Sustainable development by the "in-between spaces" in terms of energy performance analysis in Brussels

SEVERINE HERMAND[1], PHILIPPE BOUILLARD[2], AHMED Z. KHAN[3]

[1, 2, 3] Université Libre de Bruxelles, Ecole Polytechnique de Bruxelles, Building Architecture and Town Planning (BATir) dept, Brussels, Belgium

ABSTRACT: This work aims at exploring the effects of the urban texture on building energy consumption in Belgium. The focus of this study is on Brussels, Belgium located in an Oceanic climate (Köppen climate classification) where an important number of challenges in terms of urban planning exist. Indeed, since Brussels is limited by its political boundaries, the capital needs to work with the density and the reconversion of the brownfield in order to accommodate more than 170 000 new inhabitants by 2020. The hypothesis is that the building's envelope is energetically impacted by the open or the surrounding "in-between" spaces in the urban fabric of Brussels. The motivation for this work is not only showing the urban strategy in Brussels in terms of sustainable renovation, but also understanding which would be the best strategies to design the open spaces on a given site. An analysis of the LT method and DEM's will be provided in order to outline a methodological framework for assessing the role of in between spaces on the energetic performance of buildings in the Brussels-Capital Region. This kind of analysis is particularly well adapted for the district scale or block. This analysis gives more attention to the issue of urban geometry than question of function.
Keywords: Urban form; Open space; Brussels; Building energy consumption; DEMs; LT model

INTRODUCTION

This paper is an exploration of the morphology of urban open spaces as essential element in the assessment of the energy consumption of buildings. With the new demographic and energy challenges of the 21st century in cities, what is the role of a morphological study of open spaces in relation to the energetic needs? How can the European capital, Brussels, address this? What are the main tools at our disposal to perform quantitative and qualitative analysis of energetic effects of open spaces on their built environment? These are the main questions of the study.

"Architecture is the void; it is up to you to define it."
(Luigi Snozzi).

The void and emptiness has often been seen as negative in modern philosophy. However, the concept of nothingness suggests both absence and presence. It is also a process involving negation (toward nothing, tabula rasa) [1]. Solà Morales uses the French expression *terrain vague* [2], to express the empty, the abandoned space which subjugate the eye of the urban photographer. Through this expression, he highlights the void as both absence, yet also promise, the space of the possible, of expectation. In art, since the Renaissance with the *Città ideale* to the city represented by Chirico in his metaphysic painting, the void reflects the articulation between the classic architecture and the public space. The quality of "nothing" is an essential ingredient of a composition for artists. Today, as we can see in London [3], the void is at the heart of the debates about the city for town planners, architects, and politicians. Defining "empty spaces" in order to improve the quality of life, the links (social and urban), are vital to the life of cities [4]. There are several ways to analyse and perceive urban space. Camillo Sitte [5] defines the urban spaces into three complementary elements (the soil, the ceiling and the solid elements) and he extracts a fourth one: the open space. Urban open spaces can be understood in a variety of ways depending on scientific approach to describe and define them. The urban open spaces are related to *life between buildings* (Gehl, 2011) [6], *design with nature* (Mc Harg, 1969) [7], *green space* (Choay, 2005) [8] and *public realm* (Banzo, 2009) [9]. Open space is far from the urban negative conception. It is not the void in opposition to the built. For Teller (2002) [11], urban open spaces are the void separating the built volumes, which Thiberge (2002) [10] argues should be a structural element of the urban composition. Khan (2008) advances the focus on "design of open space structure as a flexible framework to unfold buildings, movement, and a variety of spatial experiences in a way that preserves human scale and facilitates a greener urban future". In line with these positions, we consider the public open space as constituted by the network of streets, plazas, squares and parks, all contributing to open space [12]. All these elements are the "in between spaces", sharing between "residual" and "dominant".

