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GENERIC FLOWS OF SUSTAINABLE URBAN FORM:

An Investigation On Integrated Interactions Between Energy And Information Flows In The Context Of Urban Form. The Case Of Isfahan.

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ABSTRACT

Urban form as an intermediate between human and its peripheral environment is embodiment of formative and transformative flows of built form. Energy flows of urban form production, operation and maintenance lead to generating and transforming of built form which is the transmitter of information flows as visual and perceptual flows between human as receptor and built environment. On this basis, continuous and integrated interactions between human and living environment have been considered as energy operational flows of environmental comfort (heating and cooling energy demand) and informational flows of perception, cognition and evaluation of built form (focusing on visual interaction) which are two generic flows of built form in relation with human. These relations and interconnections between energy and information flows have been excavated based on Eco Efficient Urban Form model (EEUF model). The present research aiming at exploring the relations between these two flows with built form and between them have been scrutinized based on two distinct state of Occlusivity factor, distribution of built elements in vertical plane (occlusivity factor for operational energy flows, Adolphe, 2001: mean openness of urban spaces to the sky, reflecting the height distribution of built elements which presents horizontal perimeter cuts in vertical planes of built form ;) and the length of the occluding radial boundary from each vantage point (Benedikt, 1979: 53) (Isovist occlusivity for visual information flows) It resembles the horizontal built elements perimeter map, which provides a comparative measure of the overall boundary of each isovist. Analytical context of the study has been chosen from the morphological aspects of Isfahan in the form of ten morphological types presenting general morphological trends of Isfahan. Regarding to these, results indicate that there is an Inverse correlation between the two state of occlusivity factor, occlusivity in vertical planes for energy performances and occlusivity in horizontal planes for sustainable visual information flows between built form and humans. The results demonstrate that the tissues with organic morphological aspects and structure have high value of energy performances occlusivisty factor especially effective for decreasing in heating energy demand in cold seasons and have low value of Isovist occlusivity factor which indicate high value of Isovist compactness leading to coherency in visual information flows. Hence, results depict that the integration between two generic flows of sustainable urban form is demonstrable for old tissues with old organic morphological patterns.

KEYWORDS

Occlusivity, Isovist, Energy demand, urban form, information flows

1. INTRODUCTION

The starting point of this study is presenting a clear understanding the gaps in our grasps of the relations between urban environment physical form and environmental performances such as material and energy flows and experienced physical qualities (in the form of information exchange between humans and environment).These relations exist and can be described and explained. They should be identified along with the methodological framework to support the evaluation of the city image and would be organized for the purpose of urban sustainability. The framework should also leads to more sustainable outputs of urban form design in all scales of the urban physical organization. Therefore, finding the interconnections and interactions between physical forms of urban environment and environmental performance, and filling existing gaps are important tasks of this study. Hence, environmental performance elaborates under the concept of urban metabolism and urban form system would be described in connection with this concept.

According to a systematic definition of urban ecology, a city is like a complex and open system including integrated flows and stocks which are exchanging between built structure and environment. For the first time in 1883, Karl Marx applied the exchanges between the material - energy flows and urban built environment under the concept of urban metabolism in industrial process criticism (Zhang, 2013).Then, Abel Wolman again applied urban metabolism idea in response to the decline in US cities water and air qualities. What Wolman was dealt with was on the basis of material and energy inputs of a hypothetical city in US (Wolman, 1965).

After that, urban metabolism studies have been considered the balancing between energy and material flows. Significant point in these analyses has been about the evaluation of energy and material input flows in urban system and evaluation, estimation of output flows in different procedures of urban system.

On the other side, Information flows are considered as an important element of urban metabolism with the introduction of information exchanges concept within the urban built environment (Coward and Salingaros, 2004; Macfarlane, 2003). In this study, information as the third flow of urban metabolism is defined based on the initial interaction (visual) between human and built form.

On the other hand ,the large volume of published studies in connection with the urban metabolism were considered the analysis and data processing of the input flows in the urban system and analysis of outputs, in the form of wastes , air and water pollution , heat islands, and etc. In continuation of these studies, in addition to codification and extraction of environmental sustainability indicators of urban ecology, socio-economic indicators related to metabolism have been entered to the cycle of urban metabolism studies (Chrysoulakis et al., 2013).

An urban ecosystem consisting of the elements and components which are permanently exchanging with its surrounding environment. Based on what has been said, materials, energy and information flows are considered as inputs of an urban system in its sustainability evaluations.

Human as the primary element of urban system interacts with the environment permanently and affected by energy and material flows in the forms of environmental indicators such as air and noise pollutions, heat islands, greenhouse gasses, etc. The energy and material flows would be emerged in the form of informational flows such as urban ambience, perceptual and semantic processes (Osmond, 2008; Salingaros, 1999). Accordingly, information flows carry the ambient qualities of material and energy to the residents. It means that human expresses his/her sense to the material and energy flows of urban metabolism through information flows. Urban form, in terms of physical aspects, is built by using energy and material flows. Then, the initial interaction would be established between human and built form.

As a general idea of the research, urban form has been scrutinized as a built structure of urban system encompassing the urban metabolism flows. It has also been regarded as an evaluative context between inputs and outputs of urban metabolism. In addition, urban form as the context of urban metabolism processes embraces the inputs of information, energy, and material flows and reveals them in the forms of interactive processes as specific outputs.

