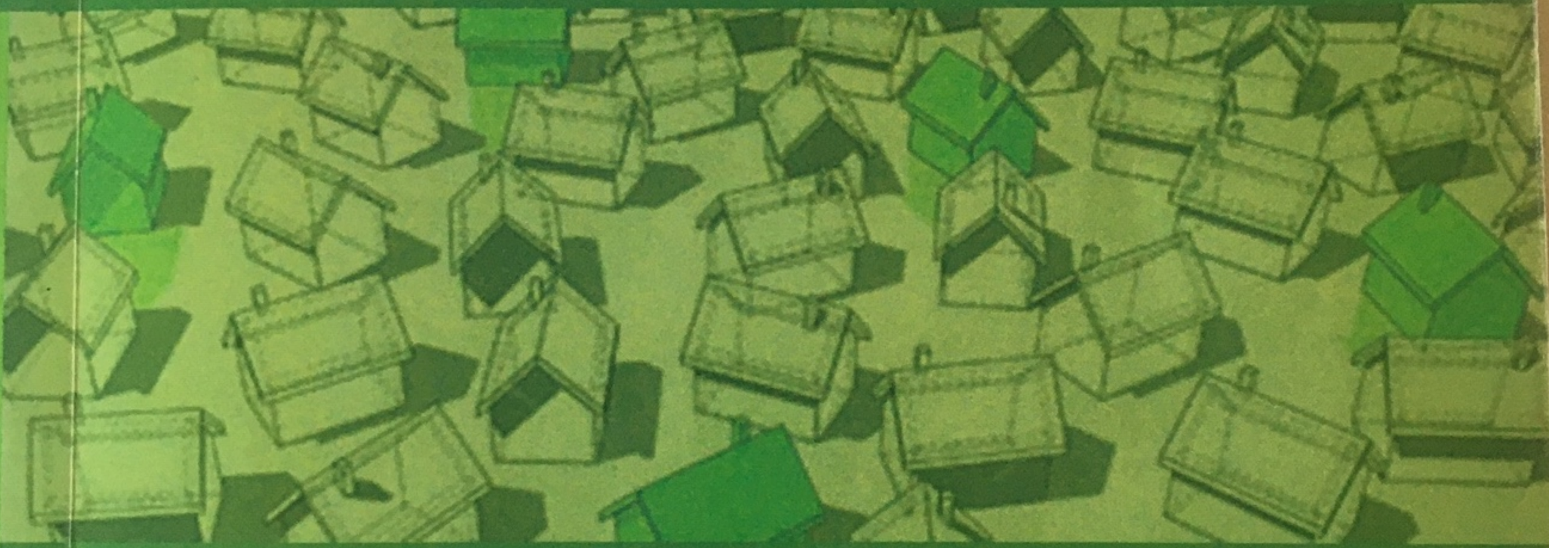
Proceedings of the International Conference on Green Buildings and Optimization Design

GBOD 2012



Editors

Prof. Peng Zhang, Prof. Hainian Liu, Dr. Jing Wu, Dr. Hao Xie

2012 International Conference on Green Buildings and Optimization Design

(GBOD 2012)

Table of Contents

URBAN MORPHOLOGICAL TRANSFORMATION VIA URBAN CONSTITUENT OPTIMIZATION: A SUSTAINABLE NEIGHBORHOOD DESIGN BASED ON INTEGRATIVE MODIFICATION METHODOLOGY

SHAHROOZ VAHABZADEH MANESH
Dipartimento di Architettura e Pianificazione (DiAP), Politecnico di Milano, Milan, Italy

MASSIMO TADI
Building Environment Science &Technology (BEST) Department, Politecnico di Milano, Milan, Italy

ABSTRACT
Due to the environmental and economical concerns, sustainable morphological urban transformation has been brought into its own. This paper explicates a possible method of sustainable urban transformation design principles, through a case study based in Barcelona; this methodology aims to reform urban assessment, as well as to design new sustainable neighborhoods as an integrated part of the city. The paper demonstrates how one can transform a neighborhood into a lower energy consumption system, using the Integrated Modification Methodology (IMM). In this approach, the city is considered as a Complex Adaptive System; the research discusses how the urban system performance could be optimized via this methodology. Accordingly, the sustainable urban form emerges through modification of its elements and integration of its subsystems. The paper is concluded by making a comparison between energy consumption of the neighborhood before and after the interventions.