Owing to the alarming pace of urbanization (70% urban world by 2050), cities have become the locus of debate over sustainable development [13]. Among the

competing models for sustainable urban development (compact, polycentric and of open / green city models) (Khan, 2011[14]), there is a growing consensus over the compact model for its perceived role in making mobility and energy consumption more efficient. Most of the time, the energy consumption in the cities is related to the transport and the building sectors. However, the cities have to be seen as complex adaptive systems of void and solid (built-up) areas. Studying the interactions between the two defines the field of urban morphology. Because the level of greenhouse gas emissions is not uniform in all cities (e.g. "Oslo produces ten times less greenhouse gas emissions per capita than Melbourne, despite comparable levels of life" [15]), a degree of freedom seems to be available in the way these relationships between solid and void are conceived, structured, articulated and managed, i.e. urban design.

In this urban "new deal", the in-between space is one of the most important elements for retrofitting cities for the 21st century concerns (climate change, sustainability) towards more compactness, in order to create more efficient urban fabric in terms of energy performances.

BRUSSELS' PUBLIC OPEN SPACE

Brussels, a city, a region, four times capital holds a very distinctive position in Belgium and in Europe. Due to its limited area (160km^2), high urbanisation level and population density (almost 1 million inhabitants), tight infrastructure network and intense economic activity, Brussels has to deal with different challenges in a limited territory. It appears as a small, highly urbanised island embedded in the Flemish Region. According to the Brussels Institute for Statistics and Analysis (BISA), Brussels is currently the fastest growing region of Belgium. Moreover, 80% of the city was constructed before energy concerns became an issue [16]. In these terms, most of its building stock is old, and need refurbishment. This renewal project is complex, time consuming and a costly business for the city. Despite the relationship between the urban morphology and energy consumption in buildings, the link is often neglected. Since the beginning of 1990, several initiatives have been taken for sustainable development, especially through the Brussels Institute for management of the Environment (IBGE in French). Thus, in Brussels, public and political institutions work together to provide detailed management plans of the development areas of the city with the goal of responsible management in terms of environment, social and economic development. In a study on the design and development of public spaces in Brussels [17], Benoit Moritz shows that since the establishment of the Region in 1989, the public space in Brussels has made important steps. From an embellishment role with reintroduction of the cultural dimension, the development of open space in Brussels has gradually emerged as a full-fledged spatial element, to revitalize a neighbourhood, or as a factor of social cohesion. Among the four models of public space development in Brussels that Benoît Moritz outlines, the last one corresponds to the current time. This time is characterized as a time of living together: the model of the "ad minimum". Several planning tools such as the "Regional Development Plan" (PRD in French) are available to planners in the Brussels development. This plan is a tool for large-scale pacification allowed by major development projects for public spaces such as the "green trail" (63km). The open space for Brussels' greenway is defined as a structural element of the green network of IBGE, referring to environment (biodiversity, soil permeability, decreasing the effect of urban heat islands). At a time when the PRD introduced the sustainable dimension as a priority, we can question from the morphological study of open space the reduction in terms of energy consumption in the city areas.

Occupying less than 3% of the planet's surface, cities are the largest CO_2 emission sites (+80%). Cities consume an average of 75% of world's energy (both for transport and housing). With the target of 20% reduction of energy consumption by 2020, what are the main plans in action in the Brussels-Capital Region in terms of urban planning to reduce the energy consumption of the buildings? According to IBGE, housing and offices represent 75% of the total energy consumed in the Region.

Brussels has three main scales of renovation in the city. Each of these scales is represented by a policy directive with global to detail target. Within these plans, the main plan for the larger scale, the future plan for the region's development, states: the "Regional Sustainable Development Plan" [18] (PRDD in French) (instead of the PRD) and the Sustainable district contract for the intermediate level. After more than four years of study, this new development plan identified six priority challenges, among which is "the environmental challenge". The plan is divided into two parts concerning the city projects and the sectorial policies. In response to the new urban challenges, the PRDD proposes a new territorial (re)organisation of Brussels in to six areas (fig.1).

The spatial reorganisation of the territory into six areas in PRDD is based on the historical paths (gates, routes, railway) as well as on the wide-open spaces (e.g. canal). Specificities such as residential attraction, mobility infrastructures or landscape features are present in each area. Besides the development of the region and the socio-economic development of Brussels, this reorganisation into six areas is also advanced as a means to achieve the goals of reducing greenhouse gas emissions in the region by 30%. In this sense, the PRDD aims to boost the polycentric development of Brussels.

