Study of the of the concept of community buildings and its importance for Land Use Efficiency

José Amarilio Barbosa
University of Minho, School of Engineering, Department of Civil Engineering, Guimarães, Portugal
jabarbosa@civil.uminho.pt

Catarina Araújo
University of Minho, School of Engineering, Department of Civil Engineering, Guimarães, Portugal
cba@civil.uminho.pt

Luís Bragança
University of Minho, School of Engineering, Department of Civil Engineering, Guimarães, Portugal
braganca@civil.uminho.pt

Ricardo Mateus
University of Minho, School of Engineering, Department of Civil Engineering, Guimarães, Portugal
ricardomateus@civil.uminho.pt

ABSTRACT: Nowadays cities are facing several environmental problems due to the population migration to urban areas, which is causing urban sprawl. This way, it is very important to define solutions to improve Land Use Efficiency (LUE). This article proposes the use of community buildings features as a solution to increase land use efficiency. Community buildings consider the design of shared building spaces to reduce the floor area of buildings. This work tests the performance of some case-study buildings regarding LUE to analyse its possible pros and cons. A quantifiable method is used to assess buildings' LUE, which considers the number of occupants, the gross floor area, the functional area, the implantation area and the allotment area. Buildings with higher values for this index have reduced environmental impacts because they use less construction materials, produce less construction and demolition wastes and require less energy for building operation. The results showed that the use of community building features can increase Land Use Efficiency of buildings.

Keywords: land use efficiency; building performance; sustainable buildings; community buildings

1 INTRODUCTION

Nowadays societies are responsible for many environmental and societal problems resulting from a mixture of population growth, the movement to urban areas and the increase of consumerism and of the standard of living of the population. With a world population of about 7.3 billion persons, the UN predicts that nowadays, about 3.8 billion already live in cities. By the year 2030, these figures are predicted to evolve to 5 billion people living in cities out of 8.4 billion (United Nations, 2014) (Figure 1).

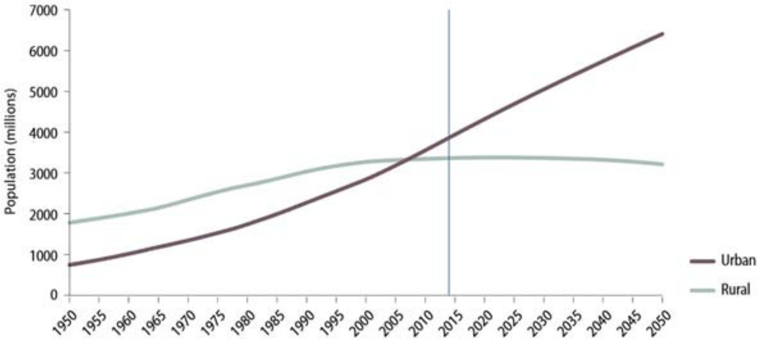


Figure 1. World population growth in urban and rural environments (United Nations, 2014).

The fast increase of population living in urban environments in combination with poor urban planning has been causing low land use efficiency and a growing urban sprawl, which is common in most cities of the world (Arribas-Bel et al., 2010, Halleux et al., 2012, Amado and Ribeiro, 2011, Habibi and Asadi, 2011). Low density areas cause unnecessary land use and destruction of natural environments, having more environmental impacts than high density areas (Norman et al., 2006). This demonstrates the need for the development of solutions to increase the land use efficiency.

To assess buildings impact on land use, it is necessary to be able to quantify the land use efficiency of a building in a quantitative approach. In a previous work from the authors, a method to quantify buildings' impact land use efficiency was developed considering population and construction density (Barbosa et al., 2014). In that work, the calculation method was based in a single index using the following variables: functional area; number of occupants; gross floor area, building footprint and the allotment area (Barbosa et al., 2014). The trend to improve the land use efficiency of buildings is to design buildings with good values for the spatial efficiency (ratio between functional area and gross floor area) and with high density (in construction and in population). Therefore, buildings with optimal values of LUE provide reduced environmental impacts by reducing the need for construction materials, the production of construction and demolition wastes and the energy consumption for building operation.

The argument of this work is that residential buildings with features of community buildings (such as shared spaces for some building services such as kitchens, bathrooms or others) can improve buildings land use efficiency. This is because the features of community buildings allow reducing the area of the buildings, maintaining functionality and number of inhabitants, increasing efficiency.

