant area is the city area with higher possibilities and needs of green roofs implementation which means the area with higher potential.

## 3. Methodology application in Lisbon

In order to test the proposed methodology, it is applied to the city of Lisbon. For that, it resorts to information given by *Câmara Municipal de Lisboa* (*CML*) through *shapefiles*, used in program *ArcGis* of the company *ESRI*, coordinating information in maps with numerical data. Some of that information was also collected from the website of *Instituto Nacional de Estatística* (*INE*) and observed in the field.

On Figure 1, is presented the flowchart that summarizes the presented methodology.

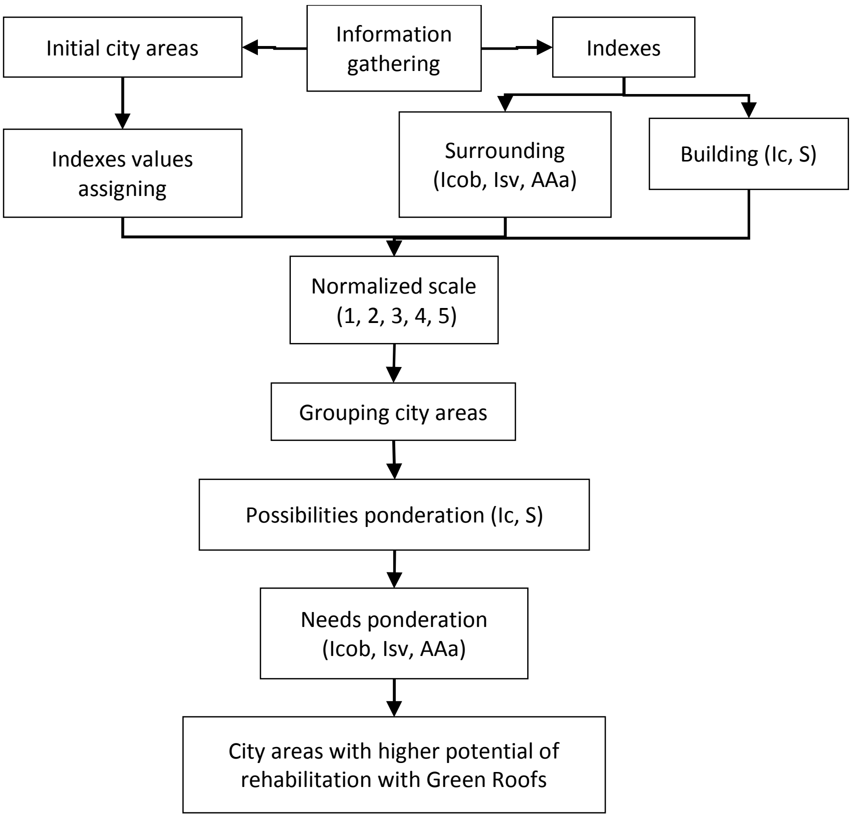



Figure 1 – Flowchart of the methodology process

First of all, it is important to divide the urban area in smaller city areas. It resorts to the parishes distribution due to the collected information being organized in this division. So Lisbon is divided in twenty four city areas.

## 3.1. Normalized scale definition

First, it is important to star by completing Table 2 with the definition of the indexes intervals which are not normalized yet. This way, for $I_c$, three intervals are defined which correspond to constructive periods with specific characteristics as can be seen on *Laboratório Nacional de Engenharia Civil* website (LNEC, 2005). Level 1 is associated to the period before 1755, year which was marked by the earthquake and tsunami on 1st November, level 2 is associated to the period from 1755 to 1880 with the *Pombal* construction and level 3 is associated to the period between 1880 and 1930 associated to the *Gaioleiro* period.

In Lisbon, the index $AA_a$ has a minimum of 14 un/km$^2$ and a maximum of 1 448 un/km$^2$. Knowing these values, five equal intervals are created in order to include all the existent values. In this case, the highest levels are associated to the lowest values, verifying higher needs of green roofs implementation when the street trees density is lower. This information is on Table 5.