KEYWORDS
Sustainable neighborhood design, Urban morphological transformation, Integrated modification methodology

PRELUDE

Cities, where up to 80% percent of world's population is accommodated, emit over half of greenhouse gasses preceded by consuming up to 80% of available energy. The severity of this critical situation is revealed, if one considers the unprecedented urban growth rate of recent decadesas well. The momentous role of urban transformation to the sustainable urban morphology is demystified, due to its competency to simultaneously deal with urban growth problems as well as environmental ones. Indeed, the feasibility of energy autonomy has already been demonstrated for isolated individual buildings; whilst, the implications of this new paradigm in neighborhoods and their relationship with urban assessments still has to be assessed.

With the assumption that the city is not the sum of all its buildings' performance, and the final emergence of the system is completely different than the individual elements' performance, our research holistically investigates the relationships between urban morphology and total energy consumption of the city. Accordingly, with consideration of city as a single entity, the presented paper demystifies how sustainable urban form could be attained, through optimization of existing constituents, over time. The approach is focused on multi-layer, multi-scale and holistic interventions, during the optimization process, which is based on modification of the city's elements and integration of existing urban subsystems. To reiterate, in the aforementioned methodology, a simplified case study tries to practically demonstrate the proposed optimization process.

The presented paper is comprised of two main divisions; in part A, the paper, briefly presents the Integratied Modification Methodology (IMM) as a design method, based on holistic complexity approach, to clarify how the urban transformation has to be performed in order to achieve a sustainable urban form; moreover, in part B, the methodology is proceeded by a case study, as a demonstrative practice, to illustrate the methodology as practical.

INTEGRATIVE MODIFICATION METHODOLOGY (PART A)

The importance of urban morphological transformation, towards an efficient energy consumer metabolism, is a crystal clear fact. Now the arisen question is how the urban contextual transformation should be optimized, toward the sustainable urban form. The city as a complex adaptive system, alike the other complex adaptive systems (CAS), is comprised of different subsystems, and every subsystem is made of different elements. These subsystems and theirs elements are the main constituents of the every CAS system [1]. "The complexity (from the Latin Complexus, meaning entwined, twisted together) denotes a fabric of heterogeneous constituents that are inseparably associated: it has the paradox of being at the same time a unit and multiple" [2]. Guiding a complex adaptive system to a certain requested level of performances is almost impossible, due to it is complex behavior. "At first sight, complexity is a quantitative phenomenon, an extreme quantity of interactions and interferences between a very large number of units. But complexity not only includes quantities of units and interactions, but also uncertainties, indeterminations and random phenomena. In a sense, complexity is always related to chance" [2]. Due to this fact, transforming the city, as a complex adaptive system, to a flawless system sounds like an utopian dream; however, with different optimization and modification interventions of its constituents, the performance of city could be improved in time.

Within every CAS, the members which either share the same function or their performance and directly rely on each other, are categorized in a 'subsystem', hereafter in the paper is called 'layer'. Every CAS consists of many subsystems, or layers, whilst each layer could be a CAS by itself. The elements of the layers are connected by numerous links and connections -nodes and links- which bring complexity to the system. Further explanation could be found in work done by authors [1]. If one wants to highlight two main features of every complex adaptive system, could emphasis on the resilience aspect of CAS, as well as complicated assessment of nodes and links within the system. Furthermore, one can improve the complex system's performances, proceeded by system transformation, through an optimization process. This optimization process could be approached in two different dimensions. If the optimization occurs between members of a layer, through modification of its constituents, is called Horizontal modification; in addition, if the optimization occurs through integration of different layers is termed as Vertical modification [3].