So, the more stable interactions between inputs and outputs of urban metabolism lead to more sustainable urban form. It means that sustainable urban form describes energy, material, and information flows in the form of resource and waste management process and also quality of place (initial interactions of human with built form, cognition, and mental evaluation). Therefore, in this study, integrated interactions of triple elements of urban metabolism (energy, material, and information) are entitled Eco-Efficient Urban Form model (EEUF) in urban morphological context.

An analytical unit of urban morphological studies (urban tissue) (Kropf, 1993; Coniggia and Maffei, 2001) is located in the core of EEUF model. This core is generated through the productive interactions between local resources of energy and material and external inputs. Urban tissue frequently exposed to operating and utilizing in formation and transformation processes of urban form. These operations and utilizations are defined based on temporal conditions, social and cultural needs and behaviours and accordingly, built form would be maintained or modified.

Hence, in both operational and maintenance modes, energy and material flows constantly are considered as metabolic inputs in urban form system. Meanwhile, the information flows streaming from the initial exposes between human and built form, is scrutinized as interaction, perception, cognition, evaluation and behaviour in environment (Nasar, 1998). But the main focus of present study (for describing information flows of urban metabolism in relation with urban form) has been founded regarding visual interactions between human and build form. It is what Gibson referred to as environmental perception based on environmental affordability (optic array) (Gibson, 1979; Osmond, 2008) and also indicated by Salingaros as information field of urban space (visual interaction between urban form as a transmitter and observer as a receptor) (Salingaros, 1999).

From a metabolic perspective for describing urban form system, urban form as a medium between human and the environment is located in balancing point between human activities and metabolic flows. Human activities are divided into two modes; production of form and living in built form. Metabolic flows are also divided into three modes; production, operational, and maintenance flows.

Therefore, urban form system which consists of physical form and function will emerge from sustainable interactions between generative and productive flows of human activities and metabolic flows. So, human's generative activities and metabolic flows are two different interactive aspects of urban form phenomenon.

According to conceptual diagram of urban form system, energy and material flows are considered as inputs of urban form system in formation and transformation processes, and wastes, recycles and pollutants are considered as outputs. Operational mode (environmental comfort), and perception, cognition, and behavioural aspects are regarded as another kind of urban form system outputs. In this model, functional aspect of urban form system indicates the specific relations between human and physical form.

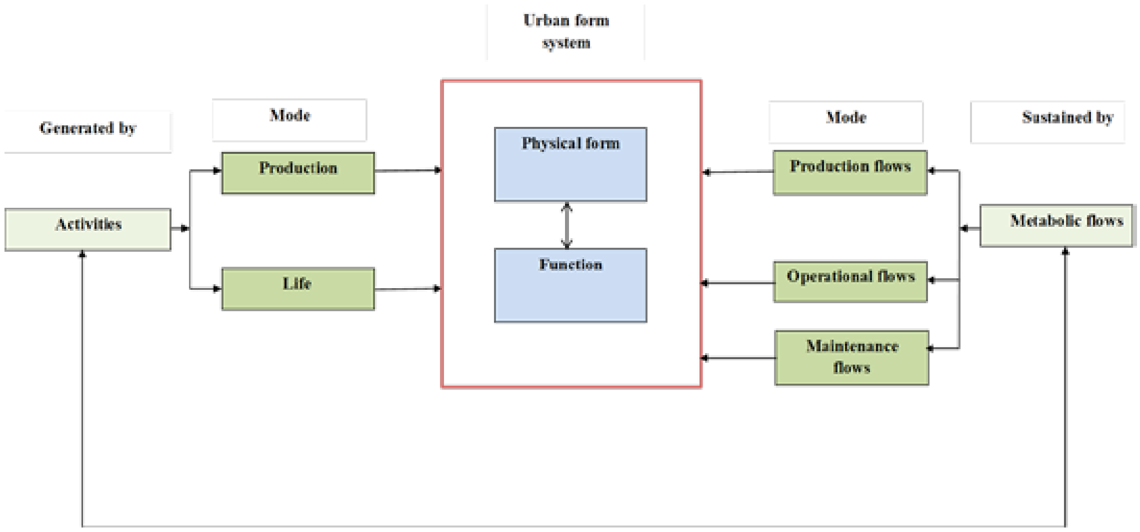


Figure 1 - urban form system diagram

1.1. THEORETICAL FRAMEWORK (EEUF MODEL)

In view of all that has been mentioned so far, EEUF model has been considered as an analytical and evaluative model of sustainable urban form studies and design. This model has been delineated in accordance with Eco-Efficiency concept (Schaltegger and Sturm, 1990) and local resource model (Kropf, 2008, 2013).

So, in the first place, the main constituent of the model includes the urban tissue, resulting from aggregation of urban form elements. These elements are the components of multi-level generic structure (Kropf, 2014) which have been evolved from the Conzen and Coniggia to Kropf urban morphological approaches and methods (Conzen, 1961; Coniggia and Maffei, 1979; 2001; Kropf, 1993, 1996, 2009 and 2014). The elements in the hierarchical structure are as: materials, structures, rooms, buildings, plots, plot series, street and urban tissue (Kropf, 2014). moreover, Kropf points out: "Returning to the hierarchy of elements, there are three distinct types of void embedded in built form, each with a distinct role within the multi-level generic structure" (Kropf, 2014: 50), including: void in building, void in plots and void in street (Kropf, 2014).