Table 5 – Indexes normalization (complete)

| Indexes | | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 |
|---|---|---|---|---|---|---|
| Applicable to the building | $I_c$ | ≤ 1755 | 1755 - 1880 | 1880 - 1930 | 1930 – 1960 | > 1960 |
| | S (º) | > 30 | 20 - 30 | 15 – 20 | 5 - 15 | ≤ 5 |
| Applicable to the surrounding | $I_{cob}$ (%) | ≤ 20 | 20 – 40 | 40 – 60 | 60 – 80 | > 80 |
| | $I_{sv}$ (%) | > 80 | 60 – 80 | 40 – 60 | 20 – 40 | ≤ 20 |
| | $AA_a$ (un/km$^2$) | > 1 200 | 900 – 1 200 | 600 - 900 | 300 - 600 | ≤ 300 |

$I_c$ – Building age
S – Roof slope
$I_{cob}$ – Coverage index
$I_{sv}$ – Green surface index
$AA_a$ – Street trees density index

## 3.2. Levels attribution and grouping city areas

### 3.2.1. Building applicable indexes

- Building age ($I_c$) – the information from *INE* website is crossed with the information from *Lisboa Interactiva* platform by *CML*. Adjustments are made on defined intervals at the normalized scale and those ones that are displayed on data. This data is from 2011 when the parishes had a different distribution, so this change should also be considered and the information has to be adapted to the new distribution used throughout this work.
- Roof slope (S) – the attribution of levels is associated to the building construction year and field observation. This way, it is considered that, until the year of 1930, all the buildings have roofs with slope over 30º and the buildings constructed after that year are observed in field.

This happens because, since the appearance of reinforced concrete, the roof structure has changed a lot and its slopes has reduced.

### 3.2.2. Surrounding applicable indexes

All the surrounding applicable indexes are determined by expressions. After their determination, it proceeds to the verification of the intervals where the values are inserted and which levels they belong to. There are some details that are important to mention on green surface index ($I_{sv}$) and street trees density index ($AA_a$).

- Green surface index ($I_{sv}$) – in some parishes, the values are discrepant when comparing the maps. For example, in Alcântara and Benfica, the $I_{sv}$ is more than 100%. It means that it is important to make corrections in five city areas. The results are on Table 6.

Table 6 – Correction of $I_{sv}$ data

| Parishes | Initial $I_{sv}$ | Final $I_{sv}$ |
|---|---|---|
| Ajuda | 99,05 % | 65 % |
| Alcântara | 232,62 % | 80 % |
| Benfica | 117,60 % | 85 % |
| Campolide | 78,90 % | 50 % |
| São Domingos de Benfica | 80,98 % | 65 % |

- Street trees density index ($AA_a$) – there is some discrepant information on street trees counting. In some city areas, the use type of the flowerbeds is not defined and there is less than 10 trees or even 0 trees. Considering that the flowerbeds are occupied by trees when that information is not explicit the numbers start to make sense, so this situation is adopted.

### 3.2.3. Grouping city areas

To proceed to the grouping city areas, the level attribution in all the city areas and indexes has to be known. That attribution is shown on Table 7.

According to the defined criteria on methodology, it joins the considered compatible city areas. After the grouping, the initial different indexes are recalculated for the new city areas of study. The results are shown on Table 8.

## 3.3. Indexes ponderation

### 3.3.1. Possibilities ponderation in terms of the building

On this first step, the tests are applied to all the city areas. The results of that application are presented at Table 9. Here, the maximum percentage of selected area is defined as 80%. Looking at the Table 9, it is easy to see that the test C is automatically excluded. Considering that a selected city area has 50%, or more, of not excluded tests selecting it, the city areas with higher possibilities to receive green roofs are Baixa Este, Beato, Belém, Benfica, Centro, Centro Norte, Lumiar, Oriente/Norte e Parque das Nações. Figure 2 shows the map with this selection.

Table 7 – Levels attribution on the several indexes

| Parishes | Building Possibilities | | Surrounding Needs | | | Parishes | Building Possibilities | | Surrounding Needs | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $I_c$ | S | $I_{cob}$ | $I_{sv}$ | $AA_a$ | | $I_c$ | S | $I_{cob}$ | $I_{sv}$ | $AA_a$ |
| Ajuda | 4 | 2 | 1 | 2 | 3 | Estrela | 3 | 1 | 2 | 5 | 1 |
| Alcântara | 3 | 1 | 1 | 2 | 2 | Lumiar | 5 | 5 | 1 | 3 | 4 |
| Alvalade | 4 | 2 | 2 | 3 | 4 | Marvila | 5 | 5 | 1 | 4 | 4 |
| Areeiro | 4 | 2 | 2 | 4 | 3 | Misericórdia | 1 | 1 | 3 | 5 | 4 |
| Arroios | 3 | 1 | 3 | 5 | 2 | Olivais | 5 | 3 | 1 | 4 | 3 |
| Av. Novas | 5 | 2 | 2 | 4 | 1 | Pq. Nações | 5 | 5 | 2 | 5 | 1 |
| Beato | 5 | 2 | 2 | 5 | 5 | P. França | 4 | 2 | 2 | 5 | 3 |
| Belém | 5 | 3 | 1 | 3 | 4 | Sta. Clara | 5 | 2 | 1 | 3 | 5 |
| Benfica | 5 | 5 | 1 | 1 | 1 | Sta. Mª Maior | 2 | 1 | 3 | 5 | 4 |
| Cp. Ourique | 3 | 1 | 2 | 3 | 4 | Sto. António | 4 | 2 | 3 | 5 | 1 |
| Campolide | 4 | 2 | 1 | 3 | 4 | S. D. de Benfica | 5 | 2 | 1 | 3 | 4 |
| Carnide | 4 | 2 | 1 | 2 | 4 | S. Vicente | 4 | 1 | 2 | 5 | 4 |