Figure 1: PRDD new territorial organisation of Brussels source Plan regional de Développement Durable

The establishment of an efficient public transport network and the densification of the existing urban fabric around the communication hub or near the unpopulated areas is currently the new urbanisation of the city, which will give a new urban morphology for Brussels. In order to ensure a balanced land development between built spaces and open spaces, the PRDD is linked with other development plans that focus more on the district and building level. The "Sustainable neighbourhood contracts" is a sustainable development tool since 2010. This tool is more active in the highly populated part of the city. It helps the social, economic and environmental development of the district by renovation of buildings and public spaces, active social cohesion and financial aids from the Region. The public open spaces are revitalized and take a large part in these projects. The other largest part in the "sustainable neighbourhood contracts" is the energy dimension, which is taken into account through mobility, promoting the urban mix and, the refurbishment of buildings by technical construction processes. The public open spaces are renovated most of the time to strengthen the social cohesion and improve the quality of life in the district.

Thus the urban fabric of Brussels-Capital Region is being transformed into a veritable patchwork of sustainable initiatives throughout the area. Because the buildings are main element of energy consumption, they are given precedence. Most of the time the urban policies take into account the building as a single entity and the different systems to implement in order to increase the energy performances. However, in 1989 (Newman and Worthy [19]), with the first study which links energy performance with urban form, the importance of the urban morphology appeared.

The urban morphology is used to show the quality of a district in terms of passive energy systems, but also is used to guide the urban renovation. Indeed, the city elements are not simply added but integrated with each other. The Urban Morphology Lab from the CSTB [20] in Paris identified the morphological parameters impacting on the energy consumption in the city as the density, the networks, and the sharing between building and empty spaces in the city. These parameters and the establishment of the relationship between urban form and energy performance is based on a study of more than one hundred districts and six cities. The laboratory considers "an optimized design of the urban morphology alone can divide the energy consumption of a city by a factor 2" [21]. At a time when more than half the world's population is urban, the shape of the city and the design of the urban open spaces is a main criterion for reducing the consumption of energy, resources and the greenhouse gases emissions.

A mapping of Brussels' open spaces can highlight the importance of the open spaces in the city as well in new projects and in the historical landscape of the city.

MAPPING OPEN SPACES IN BRUSSELS

Despite a very active urbanization, the Brussels-Capital Region has protected its green patrimonial and integrates it into its planning tools. The IBGE shows in 2007 the area occupied by open space (non built-up areas) covering more than 8,500 ha, which account for more than half of the region's surface area (161.38 km^2). These open spaces comprise the green spaces and blue spaces as detailed in figure 2.

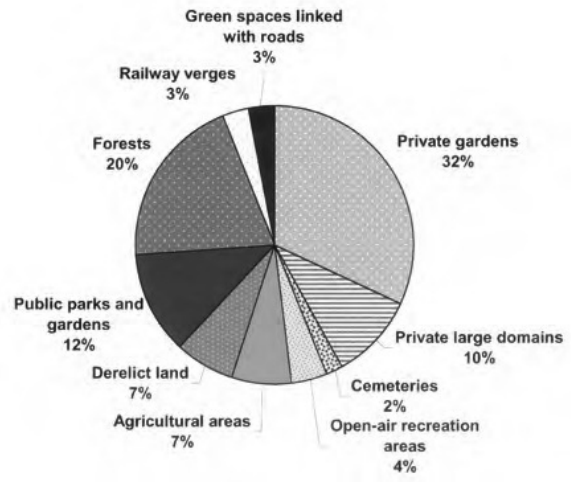

Figure 2: Types and % of total open surface area of the Brussels Capital Region source: IBGE-BIM

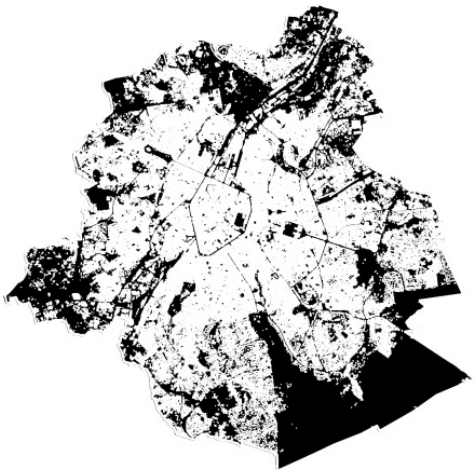

Figure 3: Brussels' open spaces in black (adapted from URBIS)

