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Classification of Urban Morphology Indicators towards Urban Generation

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ABSTRACT

Urban morphology is a complex topic that can be defined in terms of its spatial relations, properties, and measures using several equations. There are types of urban morphology indicators UMIs to explore the spatial heterogeneity, guiding the spatial morphological design and build a correlation factor between the urban form and urban microclimate. Urban morphology indicators UMIs proposed several morphological correlations (numbers, dimensions, volumes, areas, orientations, and percentages) observed between the discrete elements of urban morphology to describe the built environment's morphology, geometry, and typology. UMIs are used in diverse fields of study. The generation of urban morphology is a complex process that includes several parameters. The collection and classification of generation parameters help architects and urban planners enhance the generation process. This study aims to introduce a classification of UMIs to be suitable for the generation process. The research assumes that the classification of UMIs is an essential process that helps in urban morphology generation. It presents a novel framework of classification of UMIs through the level of implantation in urban generation and the spatial relation between elements, four main categories of UMIs, which are concluded: Streets (UMIs), Building UMIs, plots UMIs, and Open spaces UMIs. Finally, the research will mention subcategories of each UMIs, besides the UMIs at each sub-category. S(UMIs) include connectivity, integration, choice, and permeability. P(UMIs) include Openness, compactness, and diversity. B(UMIs) include V/A, S/V, BDF, GSI, FSI, VHurb, FAI, and Hbuild. O(UMIS) include Po, Si, Oc, SVf, UCI, and Ru.

Keywords: Urban Generation, urban morphology, urban indicator, urban elements

1.INTRODUCTION

Cities are generated by various physical elements as building, streets, and people, and nonphysical elements such as transportation network [1], the actions and interaction between cities element Leeds to city complexity [2]. Different engagement scales are required for urban morphology and the investigation of numerous urban aspects that influence morphology generation. As a result, numerous indicators have surfaced linked to design techniques, policies, and regulations. Different indicators have different block form types, and particular value ranges for which they are best relevant.

There are two types of UMIs: The “original indicators” of spatial urban planning and architecture, such as building density, floor area ratio, line sticking rate.... and other “derived indicators” have been introduced with metrological context such as rugosity, porosity, sky-view factor..., each level of urban planning concerned with a group of UMIs, and each urban objective is correlated with some UMIs.

Wei, D. et al. collect UMIs from different scientific databases; there are around 48 UMIs (15 native UMIs and 33 derived UMIs [43].

The term *urban morphology* requires elucidation because it is intertwined with different terminologies of urban design. Numerous urban morphologists have aligned with their discipline in their research methodologies; however, scholars often disagree about the theoretical definition of urban morphology [3]. Nevertheless, like textual syntax, urban morphology has its vocabularies of fundamental urban elements that form its ultimate appearance—these given topographic, socio-cultural, and physical contexts. Therefore, the research begins with the definition of urban morphology to clarify the term; then, it aims to analyze different UMIs, mention different UMIs statics, and classify them according to their types and factors influence.

The generation of urban morphology is an issue that has attracted the attention of many researchers. a part of studies use the genetic algorithms in generation process, and anther researchers depends on parametric design. (coorey and coorey, 2017) used a systematic model to generate streets, plots and building [19]. (Koenig et al., 2019) update a new methodology and data tree to generate urban morphology in two phases. The researchers targets streets, plots and building in their methodology. Besides, they used FSI and GSI as an objective function [20]. (Miao et al., 2018) used centrality indicators as an objective function [21]. (Choi et al., 2020) used the centrality indicators as an objective functions, and used urban canyon index (uci) in the parametric model by connecting building height to streets segments [22]. (Zhai and Riederer, 2020) aims to Minimizing building density in a specific site, accordingly this research used also FSI as an objective function [23]. (Nagy et al., 2018) depends on FSI as constrain in the proposed parametric model [24]. (El Dallal and Visser, 2017) used degree of compactness and degree of roughness as an indicators during generation process [25]. In the last years, urban morphology approaches have evolved to be one of the most important aspects addressed by architects and urban planners in a variety of sectors [44]. The study has been held to classify urban morphology depends on deep learning [45]. Besides, another study targets the impact of urban morphology on outdoor spaces lighting, and human activities [46]. More overs, the urban morphology indicators related to building heights affect Building energy consumption [47]. Many studies use urban morphology parameters to enhance microclimate [48]. According. The studies held with urban morphology targets several approaches, so classification of urban morphology indicators is an essential process. This classification is useful to enhance the perception of urban morphology definitions, applications, and urban generation as well.