Considering morphological unit and urban form system content, EEUF model consists of two levels of inputs and outputs. The inputs contain the two groups of resources, stocks and flows. The first group of inputs are the local resource bases such as, wind, topography, solar radiation, local material, soil, water bodies and etc. and the second group are external resources such as fossil fuels, electricity, imported material and flows and etc.

On the other side, the output levels could also be classified into two groups. The first group of outputs are the productions and services of the generative process of formation and transformation of urban form. Accordingly, referring to the urban form system, physical aspects and produced form would be considered as the production mode of the model. Furthermore, utilization, operation and specific services of produced form are the operational mode of EEUM model. The other outputs of the model are wastes, pollutants, recycles and also urban ambience; commenting on the issue, Osmond argues that urban ambience is: "the experienced physical and psychological qualities of the urban environment. Ambience is based on the premise that comfort, satisfaction and delight (or lack thereof) reflects inter alia the user's perception and interpretation of the physical state of an architectural or urban space" (Osmond, 2008: 146).

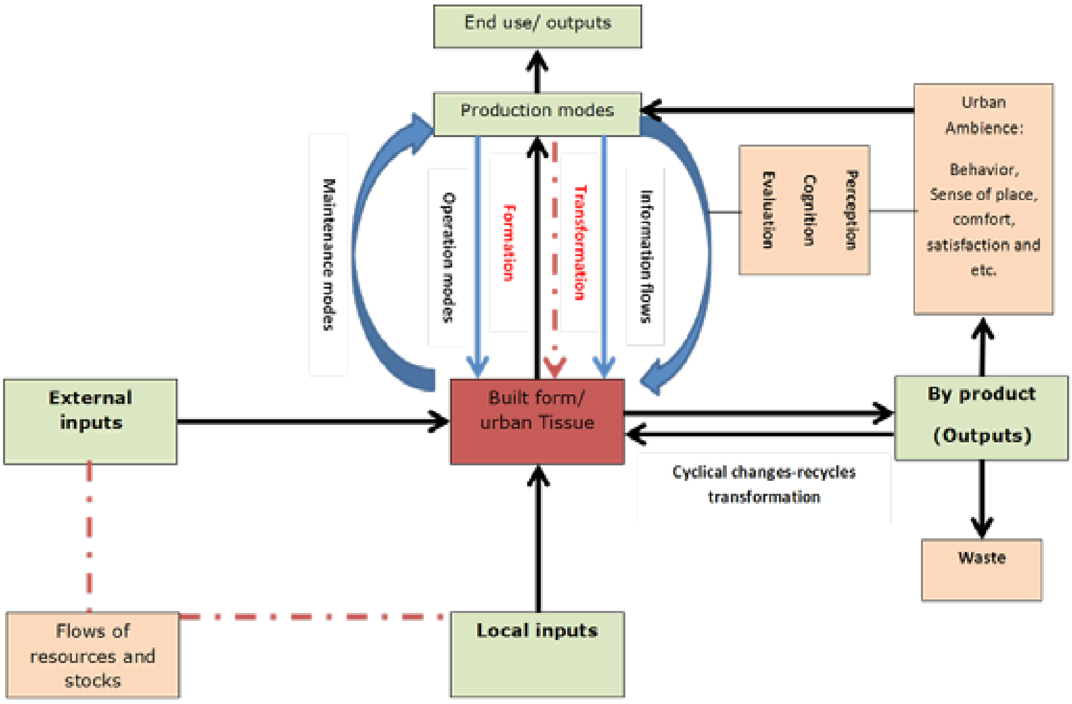


Figure 2 - Eco-Efficient Urban Form model

According to the research aim and what have been mentioned, the primary concern of the research is analysing and evaluating the main parameters of generic flows of urban form (energy and information) in the form of an integrated framework.

One of the most significant issues of the present research is the nature of selected parameters of generic flows of sustainable urban form. So, the main emphasize of the paper is based on the two forms of occlusivity factor for the two main aspects of the research; occlusivity for environmental performances and occlusivity for information flows.

Lock Adolph (2001), introduced the occlusivity factor according to the relations between urban form and environmental performances which defines the height distribution of built form elements and urban openness (Adolph, 2001; 2014).

On the other hand, Benedikt (1979) introduced the occlusivity factor in his Isovist Method for describing and analysing the relations and interconnections between urban configuration and visual information flows (Benedikt, 1979; Batty, 2001). As Yu et al., notes: "Occlusivity is the total length of all edges that are not defined by building surfaces – thus they are the unknown or ill-defined part of the visual experience of a space" (Yu et al., 2016: 3), This factor has important role in evaluating the sustainability of visual information flows in the context of built form. Moreover, environmental occlusivity factor represents the volumetric demonstrations and three-dimensional structure of built perimeters. On the contrary, information flows occlusivity factor indicates two-dimensional attributes of urban geometry such as built form perimeters and areas.

Taken together, the specific objective of the research was delineated based on analysing the morphological patterns of Isfahan according to exploring the integrated interactions of energy and information flows of investigated morphological types. The research also examines the significant relations between environmental performances and Adolph occlusivity factor as well as the significant relations between sustainable visual informational flows and Benedickt occlusivity factor. Finally, the research assesses the significance of correlation between Adolph occlusivity factor and Benedikt occlusivity factor which is the verification test for EEUF model. For the purpose of the analysis, statistical significance is analysed using analysis of Spearman correlation and P-value null hypothesis as appropriate.