$I_c$ – Building age;
S – Roof slope;
$I_{cob}$ – Coverage index;
$I_{sv}$ – Green surface index;
$AA_a$ – Street trees density index.

Table 8 – Indexes attribution in the new city areas

| City areas | Building Possibilities | | Surrounding Needs | | | City areas | Building Possibilities | | Surrounding Needs | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $I_c$ | S | $I_{cob}$ | $I_{sv}$ | $AA_a$ | | $I_c$ | S | $I_{cob}$ | $I_{sv}$ | $AA_a$ |
| Baixa | 2 | 1 | 3 | 5 | 4 | Centro Norte | 4 | 2 | 1 | 3 | 4 |
| Baixa Este | 4 | 2 | 2 | 5 | 3 | Centro Sul | 3 | 1 | 3 | 5 | 2 |
| Beato | 5 | 2 | 2 | 5 | 5 | Estrela | 3 | 1 | 2 | 5 | 1 |
| Belém | 5 | 3 | 1 | 3 | 4 | Lumiar | 5 | 5 | 1 | 2 | 4 |
| Benfica | 5 | 5 | 1 | 1 | 1 | Monsanto Sul | 3 | 1 | 1 | 2 | 2 |
| Cp. Ourique | 3 | 1 | 2 | 3 | 4 | Oriente/Norte | 5 | 4 | 1 | 4 | 4 |
| Centro | 5 | 2 | 2 | 4 | 2 | Pq. Nações | 5 | 5 | 2 | 5 | 1 |

$I_c$ – Building age;
S – Roof slope;
$I_{cob}$ – Coverage index;
$I_{sv}$ – Green surface index;
$AA_a$ – Street trees density index.

Baixa – Misericórdia e Santa Maria Maior;
Baixa Este – Penha de França e São Vicente;
Centro – Areeiro e Avenidas Novas;
Centro Sul – Arroios e Santo António;
Centro Norte – Alvalade, Campolide, Carnide e São Domingos de Benfica;
Monsanto Sul – Ajuda e Alcântara;
Oriente/Norte – Marvila, Olivais e Santa Clara.

### 3.3.2. Needs ponderation in terms of the surrounding

In this second step the ponderation of the implementation need is made. The maximum percentage of selected area in this step is 70%, less than the first step. Looking at the Table 10, the tests A, C and F are excluded. The city areas with 50% or more of not excluded tests selecting them are Baixa Este, Beato, Belém, Centro Norte and Oriente/Norte. Once this selected area is the area with higher possibilities and need of green roof implementation, it is also the area with higher potential for that implementation. The map with this selection is shown on Figure 3.