To reiterate, modification is when the members of one layer get optimized, in order to improve their own layer's performances. On the other hand, vertical modification is a symbiotic integration between different layers, in order to improve their performance, which ultimately improves the entire system's performance. It is immediately obvious that the city is comprised of superimposition of enormous number of different layers 'Subsystems', such as social, political and economic layers; however, the paper mostly focuses on layers which have direct relation to urban morphology and energy consumption of the city. The principal investigated subsystems, which affect the urban morphology as well as total energy balance of the city, are as follow [1]:

- Volume Layer (Built-up spaces)
- Void Layer (Piazza, Street, Open space & etc.)
- Functional Layer (Land use)
- Transportation Layer

The city is comprised of numerous superimposed layers. If one wants to deal with urban sustainability, he should work on the environmental, social and economical layers; however, the paper's primary intention is to discuss the four abovementioned layers, which are related to environmental layers as well as urban form. In the other words, it is clear that environmental layers are not confined to the four mentioned layers; nevertheless, the research concern is devoted to environmental layers, which are correlated to the urban morphology. Studying these layers doesn't mean that other involved layers, the social layer for instance, doesn't affect the total energy balance of the city; indeed, sustainable urban transformation is a multi- disciplinary complex task which has to be considered holistically, if more accurate results are to be obtained.

THE FIRST LEVEL OF INTEGRATION

Superimposition, or symbiotic integration, of the layers creates some morphological, typological and technological features- determinatives- of the city, which are called 'key categories' (KC), in the sustainable urban design intervention [table 1]; therefore, they could be used by designers, in the observation phase in the design process [3], to analyze the urban context of the actual situation and its performance before the design intervention, as well as evaluation phase after the intervention. Thanks to the carried out research, by the authors, based on theory and practice, the KCs have been literally defined. In addition, some measurable indicators, correlated with every KC, are needed to give the numerical dimension to these key categories. One should bare it in his mind that key categories definitions are fixed; however, the correlated indicators are different in different urban contexts. The indicators' definition should be chosen differently in different urban context, by designers and planners; in fact, the selection criteria lay on the contextual constraints, conditions, intervention's intentions and available data banks. KC is a concept which plays a significant role in modification process of CAS, in terms of system's assessment, transformation trend and eventually the system performance. One could use them both in Analyzing phase and Designing phase of the design process [3]. The following discusses about some of the possible generic definitions and possible indicators of the “key categories”: Proximity, Porosity, Diversity, Interface, Accessibility, and Efficiency.

Proximity: The integration result of the Volume and Function layers is named as Proximity [table 1]. Juxtaposition of different functions integrated into the volume layer creates the proximity of the spaces, which deeply affects the transportation layer. “This indicator measures the variety of land uses within the walkable catchment area. A high value of diversity may increase consumer choice a greater degree for maintaining an urban lifestyle without increasing the need for motorized movements” [4].

One of the possible ways of evaluating the Proximity is the number of different type of key functions in a predetermined distance; in fact, the predetermined area is walkable scale. In other words, proximity is highly related to walkability of the space; the number of key functions type that one can reach in walking distance. Key function types are educational spaces, administrative services, entertainment, commercial, business and etc. In the evaluation process, Proximity is dependent on the number of key function types; while it is independent from the quantity of each of the key function types by itself. For instance, while the presence of at least one bakery in walking distance is counted, adding two more bakeries or four doesn’t increase the proximity of the neighborhood. It means solely having two bakeries gives you less proximity rather than having a bakery and a post office. In the other words, proximity depends on the number of the key function types existing in the neighborhood, such as newsagent, restaurant or café, takeaway, food store, bank or building society, chemist, medical clinics, and walkable distance between them; meanwhile it is independent from the number of each key function, and the number of the peoples in the neighborhood. This relationship provides a clear idea about the proximity for designers and planners during the neighborhood designing process. Despite the proximity is independent from the number of people and residence in the neighborhood, another possible way to evaluate the proximity of the neighborhood could be explicated by the relationship of the number of job availability and number of dwellings in the walkable predetermined distance.