1.2.RESEARCH PARAMETERS

Following the research objectives Adolphe occlusivity factor and Isovist occlusivity have been considered as the analytical and comparative parameters of the research. The other parameters such as Isovis compactness, height ratio (L), floor space index (FSI) and coverage ratio (GSI) have been securitized as supplementary parameters.

1.2.1. ADOLPHE OCCLUSIVITY FACTOR (ENVIRONMENTAL PERFORMANCES)

The average of urban spaces openness to the sky, demonstrates the height distribution of built elements. According to Adolphe, distribution of built elements in vertical plane has an impact on solar radiation which has a great influence on heating and cooling energy demands during cold and hot seasons (Adolphe, 2001). He argues that the Effects of the distribution of built perimeter against building heights indicates the environmental performances based on solar radiation and air flows (Adolphe, 2001).

For better understanding of the confrontation between tissue/building height and perimeter, referring to the Martin centre et al. (1997), a number of horizontal cuts on urban tissue were used for each 3.5meter or for each floor (Adolphe, 2001).

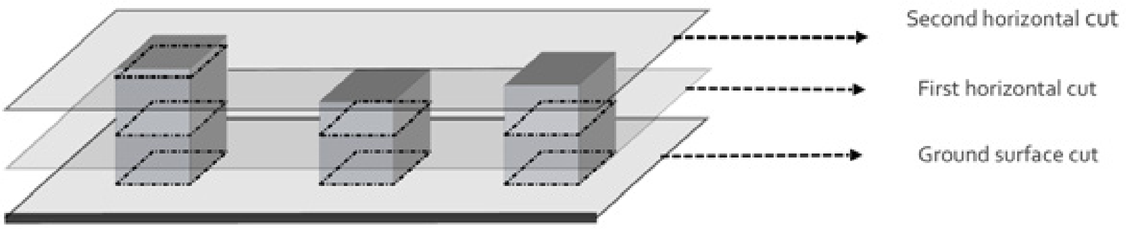


Figure 3 - illustrating the a tissue horizontal cuts, (Adopted from Merlier, 2015)

$$Adolph\ Occlusivity\ Facror = \frac{1}{Nhorz.Cuts \times \sum Pbuilt/Punbuilt} \quad (1)$$

1.2.2. ISOVIST OCCLUSIVITY (VISUAL INFORMATION FLOWS)

The isovist occlusivity factor represents the relative proportion of occluded surfaces which limit the sights from specific observation point (Osmond, 2008; Batty, 2001; Benedikt, 1979). This factor measures the length of open edges according to build form and Isovists perimeters. Therefore, the high value of the factor indicates the high rate of vagueness and spatial navigation confusion (Yu et al., 2016).

With a view to the Gordon Cullen, serial visions are made by place properties. The place properties are the forces and pressures which create the movement structure on spaces based on geometrical configuration of built surfaces. The built surface is a medium (between masses and voids) which illustrates the visual organization such as material, colour, texture and etc. This visual organization is content of townscape (Cullen, 1961; Brodbent, 1990).

Returning to the Isovist-occlusivity, the higher value of open edges and ill-defined spaces lead to the lower possibility of making serial visions on a contiguous visual movement structure. Hence, these relations could be described through visual stability (a space quality deriving from place properties). The quality of visual stability of spaces and built surfaces was depicted in Isovist method and indicates that to what extent an observer is under environmental domination. According to the designed experiments by Psarra and McElhinney (2014), it seems that there is an inverse correlation between compactness and occlusivity factors , the reason is that the spaces with high value of convexity (compactness) have lowest possibility to create open and none-defined edges which are more sustainable from the aspect of visual information flows (Psarra and McElhinney, 2014).

2. DATASETS AND METHODS

At first, selecting the suitable case study is the important part of the research methodology. For this purpose, the typo-morphological method which was used and approved by Kropf and Changalvaiee (2014), has been considered to this study for presenting a holistic and inclusive perspective of urban morphological states of Isfahan urban morphological patterns. Therefore, five tissue types were selected as morphological units following as the below table:

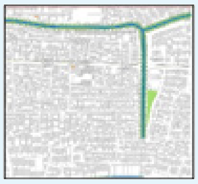
Tissue type	Plot type	General characteristics	General aspects	Tissue sample
Tissue type 1	• Central Courtyard	Old Historical Core	• Organic structure and configuration • Compact blocks	
Tissue type 2	• Central Courtyard • Multi-story front court	The Transformed Centre	• Grid structure within organic pattern • Compact blocks	
Tissue type 3	• Isolated apartment	The Transformed Extensions	• Fragmented structure • Isolated block apartments	
Tissue type 4	• Informal settlements, • Central courtyard • Single family front court.	The attached rural areas	• Organic structure and configuration • Compact blocks	
Tissue type 5	• Multi-story front court	The block apartments and grid Multi-story front court	• Grid structure • Front court block apartments	

Table 1 - typology of morphological patterns, the case of Isfahan

Then, two samples (100meter × 100meter) were selected from each type as the final analytical units of the research. As a general classification of the above table, the morphological types of Isfahan are classified into two general categories: 1- old and organic patterns (tissue types 1, 2 and 4) 2- modern, fragmented and grid pattern (tissue types 3 and 5). The tissue type 2 is turning point in urban form transformation of Isfahan with dominant characteristics of old and organic patterns. A tissue with old and organic plot types and regular semi-grid street pattern.