There are not much examples of community buildings serving as semi-permanent residences. They are found mainly working as university residences. Hotels and other types of touristic buildings can also fit in the category of community buildings. There is an obvious possibility that the features of community buildings bring social and behavior issues due to the reduction of the habitable space and to the very question of shared spaces. Although this work will try to address these issues, the objective of this work is solely to quantitatively assess the building environmental performance regarding land use.

For that, a quantitative method previously developed will be used to assess two case study buildings that serve as university residences. The buildings are part of the same complex, but one uses conventional design and the other has some features of community buildings. The difference in the performance of these two buildings is expected to be related to the expected difference between conventional residential buildings and those that would be designed using the features of community buildings.

2 STATE OF THE ART REVIEW

2.1 Land use efficiency and urban sprawl

The pursuit for land use efficiency is related to how buildings and urban areas occupy the land, promoting the use of the minimum areas possible and at the same time maximize the use of these areas. Urban areas with high efficiency in land use prevent the expansion of cities, often denominated as city sprawl. Urban sprawl is a phenomenon verified in most cities in the world. In Figure 2 are shown examples from the some cities around the world.

Figure 2. Examples of poor urban planning leading to urban sprawl in the cities of Chicago (Wikipedia, 2012) and Mexico city (http://www.dailygalaxy.com, 2012).

In the last 15 to 20 years of the 20th century, the occupancy of land increased more than the population growth would have justified (Liu et al., 2003), causing an increase in the built area per capita (de Wilde and van den Dobbelsteen, 2004, van den Dobbelsteen and de Wilde, 2004). As the world population grows, areas available for new buildings are scarcer. New construction tends to expand the cities by replacing forests and agricultural areas, destructing natural habitats and affecting biodiversity (Pauleit and Duhme, 2000). The uncontrolled expansion of cities also reduces the soil capacity to absorb rainwater and increases the cases of floods and soil erosion. Moreover, urban sprawl is also related to an increase in the distance between city functional areas and in consequence implies the necessity for more infrastructures and increased traffic congestion (Mateus, 2010, Mateus and Bragança, 2009, Mateus and Bragança, 2011).

Nevertheless, the impacts of urban sprawl are not consensual among different stakeholders and even between researchers from different disciplines. Some authors focus in social aspects such as inequality or stratification, while others focus in economic aspects and others identify the potential environmental threats (Arribas-Bel et al., 2010). However, for the sake of sustainability, the setup of land use must be optimised considering all aspects simultaneously (de Wilde and van den Dobbelsteen, 2004, van den Dobbelsteen and de Wilde, 2004).

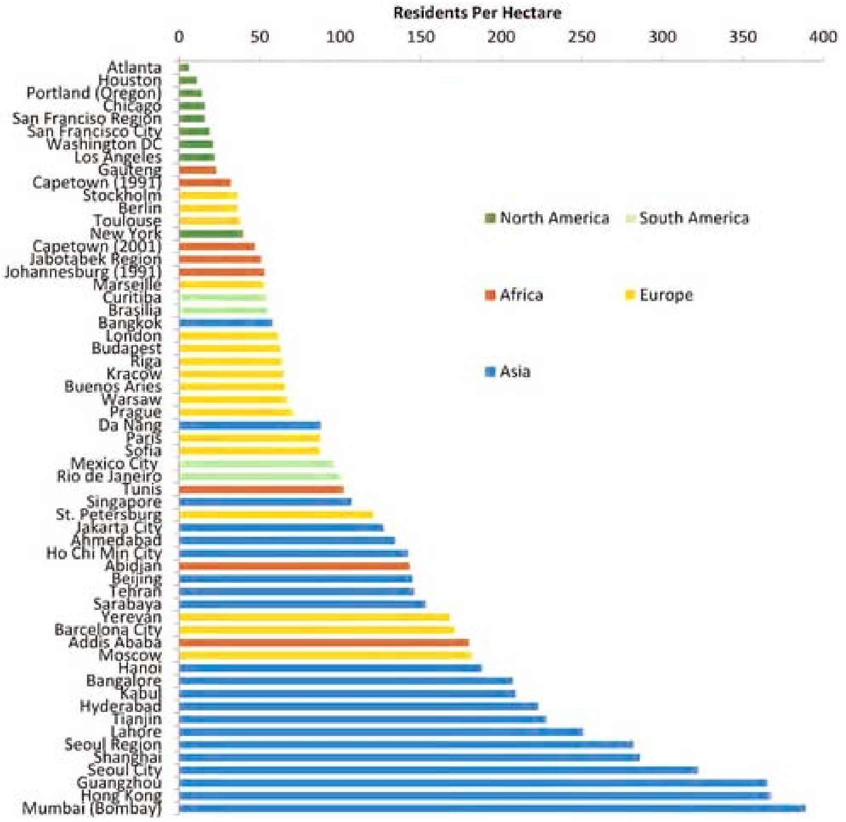


Figure 3. Population density in several world cities (Badger, 2004).