Table 9 – Possibilities ponderation tests

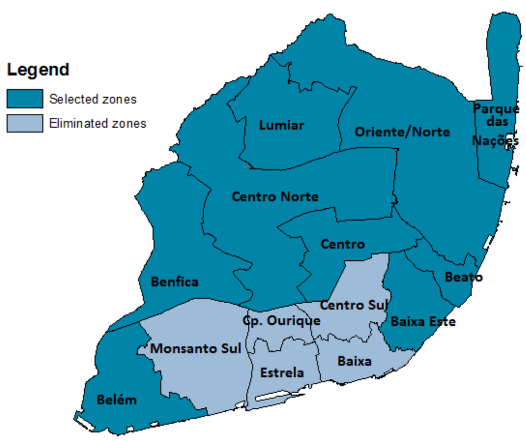
| City areas | Indexes | | Tests | | |
|---|---|---|---|---|---|
| | $I_c$ | S | A | B | C |
| Baixa | 2 | 1 | 2 | 1 | 2 |
| Baixa Este | 4 | 2 | 3 | 3 | 4 |
| Beato | 5 | 2 | 4 | 3 | 4 |
| Belém | 5 | 3 | 4 | 4 | 5 |
| Benfica | 5 | 5 | 5 | 5 | 5 |
| Campo de Ourique | 3 | 1 | 2 | 2 | 3 |
| Centro | 5 | 2 | 4 | 3 | 4 |
| Centro Norte | 4 | 2 | 3 | 3 | 4 |
| Centro Sul | 3 | 1 | 2 | 2 | 3 |
| Estrela | 3 | 1 | 2 | 2 | 3 |
| Lumiar | 5 | 5 | 5 | 5 | 5 |
| Monsanto Sul | 3 | 1 | 2 | 2 | 3 |
| Oriente/Norte | 5 | 4 | 5 | 4 | 5 |
| Parque das Nações | 5 | 5 | 5 | 5 | 5 |
| Selected area ($km^2$) | | | 68,00 | 64,55 | 83,27 |
| Percentage (%) | | | 79,2 | 75,2 | 97,0 |
| $I_c$ – Building age; | | | S – Roof slope; | | |
| Baixa – Misericórdia e Sta. Mª Maior; Baixa Este – P. França e S. Vicente; Centro – Areeiro e Av. Novas; Centro Norte – Alvalade, Campolide, Carnide e S. D. de Benfica; | | | Centro Sul – Arroios e Sto. António; Monsanto Sul – Ajuda e Alcântara; Oriente/Norte – Marvila, Olivais e Sta. Clara. | | |

## 4. Conclusions

One way to reverse the actual situation in the cities with high building density and lower amount of green spaces is the roof rehabilitation through green roofs. The developed methodology evaluates the buildings and their surrounding characteristics. The research of several indexes already used by other authors provided the knowledge of different perspectives that assisted this work. Some indexes were selected to be used in this study: building age ($I_c$) and roof slope (S), applied to the building, the coverage index ($I_{cob}$), green surface index ($I_{sv}$) and street trees density index ($AA_a$), applied to the surrounding. A definition of a normalized scale is important to allow the comparison of all the indexes and essential to their ponderation, so a scale with five levels was defined, where the level 1 corresponds to the lowest possibilities/needs/potential of green roofs implementation.

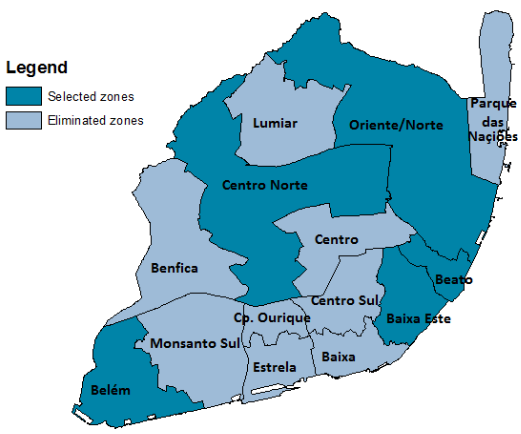
Table 10 – Necessities ponderation tests

| City areas | Indexes | | | Tests | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $I_{cob}$ | $I_{sv}$ | $AA_a$ | A | B | C | D | E | F | G |
| Baixa Este | 2 | 5 | 3 | 3 | 3 | 4 | 3 | 3 | 4 | 3 |
| Beato | 2 | 5 | 5 | 4 | 3 | 4 | 4 | 4 | 4 | 4 |
| Belém | 1 | 3 | 4 | 3 | 2 | 3 | 3 | 2 | 3 | 3 |
| Benfica | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Centro | 2 | 4 | 2 | 3 | 2 | 3 | 2 | 3 | 3 | 2 |
| Centro Norte | 1 | 3 | 4 | 3 | 2 | 3 | 3 | 2 | 3 | 3 |
| Lumiar | 1 | 2 | 4 | 2 | 2 | 2 | 3 | 2 | 3 | 2 |
| Oriente/Norte | 1 | 4 | 4 | 3 | 2 | 3 | 3 | 3 | 3 | 3 |
| Parque das Nações | 2 | 5 | 1 | 3 | 2 | 4 | 2 | 3 | 3 | 2 |
| Selected area (km$^2$) | | | | 64,00 | 13,02 | 64,00 | 58,97 | 42,29 | 70,57 | 52,40 |
| Percentage (%) | | | | 74,5 | 15,2 | 74,5 | 68,7 | 49,2 | 82,2 | 61,0 |
| $I_{cob}$ – Coverage index; | | $I_{sv}$ – Green surface index; | | | | $AA_a$ – Street trees density index. | | | | |
| Baixa Este – P. França e S. Vicente; Centro – Areeiro e Av. Novas; | | | | Centro Norte – Alvalade, Campolide, Carnide e S. D. de Benfica; Oriente/Norte – Marvila, Olivais e Sta. Clara. | | | | | | |