However, even if 50% of the regional area is "un-built", 63% of the Brussels population doesn't have access to a private garden. In addition, parks, forests and public forests represent only 2800 hectares of green area in the region, the rest are private gardens. 70% green areas are listed in the second ring, while only 10% is found in the dense urban centre, the Pentagon (Figure 3).

Special attention is paid in the Brussels-Capital Region to environmental challenges. According to the Green City Index, which is an assessment tool of the environmental policies of 30 European cities [22], Brussels reached the first position in terms of its environmental management. Sets of environmental plans as the development of green and blue network ("maillage vert" et maillage bleu") allow a basic structure to urban development linked with the environment qualities of the site. Besides environmental governance thirty indicators are taken into account in this tool. The evaluation of energy consumption in the city of Brussels through this tool reveals many faults. Mainly due to an important part of the old buildings, the city of Brussels reached eighth place for this indicator behind London and Paris. However, as shown in the study of Mertens et al by modelling, "extensive roof greening on just 10% of the buildings would already results in a runoff reduction of 2.7% for the region and of 54% for the individual buildings" [23]. In taking part of the environmental plan (green roof takes part in the Brussels' green network) the reduction of the runoff has a high impact on the reduction of the urban heat island effect. In this way, the energy consumption in the building will be affected. Including the energy dimension in environmental policy can result in a decrease in the energy consumption in the building of Brussels. The new urban projects in the city start to integrate the morphological dimension as a key element of the conception. The "urbain-Loi" project considered as an exemplary eco-neighbourhood in the European Quarter is one of the example of this new trend. In this project, Christian de Portzamparc plays with the urban form and organise the street according to the concept of open block [24].

In terms of reconversion, the Tour&Taxi project is one of the more relevant projects for historical reasons, stakeholder organisation and the final proposition. Tour&Taxi is a brown field designed as an enclave in periphery close to the Brussels centre, the Pentagon (figure 4). The site is surrounded by densely populated working-class districts, and by infrastructure and "frozen" areas (e.g. the Royal domain and railway area of Schaerbeek Formation). The site covers around 45 ha that was initially developed during the beginning of the 20th century as a port station. During this period, noticeable buildings were built like the Royal Warehouse and stores, by the Canal Company and Port facilities but also the Post and Maritime Station contracted by SNCB (National society of railway transport). The presence of these activities had a strong impact on the surrounding environment in terms of economic and social development.

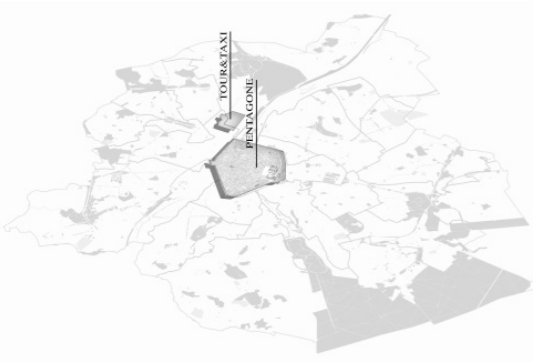

Figure 4: Localisation of Tour&Taxi (adapted from URBIS)

After 80 years of full activity, the economic activities of this site declined. From this time onwards a very long speculative period about the future of the Tour&Taxi brown field began. This period is characterized by, a partial loss of control over the land from the government, numerous propositions of projects and cons-projects, a gradual awareness that the future of the site must be thought of in relation to its environment, including the surrounding neighbourhoods. This last point will be the guideline of the refurbishment of the area. After more than thirty years of debates, the government, the city and the different stakeholders reached an agreement. The first proposition was made public in 2004 and the work started in 2011 after obtaining the urbanism and environment permits in 2010 for the first zone of the development. Linked with the ZIR (area of regional interest) the PRAS (regional land use plan) and the strategic area in the PRD (regional development plan), the Tour&Taxi project is a key element of the urban renovation in Brussels area.