2.2 Implications of building design for land use efficiency

It is almost common sense that building design is important for land use efficiency. An urban area solely with low density buildings like single family houses will need a bigger amount of land to accommodate the same number of inhabitants than an urban area with higher density buildings such a tall buildings. But for similar buildings, the comparison is not that simple. Nevertheless, it is understandable that buildings with higher areas per occupant will make urban areas require more land. Also the amount of construction area in comparison to the allotment area of each building is important. Allotments with big empty areas are underused and make the urban areas need more land for other buildings. Consequently, buildings can have different performance regarding land use based on their design and density. This way, it is very important to be able to evaluate the buildings impact on land use.

To be able to measure the importance of buildings design for land use efficiency, it is firstly necessary to be able to quantify the buildings impact on land use. In the work of Barbosa et al., an index was developed for the assessment of Land Use Efficiency of buildings (Barbosa et al., 2014). The calculation method and the definitions of the variables are described below.

$$LUE = \frac{FA \times OC}{GFA \times IA \times AA} \quad (1)$$

- Gross Floor Area (GFA): It is the area of the total surface of the building, measured by the external perimeter of exterior walls and includes balconies.
- Functional Area (FA): It is the area of all compartments of the building, measured by the internal perimeter of external walls, not including internal walls, ducts, vestibules, interior corridors, bathrooms, storage areas, other compartments of similar function and closets in the walls.
- Allotment Area (AA): Area of terrain, resulting from an allotment operation approved under

the current legislation.

- Implantation Area or Deployment Area (IA): Area resulting from vertical projection of the building in a horizontal plan, measured by the external perimeter of exterior walls including basements and attachments, excluding balconies, parapets, peaks, eaves and porches.
- Number of Occupants (OC): Predicted number of occupants of the building.

This index indicates that buildings have better performance with higher values for functional area and the number of occupants and with lower values for the gross floor area, the implantation area and the allotment area. Consequently, land use efficiency is improved with high construction density and population density.

It is expected that the implementation of community building features in nowadays buildings would have a positive influence on land use efficiency regarding this calculation method. This is because the use of shared spaces would reduce the size of individual apartments, reducing the gross floor area (maintaining the same relation with the functional area) and the implantation area of the buildings.

2.3 Definition of community buildings features

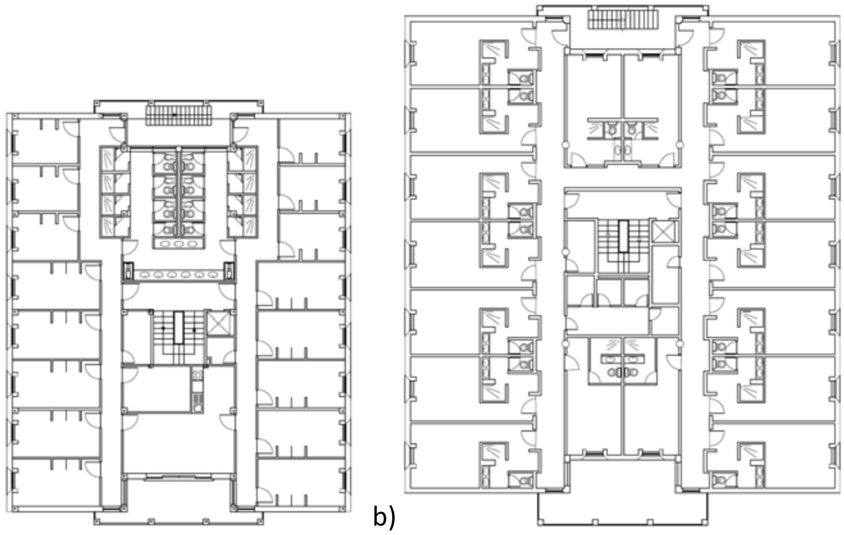
Community buildings are a new concept of residential buildings developed in this work, in which some parts of the buildings are common for a group of apartments. The term “community” was chosen because some studies show that public spaces can improve the sense of community by the nearby inhabitants (Francis et al., 2012), even though these studies were not aimed at public spaces inside buildings. The main characteristic of these buildings is that the use of shared or common compartments such as bathrooms, kitchens or living rooms, allow reducing the area of each individual apartment since these do not need to have individual compartment for the same purpose. It is expected that using these features, it is possible to reduce substantially the area of buildings. A deep research in the literature for examples of buildings that may have such features showed that only students’ residences and touristic buildings share these features. This shows a new potential area for scientific research about the possibility to use some of these features in residential buildings in order to reduce environmental impacts.