The second step of the methodological process is simulating energy performances (heating and cooling demand for buildings) and analysing the visual information flows. Hence, environmental performances were simulated in terms of theoretical energy demand. The purpose of theoretical demand is that all non-morphological factors such as utilizing factor, glazing ratio and etc. were kept constant (Salat, 2009). In order to simulating of environmental performances, the CitySim model (Robinson, 2012; Kampf and Robinson, 2007) was employed to calculating and estimating the energy flows in the scale of an urban tissue or whole city based on geometrical and configurational aspects. The main important part of the model is using a simplified radiosity algorithm (Robinson and Stone, 2004) to calculating the solar radiations and their interactions with built form elements.

On the other side, for analysing the visual information flows the Isovist method from depth map software was used and the compactness and occlusivity factors were investigated (Turner, 1997; Batty, 2001). On this basis, the occlusivity as a morphological factor of visual information flows describes the change in sight lines within the built form. Accordingly, in order to control the occlusivity, the compactness factor was analysed which describes the stability of information flows of sight lines (Psarra and McElhinney, 2014).

3. RESULTS

Considering the research aim, objectives and also presented factors, the results have been focused on the correlations between Adolphe occlusivity and environmental performances. The research results have also emphasized on the Isovist -compactness and Isovist-occlusivity correlations for visual information flows. Eventually, the results have been scrutinized according to the integrated interconnections and interactions of generic flows of sustainable urban form (Energy-information) based on dual nature of occlusivity factor.

3.1. ADOLPHE OCCLUSSIVITY FACTOR AND ENVIRONMENTAL PERFORMANCE CORRELATIONS

As an energy simulation method, the CitySim model is used to estimate the energy demands for heating and cooling (In this process the urban configuration has noticeable impact on building energy demands via solar radiation, heat transfer, natural ventilation, lighting and etc.) (Robinson, 2012). So, it is very important to determine the model inputs appropriately.

One of the most important inputs of the model is 3D configuration and geometrical attributes of each morphological samples. In addition, the other type of input is climatic data resulting from Meteonorm software (In .Cli and .Hor formats) (Perez, 2014). The climatic parameters are wind velocity, wind direction, global irradiances, relative humidity, air temperature and etc. The case study of the research, Isfahan, is located in hot and arid climate (Kampf, 2009).

Another important parameter of the model is determining the thermal comfort ranges in cold and hot seasons regarding the climatic conditions. Therefore, considering the related literature reviews (Nikolopoulou and Baker, 2001; Perez,2014) and Iran's national standards of building sector (energy saving 19th issue) (Ministry of road and urban development, 2010) , 20 °C and 26 °C are determined as the minimum and maximum thermal comfort temperature for cold and hot seasons.

As noticed in methodology section, the parameters and inputs such as façade detail, glazing ratio, wall and roof material, infiltration ratio, plant and equipment model, utilizing factor and behavioural model have been kept for ten samples of the study.

On the other side, the morphological characteristics of the samples indicate the noticeable differentiations between old and modern patterns in terms of Adolphe occlusivity factor. Furthermore for better illustrating the morphological profiles of the sample tissues, the two factors of Floor Surface Index (FSI) and height ratio (L) are calculated. The results represent the higher value of occlusivity factor for old tissues (T1, T.1.1, T2, T.2.2, T4 and T.4.1) compared with modern tissues (T3, T.3.1, T5 and T5.1). The results, as shown in Table () indicate the lower ratio of FSI and L for old tissue in comparison with modern tissues.

The simulation results for old tissue samples demonstrate the lower value of energy demand for heating in cold seasons and very higher value of cooling energy demand in hot seasons. In explaining this characteristic, the higher ratio of occlusivity factor along with the lower values in height index and surface density index indicate the more exposure surfaces and urban masses to solar radiations leading to increasing in solar gains. On the other side, it could be inferred that occlusivitye factor represents the compactness and adjacency of the plots within the tissue. In old tissues, the higher value of occlusivity demonstrates the higher compactness and adjacency values in plot types (Central courtyard type) which lead to the lower heat transfer and loses between plot surfaces. By the same token, exposure to the solar irradiances and restriction on air flows for natural ventilation due to the compact plot types cause to increasing in cooling energy demand for hot seasons.

Tissue type	Heating Demand-Kwh/m3/Y	Cooling Demand Kwh/m3/Y	FSI	L	Occlusivity
T1	14.08	61	0.57	1.06	0.88
T.1.1	16.19	31	0.74	1.3	0.72
T2	21.73	50	1.31	2.27	0.54
T.2.1	18.31	48	1.5	2.7	0.41
T3	23.38	18	1.98	6.6	0.16
T.3.1	22.57	16	3.7	11	0.095
T4	10.16	56	0.51	1.11	0.81
T.4.1	11.21	57	0.69	1.15	0.77
T5	24.14	24	2.48	5.62	0.184
T.5.1	24.63	19	3.4	5.5	0.188

Table 2 - energy performances and morphological parameters results

Therefore, the Spearman correlation analysis results depict that a significant strong negative correlation is found between Adolphe occlusivity factor and heating energy demand (rho: -0.830, P-value: 0.003). Accordingly, for old tissues with higher value of occlusivity factor, the heating energy demand in cold seasons is lower than the modern tissues.