The ambition of the proposed project for Tour&Taxi is to be a showcase for sustainable urban renovation in Brussels. The promotion of the social mix, the urban mix, the connectivity of the site to public transport, and a work on urban landscape were the main guidelines of this project. One other important aspect in the project is the construction of a public area. The region and the promoters wish to build the biggest public park since the 19th century in Brussels-Capital Region. In total 45% of the total space of the area will be dedicated to the park. Like a spine, the 20ha park consists of the public space around which all activities are organized: housing, offices, leisure, and mobility (figure 5).

Figure 5: 3D view of the Tour&Taxi project source: Master Plan Tour&Taxi, 2009

In becoming the new heart for the city, but also for the surrounding districts, the Tour&Taxi's park is conceived in terms of:

1. Social aspects, with a strong link with the other surrounding districts. During all the consultation phases the inhabitants from the Molenbeek Maritime, or Marie-Christine districts took part in the discussion. Instead of being an island in the middle of these historically industrial districts, this project aims to be integrated with the existing urban fabric. The project was thought of in terms of gains (quality of life, economic, activities) for the inhabitants close to it.
2. Economical aspects: increasing the quality of life, promoting the urban mix with a large part to the offices and housing and shops. The park will also contribute to promoting the global image of Brussels as a green capital.
3. Environmental aspects, the re-vegetation of this part of the city form part of the project of a green grid for Brussels to improve the biodiversity, and the impermeable soils in the Region.

To sum up, the new park of Brussels is located in an industrial area close to the canal, and will be a key element for the design of the new built up area. In terms of openings, views, activities, and functions, the pattern of the public open space in this case is essentially green. Proximity to the canal also affects the site. Therefore, in this project with such a big open space it will be interesting to quantify the need of the surrounding buildings in terms of energy. It will be possible also to make different scenarios by modelling for example to define the effectiveness of the morphology of the urban open space in terms of urban patterns, urban furniture, to avoid the losses of natural gain (solar, wind), increase the quality of life in the public space and create a complete architectural project closely linked with its environment.

To this end, we can ask, how do we measure the contribution and the effect of public open space morphology in terms of Energy Use of the surrounding buildings?

TOWARDS AN ASSESSEMENT FRAMEWORK

Our ambition in this article is not to offer quantitative analysis to illustrate the importance of the morphology of the open space in the building energy consumption. Instead, we propose to outline a methodology that aims to help further research in this domain, and help practitioners and policy makers in analysing and assessing the energy performances of different open spaces according to the design concepts. The urban form indicators are selected to be the main structural components of the urban fabric as: the buildings and their volumes, the open spaces and the verticality and the urban networks.

Our intention behind the choice and the overlapping of the structural indicators is to keep the complexity of the city's structure while structuring it in order to understand the mechanisms. The diagram below (Figure 6) shows the overlap of spatial scales and analysis grids, which is composed of two levels of interpretation:

- First level (outside the circle), the grid of spatial analysis to guide thinking and determine the objectives,
- Second level (inside the circle), the choice of actions involved in the analysis, which are also ways to achieve the goals of energy efficiency.

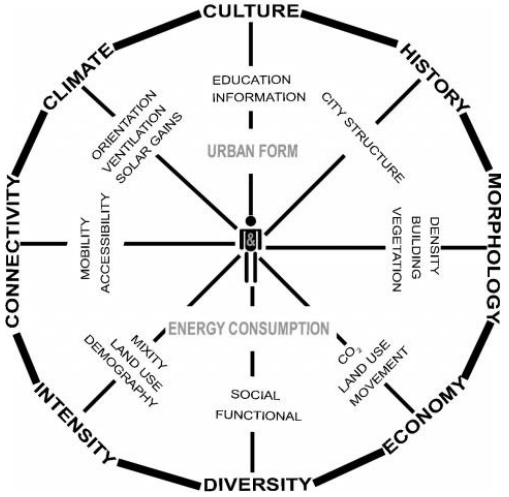

Figure 6: Overlapping between spatial scales and analytical tools, source: S. Hermand 2013