The main objective of this research is to classify UMIs; this classification helps in urban morphology generation. For example, these indicators are used as parameters from the parametric model in a parametric design system. In evolutionary design systems, these indicators are suitable for a fitness landscape process as an objective function. Accordingly, the research defines urban morphology, introduces several urban morphological elements, and then describes the urban morphology generation process after reviewing several studies. Finally, the research classifies UMIs to fit the urban morphology generation process.

2.URBAN MORPHOLOGY

The great poet and philosopher Goethe (1790) first defined the term morphology as the science dealing with the very essence of forms, the science of form, or various factors that control and influence forms. Morphology denotes form-lore, or knowledge of the form [4]. According to the Oxford dictionary, the construct is rooted in two words, *morph* and *logy*, and literally signifies the logic of form recognition. This word represents a science that seeks to assess shapes, forms, and external structures [1]. Urban morphology is the science that deals with the essence of forms, and added that, in central of Europe, morphology was used as a term in biology science until be used in city science [5]. Morphology is the science that deals with the essence of forms, adding that in central Europe, the word morphology was used as a scientific biological term before it entered the parlance of city science. this word was defined in terms of the study of the material and built form of urban landscapes [6]. Morphology is an abstract image of physical reality manifested as shapes, properties, and types, and represented in the form of maps [4]. In textual syntax, a single letter or word attains a clear meaning only when it is contextualized in sentences. The roots of urban morphology have influenced several fields of scholarship such as urban geography, history, architecture, and spatial economics. Further, this domain is considered an important component of urban design. Muratori (1950) defines urban morphology as an "operational history of urban form," because this discipline records changes in urban form effected by planners, architects, and builders over time. Urban morphology represents perceived, lived, and conceived reality [7]. The study of urban morphology attends to the patterns and processes of transformation of the physical sizes and compositions of cities across years [8] [9].

3.URBAN MORPHOLOGY ELEMENTS

Moudon posited in 1997 that streets, plots, and buildings with open spaces were the fundamental physical elements of urban morphology [10]. Levy's study in 1999 introduced the same physical elements [8]. Then added land-use as a component of urban morphology. Kropf and Wiley (2017) included the natural environment, and others appended greenery. In sum, urban morphology can be asserted to embrace physical characteristics such as the shape, size, density, and configuration of settlements [11].

3.1.Cadastral pattern (Street System)

Streets signify the public domain network that connects different parts of the city. They allow people to move between the private domains (street blocks) through the urban landscape and include avenues, boulevards, and other roadways [8] (Marshall, 2005) explained that streets may be represented in several ways. In the present context, the study is concerned only with the composition and configuration of streets.

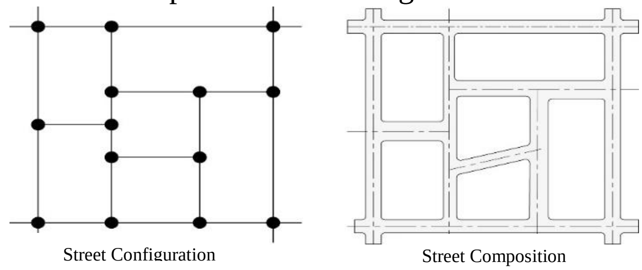


Figure 1 : street configuration and street comosition Drawn after [12]

The composition refers to the absolute shape of the street and takes into account the complete geometrical data such as width, position, lengths, areas, and orientation. Configuration, on the other hand, alludes to the topological shape illustrated in an abstracted diagram in which only spatial relationships can be considered [12], as shown in **Figure 1.**

3.2. Cadastral Units (Plot System)

As illutered in **Figure 2**, The cadastral units form the fundamental output of the division of the private domain into a single plot to generate a pattern of land division in several compositions. This classification addresses the territorial limits of ownership and distinguishes the public and private domains.

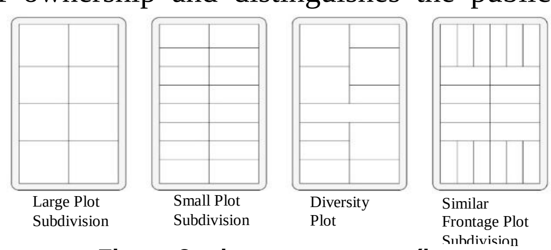


Figure 2: plot systems type (by

3.3. The Buildings Block

Urban blocks denote the smallest surrounded areas that include a number of buildings [13]. The block is not a single architectural element; rather, it is a group of interdependent building plots bounded by a street network [14]. The urban block includes different typologies as illustrated in unlike other elements, buildings adapt constantly to variations in their usage .The same building can successively become an upmarket single-family house, an office space, or accommodation for students during its lifespan [8]. In general, cities comprise of two types of buildings, ordinary and exceptional [10].