On the other hand, the analysis results indicate that a significant strong positive correlation is found between Adolphe occlusivity factor and cooling energy demand (rho: 0.939, P-value: 0.001).

2.3. BENEDIKT OCCLUSSIVITY FACTOR AND VISUAL INFORMATION FLOWS

For isovist-occlusivity factor results demonstrate that modern tissues with grid pattern and isolate apartment blocks have the higher average of occlusivity factor value and also higher standard deviation in comparison with old tissue with organic pattern. Thus, these tissue have the more open edges, ill-defined spaces and higher spatial changes intensity. The combination of results provides some support for the conceptual finding that there is a significant correlation between the morphological patterns with high ratio of ill-defended spaces and spatial change intensity (spatial vagueness and confusion) in terms of visual information flows.

Besides, for isovist-compactness the results represent that old tissues have the higher average of compactness value and also higher standard deviation compared with modern tissues. Therefore, the stability in visual information flows is the main characteristic of old tissues with organic pattern. The stability of visual information flows and diversity of spatial changes (convexity factor) could be scrutinized according to the serial vison and sequence of spaces in old tissues. On this basis, conditions would be provided to attaching the secondary information flows such as texture, colour, proportions and etc.

Accordingly, the spearman correlation analysis show the significant negative correlation between isovist-occlusivity and isovist-compactness (rho: -0.733, P-value: 0.016).

Tissue types	Isovist-compactness				Occlusivity-Isovist			
	Average	Minimum	Maximum	Standard Deviation	Average	Minimum	Maximum	Standard Deviation
T1	0.181	0.036	0.778	0.116	84.43	4.26	296.94	47.62
T.1.1	0.134	0.28	0.577	0.069	79.28	0	225.93	47.76
T2	0.179	0.22	0.703	0.156	87.97	3.15	303.22	53.68
T.2.1	0.119	0.031	0.503	0.117	117.73	1.69	318.38	77.90
T3	0.149	0.072	0.752	0.070	384.61	33.66	668.65	119.25
T.3.1	0.169	0.049	0.451	0.044	327.38	32.42	760.005	117.90
T4	0.206	0.044	0.607	0.102	68.99	3.41	200.27	40.44
T.4.1	0.271	0.112	0.660	0.082	14.76	0	57.36	10.86
T5	0.166	0.032	0.613	0.068	116.64	6.36	339.523	56.45
T.5.1	0.257	0.089	0.522	0.037	52.6	11.40	213.51	20.99