The variation of the city morphology has direct impact on outdoor and indoor climates: wind speed, solar gains (lighting and heating), wide range of dry air temperature. Thus, to better understand the functioning of the city, and better assess the impact of development policies conducted, it is therefore necessary to understand its form through the method of analysis behind it (figure 6). Modelling the interaction between all these indicators can be a way to understand and assess the energy performances of an urban fabric. Morello and Ratti [25] used 3D analysis as part of their approach to reconsidering the urban analyses of Kevin Lynch (1960). They use the *Digital Elevation Model* (DEM). The DEM is a compact way of storing urban 3D information using a 2D matrix of elevation values; each pixel represents building height and can be displayed in shades of grey as a digital image. The analysis of DEMs with image processing techniques has already proven to be an affective way of storing and handling urban 3D information, and being very conducive to a number of urban analyses [26]. Using the DEM in their analysis on the urban fabric of Berlin, London and Toulouse, Ratti et al. have shown the DEM to be an effective support to quickly derive the morphological urban parameters. However, a simulation tool like the *Lighting and Thermal simulation* (LT) seems to be indispensable in order to get an energy consumption figure. The LT method is an energy design tool. This tool, predicts the potential performance of the building, assuming that both systems and occupants function optimally [27]. The output of the method is annual primary energy per square meter. The LT Method uses the concept of *passive* and *non-passives zones* referring to the potential of the zone to use the natural energy gains (e.g. ventilation, solar) (figure 7).

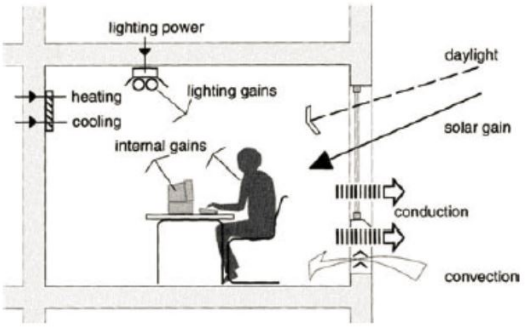

Figure 7: Energy flows considered by the LT model within a unit cell 3 m x 3 m x 6 m; from Baker and Steemers [27]

Another assessment tool often used in the analysis of urban morphology and energy efficiency is the *spherical projections*. This method can be used in the field of urban practises like the Teller's spherical metric (2005) [11]. Teller utilized a 2D map of a spherical projection, which enabled him to generate a metric for sky opening, representing the percentage of hemispherical sky dome visible from a point. However, this method is used most of the time in the field of energy analysis for calculating solar paths and masks (Morris, 1980 [28]), or solar availability within urban open spaces (Bosselmann, 1998 [29]). The spherical maps are useful to provide a means of comparison between buildings and environment and between views points within the buildings.

CONCLUSION

In an energetic analysis, lighting, heating/cooling and ventilation are the main component taken into account. An energetic analysis uses plans, sections, the orientation of the site in order to model the interaction of the energy fluxes.

The form factor is an important element to make an evaluation of the existing city and for the design project. It can be used to show the potential of the renewable energy in the site. With this in mind, the modelling tools are indispensable to assess the energy performances of the area. However, using modelling tools seems to be not enough to cover the large problematic of energy consumption. In this sense, the DEM method and the spherical projections can be used to model the open spaces. To get an energy consumption figure the LT method can be linked with one of the previous tools.

This analysis is particularly well adapted for the district scale or block.

In summary, we propose a methodological framework for assessing the impact of open spaces on building's energetic performance as a series of interactive sub-methods. It includes i] determining a set of context specific spatial indicators and modelling their interactions [& overlapping, see fig 6] as a first step; ii] DEM based analysis to derive parameters; iii] simulation through LT, and iv] assessment through spherical projections.

In this paper, we introduced a methodological framework for producing energetic analysis on the building envelope regarding the morphology of the open space. In our future work, we intend to fine-tune this framework by carrying out its application on the Tour&Taxi project, and also addressing the question of comparison between different open spaces morphology by testing it on another case study within Brussels.