Porosity: Vertical optimization of Volume and Void layer defines the Porosity. “The volume layer clearly defines the presence of this principle layer, the urban conveys the physical meaning of the city. Indeed, one can imagine the city as a solid porous volume, sponge like, with various sizes of holes linked by linear void layer; whereby the integration of these two layers, urban volume and void, porosities” [1].

Layers' superimposition	First level (Key Catagories)	Second level	Determinants	
Volume / Function	Proximity	Compactness	Morphology	Energy efficient form
Volume / Void	Porosity			
Function / Void	Diversity	Complexity	Typology	
Transport / Void	Interface			
Transport / Function	Accessibility	Connectivity	Technology	
Transport / Volume	Efficiency			

Table 1. The First Level Integration creates the measurable Key concepts; additionally, the Second Level defines Morphological, Typological and Technological feature of the city. The city could be transformed toward more energy efficient form, if one creates symbiotic relation between the key concepts.

The definition of porosity could be evaluated by the built-up space density. The proportion between the urban mass to the urban void, densification, provides a clear idea of the porosity; however, involving the residence density adds another dimension to the complexity. To reiterate, the mass density evaluates the porosity; nevertheless, involving people parameters, will provide more accurate results for designers and planners. This involvement increases the level of complexity and brings more accuracy to the final results [1, 5].

Diversity: The integration of the void layer with the function layer creates the diversity of the city, which has direct relationship to the number of the nodes and links. As result, how complicated these nodes are bonded to the each other within different networks, makes the system more diverse and complex. One can explain it as numbers of interactions between nodes within a network; it could be seen as number of links between the networks' nodes. The diversity, the distribution of the different functions in public open spaces as well as indoor spaces such as urban piazzas and shops, coincides with probability of different urban activities and occurrence of the public to encounter and mingle for social and economic events [1]. Diversity is dependent on the number and type of the functions and independent from the distance; however and in order to simplify it, the diversity could be measured as the number of different type of key function in a predetermined distance. Despite the Proximity evaluation, not only the number key function type is important, but also the quantity of each key function is counted. Going back to the bakery example, regarding to Proximity, having two bakeries in a neighborhood doesn't increase the proximity; conversely, having two bakeries gives more diversity, with respect to having just one in the neighborhood.

Interface: The integration of the void layer with the transportation layer creates the Interface, which has a direct relationship to mobility inside the urban morphological cavities.

Accessibility: The Integration of Function and Transportation, creates the Accessibility, which refers to the ease of reaching destinations. People who are in places that are highly accessible can reach many other activities or destinations quickly; people living in inaccessible places can reach fewer places in the same amount of time. Unlike the Proximity, which depends on the distance parameter, Accessibility is a distance independent parameter, that relies solely the on time factor. Thanks to the high speed train, a city that is thousand kilometers away, is more accessible than a city that is hundred kilometer away, yet without fast transportation mobility, for instance. Despite the greater distance of the former city, one can reach it in less time than latter one. Hence, a residence that lives in an accessible neighborhood will have more job opportunities reachable in the certain amount of time. Accordingly, a possible definition is the total number of opportunities [employees number] that could be reached in a predetermined time [6].

Efficiency: Integration between Transportation and Volume, Efficiency, is a complicated feature, mostly related to the economy efficiency. A possible and simple definition could be explained through the ratio between number of trips operated by public transport and total transportation demands of the study area. It means efficiency could be evaluated by a classical ratio between supply and demands in the public transportation sector. As well as other features, the horizontal modification of the Transportation layer, as well as its vertical optimization, or integration with other layers, have to be implemented in both local and global scale. In the other words, the efficiency of the neighborhood couldn't be improved without consideration of the entire city transportation system.

THE SECOND LEVEL OF INTEGRATION

The results of the symbiotic integration of the preceding part results, entailing of three layers, depicts compactness, complexity and connectivity of the city, which are morphological, typological and technological feature of the city [table 1].