Table 3 - Isovist occlusisivty and compactness results

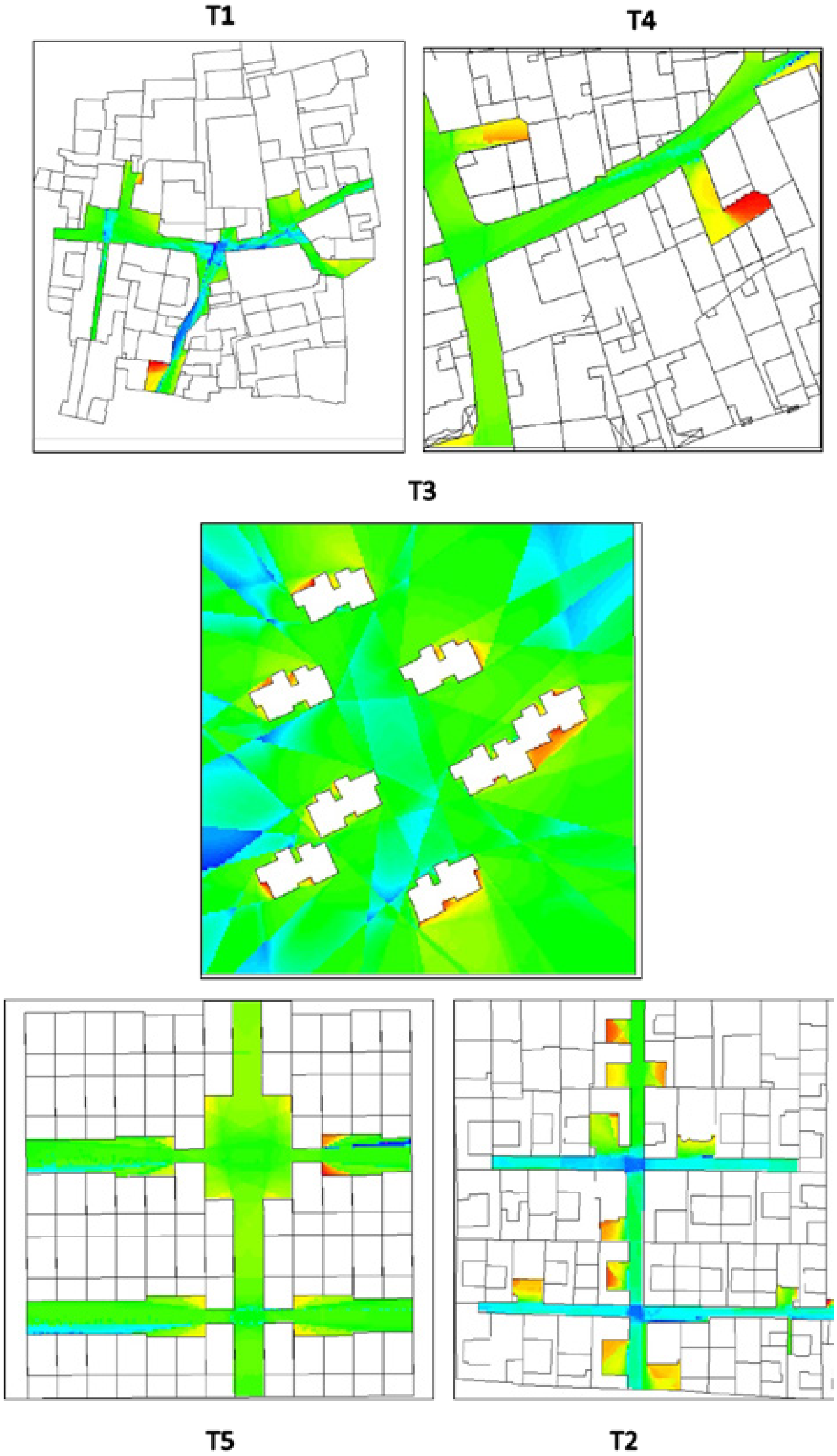


Figure 4 - graphical results of Isovist-compactness analysis, the case of 5 samples of Isfahan morphological tissues. The red, green and blue colors demonstrate high, medium and low value of Isovist compactness.

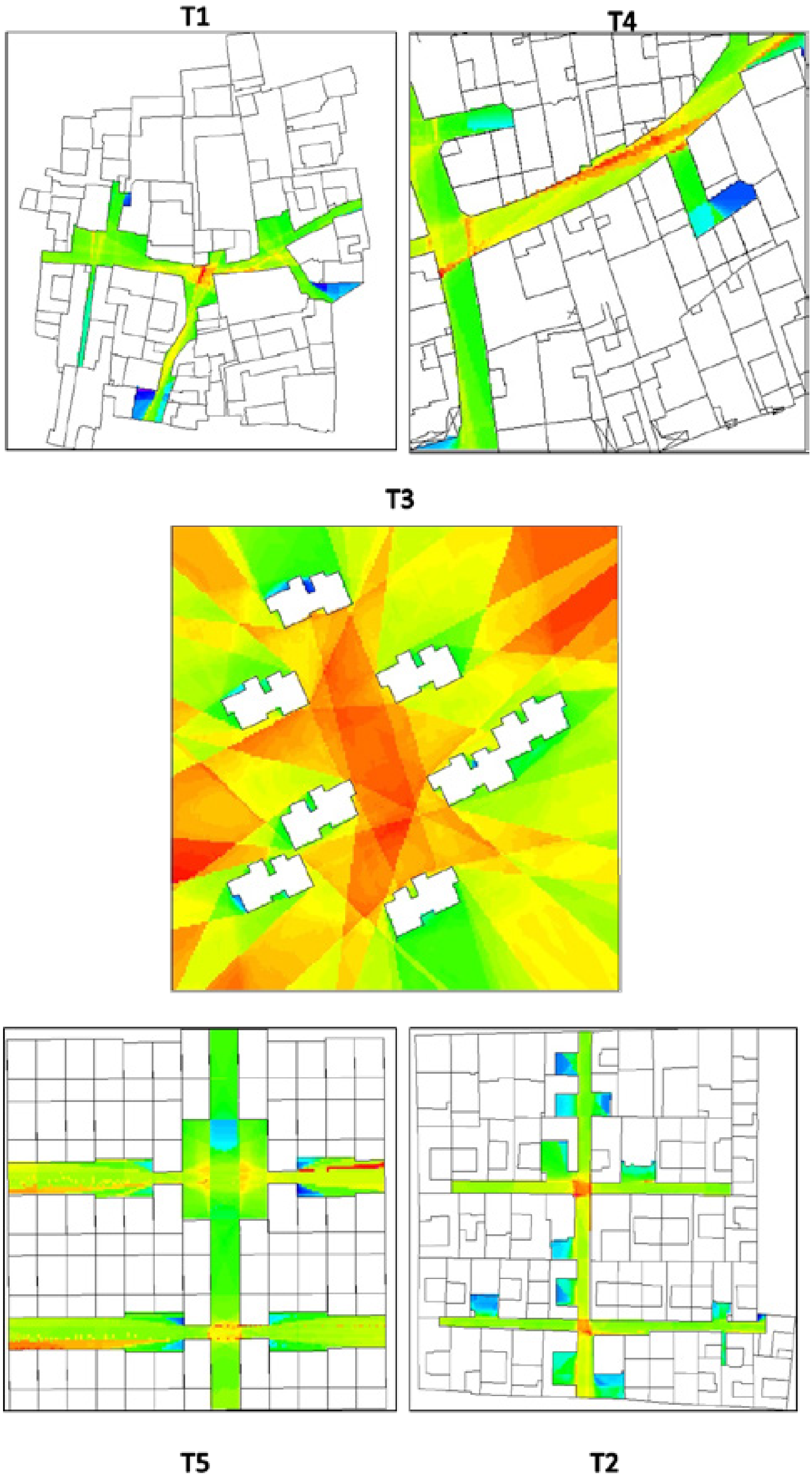


Figure 5 - graphical results of Isovist-occlusivity analysis, the case of 5 samples of Isfahan morphological tissues. The red, green and blue colors demonstrate high, medium and low value of Isovist occlusivity.