REFERENCES

1. Miraj Ahmed and Martin Jameson, (2011-2012). The void, Architectural Association School of Architecture.
2. Ignasi de Solá-Morales Rubio, (1995). Terrain Vague, in: Cynthia Davidson (ed.), Anyplace, Anyone Corporation, MIT Press, New York/Cambridge, Mass., pp. 118-123, at p. 120.
3. The City of London, (2008). Open Space Strategy.

4. Catharine Ward Thompson, (2002). Urban open space in the 21st century, Elsevier, Landscape and Urban Planning 60, pp. 59–72.
5. Camillo Sitte, (1945). The art of building Cities: City building According to its Artistic Fundamentals, Reinhold, New York.
6. Jan Gehl, (1987). Life between buildings: using public space, translated by Jo Koch, Van Nostrand Reinhold, New York.
7. Ian L. McHarg, (1969). Design with Nature, Published for the American Museum of Natural History [by] the Natural History Press - 197 pages.
8. Françoise Choay & Pierre Merlin, (2005). Dictionnaire de l'urbanisme et de l'aménagement, Paris, PUF.
9. Mayté Banzo, (2009). L'espace ouvert pour une nouvelle urbanité, Dossier d'habilitation à diriger des recherches (HDR), sous la direction de Guy Di Méo, Bordeaux.
10. C. Thiberge, (2002). La ville en creux, éd. Du Linteau, Paris.
11. Jacques Teller, (2003). A spherical metric for the field-oriented analysis of complex urban open spaces, Environment and Planning B: Planning and Design, volume 30, pp. 339-356.
12. Ahmed Z. Khan, (2008). *Constantinos A. Doxiadis´ Plan: The Making of a 'City of the Future'*. PhD diss., KULeuven, 678 pages.
12. Ahmed Z. Khan, (2013). On Design and Politics of Co-producing Public Space, International Journal of Islamic Architecture 2: 1, pp. 125–156.
13. UN-Habitat, (2010). State of the World's Cities 2010/2011 - Cities for All: Bridging the Urban Divide.
14. Ahmed Z. Khan, (2011). Towards Sustainable Built Environment: Understanding Sustainability Prospects in a Metropolitan Framework, Journal of Research in Architecture & Planning 11, no. 2, pp. 31-55.
15. Alin Cluzet, (2012). Le climat sauvé par les villes ? Editeur : L'Harmattan.
16. Brussels, from eco-building to sustainable city, (2010), published by the Brussels-Capital Region.
17. Benoit Moritz, (2011). Designing and developing public spaces in Brussels, Translation Jennifer Corrigan, Brussels Studies.
18. Plan Régional de Développement Durable (PRDD), (2011), phase préparatoire – état des lieux de la région de Bruxelles-Capitale.
19. P. Newman & J. Kenworthy, (1989). Cities and automobile dependence », Editeur : Avebury Technical, 406 pages.
20. Serge Salat, (2011). Cities and Forms: On Sustainable Urbanism, Editions Hermann, 544 Pages.
21. Serge Salat&Caroline Nowacki, (2010). De l'importance de la morphologie dans l'efficience énergétique des villes, liaison énergie-francophonie n° 86.
22. European Green City Index, (2009). Assessing the environmental impact of Europe's major cities, A research project conducted by the Economist Intelligence Unit, sponsored by Siemens.
23. Jeroen Mentens, Dirk Raes, Martin Hermy, (2005). Green roofs as a tool for solving the rainwater runoff problem in the urbanized 21st century? Elsevier.
24. Urban Project Loi An urban design for the rue de la Loi and its surroundings, (2010).
25. Eugenio Morello, Carlo Ratti, (2010). A Digital Image of the City: 3-D isovists and a tribute to Kevin Lynch, Environment and Planning B: Planning and Design 2009,36:5 p.837-853.
26. Carlo Ratti, Nick Baker, Koen Steemers, (2004). Energy consumption and urban texture, Elsevier.
27. Nick Baker and Koen Steemers, (2000). Energy and Environment in Architecture: A technical Design Guide, E&FN Spon, London.
28. Markus and Morris, (1980). Buildings, Climate and Energy, Pitman, London.
29. Bosselmann, (1998). Representation of Places: Reality and Realism in City Design, University of California Press, Berkeley, CA.