3 RESULTS AND DISCUSSION

To test the argument that community buildings features can increase Land Use Efficiency, this work analyses a case-study building that has some features such as shared kitchen and bathrooms for all apartments of the same floor (Building G1). The building is a 5 floors students’ residence which is part of the students’ residences complex of University of Minho, in Guimarães (Figure 4). The area of each apartment of this building is very small when compared to the area of apartments in conventional residential buildings, so it would be unreasonable and inaccurate to compare this building to conventional residential buildings.

Figure 4. Photo of the case study buildings complex (Serviços Acção Social, 2014).

Nevertheless, next to this building, there is another very similar building (in the same complex) but using a more conventional design, in which each apartment has its own bathroom and a small kitchen (Building G2). This second building has also 5 floors and also uses much less area for each apartment when compared to conventional buildings. In the absence of conventionally sized community buildings to be compared to conventional residential buildings, the comparison of results between these two buildings will give insights about the difference between the performance of a conventional residential building and a residential building using community building features. The designs of both buildings are presented in Figure 5 and the results from the assessment of each building are presented in Table 1.



a) b)

Figure 5. Floor design of students' residence buildings in the same scale; a) "Building G1" using some community buildings features; b) "Building G2" using a conventional design.

Table 1. Calculation data from both buildings.

Building G1	Building G2
AA: 1146 m^2	AA: 1723 m^2
IA: 410 m^2	IA: 616 m^2
GFA: 2051 m^2	GFA: 3082 m^2
FA: 1319 m^2	FA: 2010 m^2
OC: 125 oc	OC: 160 oc
LUE = 17,1 E^{-05} oc/m^4	LUE = 9,83 E^{-05} oc/m^4

It is possible to conclude that the design of building G1, has a better performance in land use than building G2. When compared to building G2, building G1 has 33% less gross floor area (and implantation area), while having only 22% less occupants. However, both buildings show a similar relation between the functional area and the gross floor area (known as spatial efficiency). The values of LUE calculated for both buildings show clearly that building G1 (LUE = 17.1 E^{-05} oc/m^4) has a better performance (around 74%) than building G2 (LUE = 9.83 E^{-05} oc/m^4). Considering that both buildings have the same function and a similar size, these results indicate that community buildings features may improve the buildings impacts on land use and prevent urban sprawl. Here we consider only environmental impacts regarding land use efficiency, not comfort or other social issues.

As expected, the results obtained from the assessment of these buildings provided higher values when compared to similar buildings due to the small areas for each apartment. In a previous work, the assessment of two conventional buildings provided values of LUE between 2.7 E^{-05} and 3.3 E^{-05} (Barbosa et al., 2014), while the values obtained for these two case studies are in average four to five times higher.

The main issue regarding community buildings is the possible discomfort due to the reduction of the habitable space and due to the loss of privacy in the shared spaces. It is still necessary to perform behavioural studies and questionnaires, real size tests and interviews to study the response of building occupants to this new concept of buildings. Community buildings features are easy to implement in new construction, but in existing buildings there is the need for rehabilitation. Considering the lack of flexibility of nowadays conventional buildings, it is predicted that these features may require considerable retrofit operations. This may be another issue in the implementation of these strategies. However, this study focuses only in proving the argument that it is possible to improve land use using community buildings features.

4 CONCLUSIONS

The results obtained by the assessment of the case study buildings give insights about the expected performance regarding LUE of residential buildings if community building features were used. The results propose an improvement of around 74%. The performance improvement is considerable not only regarding Land Use Efficiency, but also regarding the materials consumption. Considering the reduction in the building gross floor area needed for the same number of occupants and the overall weight reduction of the building, the structural elements could also be reduced. Consequently, the initial costs of the building would be much less. Moreover, the costs for building operation could also decrease because the reduced building volume would require less energy for acclimatization.