Compactness (Morphological aspect): Proximity and Porosity integration, the second level of integration of Volume, Function and Void, defines the compactness of the city. How dense or diffuse a city is, and how closes or far different functions within the city are, describes the compactness of a city. This morphological aspect has great impact on final energy consumption of the city. "The idea of the compact city was integrated into the concept of sustainable urban form, which includes compactness amongst other aims such as sustainable transport and a diversity of potential activities within a neighborhood" [7]. However, the compactness by itself doesn't make a city or neighborhood sustainable; the compactness alongside the complexity and connectivity will create less unsustainable urban context. Additionally, the optimal level of compactness should be considered, based on contextual concerns, to avoid any physical or data connectivity congestions. This kind of compactness has been evidenced in European and Asian historical cities. A possible way of interpretation of compactness could be land use efficiency, an optimized solution between Volume, Void and Function layers. The "compact city" is characterized by high densities and relatively shorter distances; it is meant to accommodate urban development while minimizing the use of undeveloped land. The European historical cities are featured by a high density of usage, short travel distances and a higher quality of life. Conversely, Sprawl "Urban sprawl" is the large and low density of city expansion to the urban suburbs. The sprawl form, which could be found in United State more often than anywhere else, is identified by new low-density suburbs with detached or semi-detached housing and large commercial strips [7].

Complexity (Typological aspect): The convoluted integration of the three layers carries the complexity feature of the city. To reiterate, the interface alongside the diversity, that being the vertical adaptation between the three principle layers for Function, Void and Transportation, forms the complexity of the urban system.

"Complexity is thus linked to a certain mixture of order and disorder, an intimate mixture that in urban systems may be partly analyzed using the concept of diversity. Living organisms, and especially man and his organizations, are information carriers that accumulate, dynamically in time, characteristics that indicate the degree of accumulation of information and the capacity to have a significant influence on the present and to control the future" [2].

Connectivity (Technological aspect): Accessibility and Efficiency integration, superimposition of Volume, Function and Transportation layers, draws the connectivity aspect of the city. The connectivity is highly related to the either transport or transfer of the peoples and goods. The connectivity is not confined solely to transportation of physical objects, but also exchanging data and information. It is clear that, this new dimension of connectivity, information and data connectivity correlates vertically with diversity and complexity feature of the complex system.

The following part, Part B, demonstrative practice, aims to illustrate a possible way, how one can monitor an urban transformation, by using the presented methodology. The presented case study tries to demonstrate this methodology, implemented on four urban blocks of Ensanche, in the city of Barcelona, Spain. The practice attempts to illustrate a simplified urban transformation project, through the optimization process, based on the demonstrated methodology.

DEMONSTRATIVE PRACTICE (PART B)

The initial request of the presented project was directed to individual transformation of four Barcelona urban block courtyards, toward sustainable public spaces which could serve the surrounding area. Redesigning these four courtyards is part of a greater Barcelona urban strategy, called ProEixample [8], which aims to recover an identified number of courtyards.

As aforementioned, the project's initial demand was solely to recover four urban courtyards individually; however, the proposed approach is based on