Baixa – Misericórdia e Sta. Mª Maior;
Baixa Este – P. França e S. Vicente;
Centro Norte – Alvalade, Campolide, Carnide e S. D. de Benfica;

Figure 2 – Selection of the City areas with higher possibilities to green roofs implementation




Centro – Areeiro e Av. Novas;
Centro Sul – Arroios e Sto. António;
Monsanto Sul – Ajuda e Alcântara;
Oriente/Norte – Marvila, Olivais e Sta. Clara.

Figure 3 – Selection of the City areas with higher potential of green roof implementation

The ponderation process implies two steps, possibilities and needs. After these two ponderation steps, it was concluded the city areas with higher potential for green roof implementation are Baixa Este, Beato, Belém, Centro Norte and Oriente/Norte. It corresponds to a selected area of 44,5 km$^2$, approximately to 52% of total area of Lisbon (85,9 km$^2$). These results are conciliated with the limitations initially defined where the selected area can not be higher that 70%. The selected city areas have younger buildings, a few green spaces and major building density, as expected. There is only a small doubt with Baixa Este. It is an older area with older buildings which could hinder the implementation of this type of roofs.

It calls attention for the fact of the building type index (E) had been excluded for the evaluation of potential. However, this factor can create a starting point to the green roof implementation. In other words, the public buildings can be the first ones to be intervened to receive green roofs, so as to serve as example and encourage this practice, once done their management is the responsibility of governments and public organisms.

## 5. Bibliography


Bowler, D. E., Buyung-Ali, L., Knight, T. M. & Pullin, A. S., 2010. Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning,* Volume 97, pp. 147 - 155.

Correia Pinto, C. I., 2014. *Introdução às coberturas verdes,* Porto: Faculdade de Engenharia da Universidade do Porto.

Filogamo, L., Peri, G., Rizzo, G. & Giaccone, A., 2014. On the classification of large residential buildings stocks by sample typologies for energy planning purposes. *Applied Energy.*

Gedge, D., 2010. *Green Roofs in The Inner London Urban Core.* London: European Federation of Green Roofs Association - EFB.

Izquierdo, S., Rodrigues, M. & Fueyo, N., 2008. A meythod for estimating the geographical distribution of the available roof surface area for large-scale photovoltaic evergy-potential evaluations. *Solar Energy,* Volume 82, pp. 929 - 939.

Kosareo, L. & Ries, R., 2007. Comparative environmental lofe cycle assessment of green roofs. *Building and Environment,* Volume 42, pp. 2606 - 2613.

Kumar, A., Chani, D. P. S. & Deoliya, D. R., 2014. Green Retrofit Potential in Existing research Laboratories and Demonstration of energy Effcient and Sustainable Technologies: Case study. *Intrernational Journal of Science, Engineering and Technology Reseach, 3(3),* pp. 400-405.

Laboratório Nacional de Engenharia Civil, 2005. *LNEC.* [Online]
Available at: http://www-ext.lnec.pt/LNEC/DE/NESDE/divulgacao/evol_tipol.html
[Acessed on 11 June 2014].

Lawlor, G., Currie, B. A., Doshi, H. & Wieditz, I., 2006. *A Resource Manual for Municipal policy Makers.* s.l.:Canada Mortage and Housing Corporation (CMHC).

Maurer, E., 2013. *Green Roof City Linz.* Linz: Linz Verandert.

Oliveira, S., Andrade, H. & Vaz, T., 2011. The cooling effect of green spaces as a contribution to the mitigation of urban heat: A case study in Lisbon.. *Building and Environment,* pp. 20186 - 20194.

Shepard, N., 2010. *Green Roof Incentives - A 2010 Resource Guide.* United States of America (USA): DC Grennworks.

Stevanovic, J., 2010. *Possibility of bringing roof gardens in Banovo BRDO in Belgrade.* Belgrade: Faculty of Forestry.

Theodoridou, I. et al., 2012. Assessment of retrofitting measures and solar systems' potential in urban areas using Geograpfical information Systems: Application to a Mediterranean city. *renewable and Sustainable Energy Reviews,* Volume 16, pp. 6239 - 6261.

Zhang, X., Shen, L., Tam, V. & Lee, W. W. Y., 2012. Barriers to implement extensive green roof system: AHong Kong study. *Renewable and Sustainable Energy Reviews,* Volume 16, pp. 314 - 319.