The main obstacles for the implementation of community buildings are comfort issues and difficulties in the adaptation of existing buildings. However, the objective of this work solely to analyze quantitatively the impacts of community buildings features in land use and propose a design alternative that may increase the sustainability of the built environment.

The superior environmental performance of community buildings considering land use (and other benefits) presents an interesting alternative to the conventional practices in construction that is worth investigation and further analysis. Mainly when considered the progressive increase of population living in cities and the consequent increase in urban sprawl that may be predicted in the next decades. This work provides a possible answer to the growing necessity of solutions to reduce the environmental impacts of buildings and urban areas.

REFERENCES

Amado, M. P. & Ribeiro, M. R. Urban Sprawl promoted through Master Planning. World Congress of Sustainable Building, 2011 Helsinki, Finland. SB11,

Arribas-Bel, D., Nijkamp, P. & Scholten, H. 2010. Multidimensional urban sprawl in Europe: A self-organizing map approach. *Computers, Environment and Urban Systems,* 35**,** 263-275.

Badger, E. 2004. *The spatial organization of cities: Deliberate outcome or unforeseen consequence?* [Online]. Available: http://alainbertaud.com/].

Barbosa, J., Bragança, L. & Mateus, R. 2014. Assessment of Land Use Efficiency Using BSA Tools: Development of a New Index. *Journal of Urban Planning and Development,* 0**,** 04014020.

De Wilde, S. & Van Den Dobbelsteen, A. 2004. Space use optimisation and sustainability - environmental comparison of international cases. *Journal of Environmental Management,* 73**,** 91-101.

Francis, J., Giles-Corti, B., Wood, L. & Knuiman, M. 2012. Creating sense of community: The role of public space. *Journal of Environmental Psychology,* 32**,** 401-409.

Habibi, S. & Asadi, N. 2011. Causes, Results and Methods of Controlling Urban Sprawl. *Procedia Engineering,* 21**,** 133-141.

Halleux, J.-M., Marcinczak, S. & Van Der Krabben, E. 2012. The adaptive efficiency of land use planning measured by the control of urban sprawl. The cases of the Netherlands, Belgium and Poland. *Land Use Policy,* 29**,** 887-898.

Http://Www.Dailygalaxy.Com. 2012. *EcoAlert: Urban Sprawl! --Welcome to the 'Anthropocene Epoch'* [Online]. Available: http://www.dailygalaxy.com].

Liu, J., Daily, G. C., Ehrlich, P. R. & Luck, G. W. 2003. Effects of household dynamics on resource consumption and biodiversity. *Nature,* 421.

Mateus, R. 2010. *Avaliação da Sustentabilidade da Construção - Propostas para o Desenvolvimento de Edifícios Sustentáveis.* PhD, University of Minho, Guimarães.

Mateus, R. & Bragança, L. (eds.) 2009. *Guia de Avaliação SBTool PT-H*: Associação iiSBE Portugal.

Mateus, R. & Bragança, L. 2011. Sustainability assessment and rating of buildings: Developing the methodology SBTool PT-H. *Building and Environment,* 46**,** 1962-1971.

Norman, J., Maclean, H. & Kennedy, C. 2006. Comparing High and Low Residential Density: Life-Cycle Analysis of Energy Use and Greenhouse Gas Emissions. *Journal of Urban Planning and Development,* 132**,** 10-21.

Pauleit, S. & Duhme, F. 2000. Assessing the environmental performance of land cover types for urban planning. *Landscape and Urban Planning,* 52**,** 1-20.

Serviços Acção Social, U. M. 2014. *Photos, Accommodation, Residential Complex of Azurém* [Online]. Available: http://www.sas.uminho.pt/default.aspx?tabid=4&pageid=121&lang=pt-pt&path=Alojamento [Accessed 2014].

United Nations. 2014. *World Urbanization Prospects: 10 The 2014 Revision, Highlights* [Online]. Department of Economic and Social Affairs, Population Division. Available: http://esa.un.org/unpd/wup/ [Accessed 2014].

Van Den Dobbelsteen, A. & De Wilde, S. 2004. Space use optimisation and sustainability-environmental assessment of space use concepts. *Journal of Environmental Management,* 73**,** 81-89.

Wikipedia. 2012. *Urban Sprawl* [Online]. Available: https://en.wikipedia.org/wiki/Urban_sprawl].