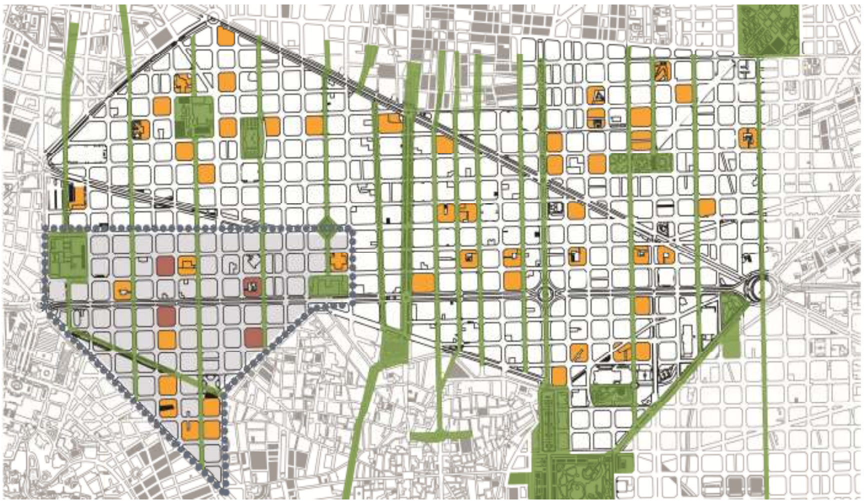


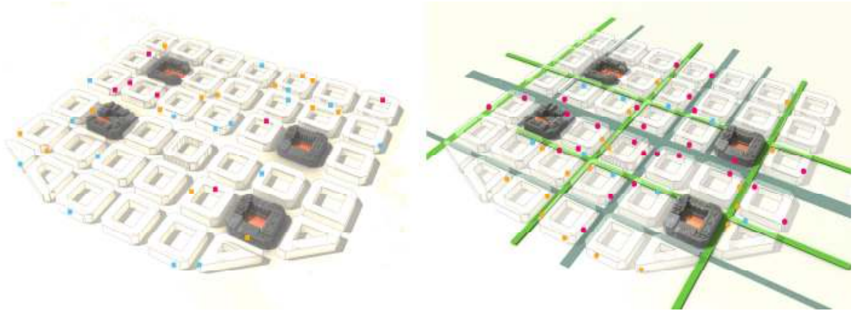
Fig. 1: ProEixample courtyards regenerating project is indicated by orange; while, the location of the four design blocks under consideration of regeneration are indicated in dark red. The green corridor, proposed by M.Gausa is shown by green lines. The area bordered by blue dotted line is the intermediate scale project area.

consideration of those blocks as a part of whole Barcelona urban system. In the other words, in chasing after sustainable urban blocks, not only sustainable building technology is considered, but also their effect on urban assessment as a member of whole system has to take into account. According to this holistic and multi-scale approach, the implemented intervention focuses on Global scale (city scale) as well as local scale (block scale). Beside the two mentioned scales, Global and Local scale, another scale plays a significant role in the urban transformation scenario, which is "Intermediate scale (neighborhood scale)".

The neighborhood scale bridges the local and global scales in the process of urban morphological transformation. The intermediate scale also could be defined as the area that gets directly influenced by the local interventions, having a role of global transformation. To reiterate, intermediate scales illustrate the impact of local scale modification on the bigger scale. The size and measure and form of the intermediate scale is highly depends on the size and scale of local interventions, as well as the morphological aspects of the site.

In the global scale, one should involve the local project in urban scale strategies; therefore, the four courtyards, has been seen as constituents of two different urban strategies, ProEixample and Urban green corridors. The latter strategy is still a proposal plan, proposed by Gausa [9], when the former is under its last stages of implementation. The integration of the two mentioned strategies is seen as the global scale of the proposed intervention.

Accordingly, the intermediate scale of intervention has been defined with inclusion of 41 blocks of the Eixample as the neighborhood scale [fig. 1]. Thanks to integration with the green corridor project and horizontal modification of the Transportation Layer, the number of private cars is reduced, while public transportation is promoted.



(a) (b)

Fig. 2: Close-up intermediate scale and the location of four courtyards in the neighborhood. Administrations and services are indicated by red, when cultural and entertainment is shown with yellow and educational spaces with light blue.

(a) Neighborhood diversity actual situation is illustrated by colored rectangles;

(b) M.Gausa green corridors are shown by green lines when new proposed transportation lines are illustrated by dark blue lines. *Diversity* is improved by increasing the number of key facilities. The Vertical modification of *Diversity* and *Interface* (Function layer, Void and Transportation layer) brings more *Complexity* to the neighborhood. To improve the *Accessibility*: The functions are proposed with consideration of symbiotic relationship with transportation and green layers; administrative and services are mostly along to the public transportation lines and entertainment spaces are along green corridors.

Accordingly, and in order to increase the Accessibility, which is the vertical modification of Transportation and Functional layer, different functions such as administrations and services are proposed along the public transportation corridors [fig.2]. The urban assessment modifications, different transportation and pedestrian networks for instance, not only improve the energy efficiency of the Barcelona, but also will increase the morphological complexity of the city, by increasing the hierarchy of spaces and networks.

According to Salat [10], increasing the complexity and morphological hierarchy of the city leads to a more sustainable form.