On the other side, the correlations between surface configurational aspect of urban tissues (GSI ratio) and iso-compactness and occlusivity indicate that the coverage ratio of plot and block types have significant impact on visual information flows. Results show the significant and negative correlation between iso-occlusivity and coverage ratio (rho: -0.790, P-value: 0.007) which emphasis the morphological configuration of plot types and the position of built area within the plot. The fragmented and regular plot types in modern samples have the higher value of occlusivity and more open edges in visual information flows. Accordingly, there is a significant and positive correlation between iso-compactness and coverage ratio (rho: 0.592, P-value: 0.048). This correlation emphasises the geometrical style of the plot and block types. The street and open spaces boundaries in old and organic pattern types are defined by courtyard plot and block types with built area around the central court or similar types. These well-defined boundaries and open spaces lead to the compactness in visual information flows.

Tissue types	Isovist-compactness	Occlusivity-Isovist	GSI
	Average	Average	Value
T1	0.181	84.43	0.54
T.1.1	0.134	79.28	0.57
T2	0.179	87.97	0.58
T.2.1	0.119	117.73	0.54
T3	0.149	384.61	0.3
T.3.1	0.169	327.38	0.34
T4	0.206	68.99	0.46
T.4.1	0.271	14.76	0.6
T5	0.166	116.64	0.44
T.5.1	0.257	52.6	0.62

Table 4 - Isovist occlusisivty and compactness results comparing with coverage ratio

4. CONCLUSIONS

In this investigation, the aim was to assess the interconnections and interactions of generic flows of sustainable urban form. Taken together, the results indicate that at first, there is a significant negative correlation between Adolphe occlusivity factor and Benedikt occlusivity factor. From the aspects of urban form geometry and configuration, the lower value of Benedict occlusivity demonstrates the compactness of built form perimeter in 2D built form boundaries and high ratio of space convexity. On the other side, the higher value of Adolphe occlusivity factor depicts the lower built form elements height and mass density.

Secondly, environmental sustainability of urban form in old tissues (cold seasons) and their sustainability of visual information flows indicates the interactions and interconnections between energy and information flows in the case of Isfahan old tissues with organic pattern. Therefore, it could be claimed that the research findings would be considered as a set of evidences to verifying the EEUF model and integrated relations between generic flows of urban form in production, operation and maintenance modes.

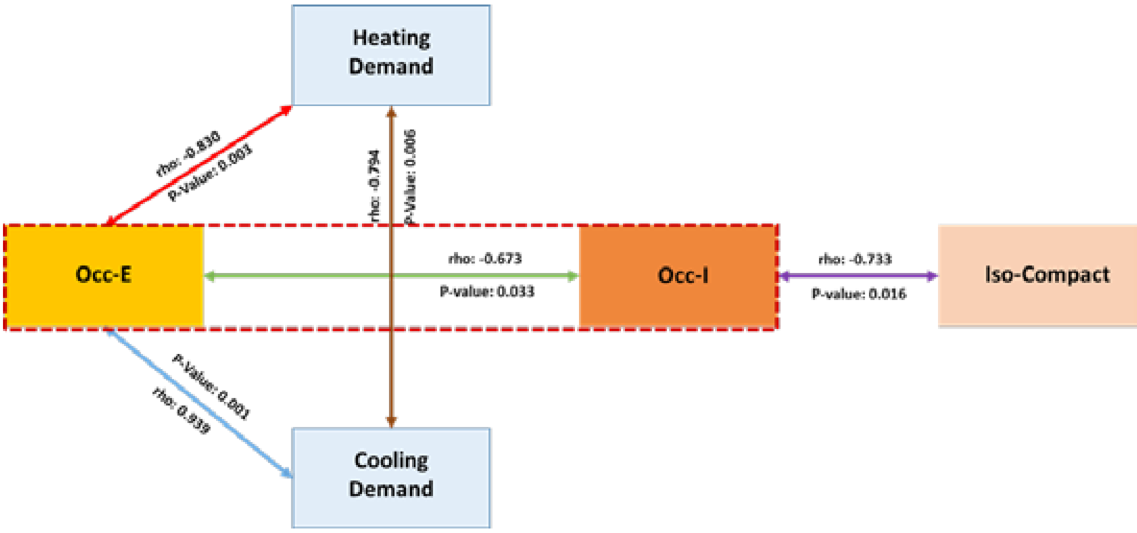


Figure 6: the summary of correlation among research parameters

The contribution of the study has been to confirm the relation and interconnection between generic flows of energy and information as the main contents of EEUF model. This research provides a framework for the exploration of the two states of occlusivity factor, as one of the important morphological indicators, in analytical context of urban form sustainability. The empirical findings in this study provide a new understanding of urban design strategies according to the existing morphological patterns in terms of the research approach: the integrity between energy and information flows as a new concept of sustainable urban form and design.

The research has been focused on the operational mode of energy flows (indoor energy demand) and also visual interactions for information flows. Finally, Future research should therefore concentrate on the investigation of the integrity between perceptional aspects of urban form and outdoor environmental comfort as the main characteristics of urban form environmental performance in the form of EEUF model.

NOTES

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1. Urban metabolism is an encompassing concept of sustainable settlements in terms of sustainable processes of inputs and outputs cycles of urban systems. The traditional dimensions of this concept were material and information flows, but the new dimension focusing on this research is information flows.

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