Actual situation of 41 blocks	**GWh/Y**	**prospective situation of 41 blocks after the first stage of intervention**	**GWh/Y**	
Total energy consumption	276	Total energy consumption	231	optimized energy efficiency = 16.2 %
Energy consumption in Residential sector	77.67	Renewable energy generated in Residential sector	39.53	
consumption in Transportation sector	66.64	Energy saved in Transportation sector	5.2	

Table 2. Comparison between actual situation of the neighborhood and the prospective situation after the intervention. Renewable energy generation is based on usage of PV Cells, PV leaves and solar collector, covering 20% of the 41 blocks available surfaces. Energy saved in transportation sector is calculated solely based on *horizontal modification* of transportation layer and integration with green corridors. The energy saved in Transportation sector due to *Proximity* and *Diversity* is not considered. If the number of reduced travel demands caused by Proximity is considered, the energy saved in transportation would soar significantly.

CONCLUSIONS

Due to that fact that the city is a complex adaptive system, and the final emergence of the system is completely different than individual elements' performance, the total energy consumption of the city is different than the sum of all the building's consumption. The concealed account of the copious gap between the sum of all consumers and total energy consumption of the city could be unearthed, by discerning the urban transformation. Any intervention based on the holistic methodology is a multi-scale operation; hence, one should deal with three different scales, Global scale, Intermediate scale and Local scale, simultaneously. In urban design and its transformation, neighborhood transformation acts as an intermediate scale optimization, which will change the urban assessment in the global scale. Besides, the transformation of the intermediate scale is highly relied on local scale modification, as well as global scale transformation. In other words, thanks to this holistic methodology, the sustainable urban form could be attained through optimization of existing constituents, by continues modification of urban elements, driven by the local transformation (project), and coincided with the integration of the subsystems. The final performance of system could be optimized by modification of urban assessment based on Morphological, Typological and Technological modification of urban assessments. Eventually the urban sustainable form could be achieved by increasing compactness, complexity and connectivity, of the urban system.

REFERENCES

[1] Vahabzadeh Manesh, S., M. Tadi, and F. Zanni, *Integrated Sustainable Urban Design: Neighbourhood design proceeded by sustainable urban morphology emergence.* WIT Transactions on Ecology and The Environment,, 2012. **Vol 155**: p. 12.

[2] BCNecologia, *Complexity, Barcelona a compact and complex mediterranean city, a more sustainable vision for the future.* , A.E.U.d. Barcelona, Editor, Municipality of Barcelona.

[3] Vahabzadeh Manesh, S. and M. Tadi, *A Sustainable Urban morphology for a greener City: Strategy Applied for a Sustainable-oriented Urban Design* Design Principle and Practice, 2012. **In press**: p. 10.

[4] Porta, S. and J. Luciano Renne, *Linking Urban Design to Sustainability, Formal indicators of social urban sustainability field research in Perth, Western Australia.* URBAN DESIGN International, 2005: p. 14.

[5] Vahabzadeh Manesh, S. and M. Tadi, *Sustainable urban morphology emergence via Complex Adaptive System analysis.* Procedia Engineering, 2011. **21**: p. 89-97.

[6] BCNecologia, *Indicators, Barcelona a compact and complex mediterranean city, a more sustainable vision for the future.* , A.E.U.d. Barcelona, Editor, Municipality of Barcelona.

[7] Schwarz, N. *InUrban form revisited—Selecting indicators for characterising European cities*. Landscape and Urban Planning, 2010. **96**, 19 DOI: 10.1016/j.landurbplan.2010.01.007.

[8] ProEixample. *Urban block courtyards recovery plan* Available from: www.proeixample.cat/index.php.

[9] Gausa Navarro, M., ed. *Multi-Barcelona, hiper-Catalunya. Hacia un nuevo abordaje de la ciudad y el territorio contemporaneos*. 2009. 288.

[10] Salat, S. and L. Bourdic, *Urban complexity, scale hierarchy, energy efficiency and economic value creation.* WIT Transactions on Ecology and The Environment,, 2012. **Vol 155**: p. 11.