4.URBAN MORPHOLOGY GENERATION

(Koenig et al., 2012) claimed that Bill Hillier's alpha syntax model of space discharges a significant role in generative design. Over the past decade, many researchers have promoted design optimization as a field of study [15]. Consequently, various investigations explored

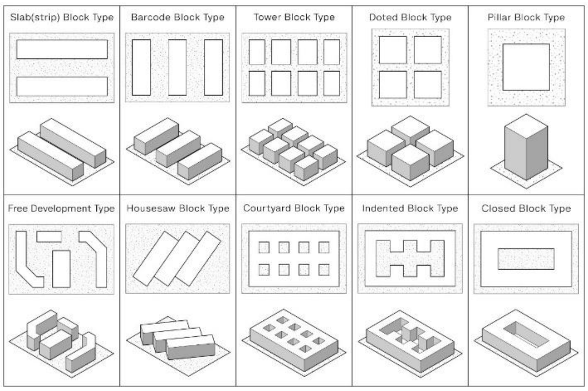


Figure 3:Urban Block Typologies [8] [10] [16]

design space to optimize the design process until Janssen (2000) suggested an evolutionary system of design optimization. Turin et al. (2011), who proposed a system based on parametric modeling as well as genetic algorithms, conceived this field of study. In 2015, Stuffs combined generative and evolutionary methods [17]. Several quantitative analysis methods have been applied to urban design to ensure the satisfaction of design optimization criteria. Given the complexity of urban design problems, optimization has evolved as a type of generative design method. The extant research has generally applied evolutionary multi-objective optimization methods and hybrid approaches for both meta-heuristic and model-based optimization. In applying the parametrization process, design requirements are translated into parameters that are connected to each other through one or more rule systems established as instructions [18]. It is easy to define the previous generational terms as part of the parametric architecture or parametric urbanism. Parametric architecture considers parametric variables as key factors influencing design. The proposed parameters can be used in the generation process for each element of urban morphology to understand the logic of the parametric and to begin the research-based process of generation that introduces the vocabulary and indicators as the parameters. The process of generation of urban morphology encompasses five phases. The first step is to establish the use grid or the configuration of streets within an urban space. The second stage converts this grid into a composition of streets. Subdivisions are plotted at the third level.
Building blocks are created at the fourth stage, automatically leading to the final phase of open spaces. Table 2 displays each processing target.

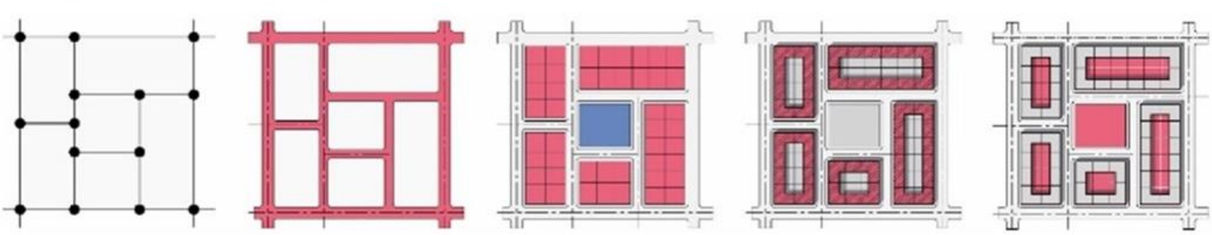
P1: Street Configuration	P2:Street Composition	P3: Plot System	P4:Building Block	P5: Open Spaces
				
• Design urban grid	• Indicate Streets width • Design Street shape • Indicate street directions	• Indicate built. • Indicate non-built (open spaces). • Plot subdivision.	• Block typology. • Extrude building heights. • Building typology	• Public open spaces (Unbuilt plots) • private spaces (Unbuilt area at each plot)

Table 1: Urban Morphology Generation Phases (by reserachers)

5.URBAN MORPHOLOGY INDICATORS (UMIS)

The indicators of each element characterize the physical dimensions of urban form. Regardless of the measured element, the term *indicators* signifies the essence of the measure, while the word *element* apprehends the nature of the component that is measured, regardless of how it is measured. The characteristics of urban form described by a mix of these two terms become consistently coherent and comparable in varied ways. Quantitative approaches to the study of urban morphology are critical for city science. Thus, the limitations and potentials of these methods must be grasped to bridge existing knowledge gaps. The use of terminology is also often unclear, and descriptions of the methods and characteristics of urban form vary in ways that are sometimes difficult to understand [26] Urban morphology is a complex topic that can be defined in terms of its spatial relations and properties and measured using several equations. These indicators calculate several morphological relations (numbers, dimensions, volumes, areas, orientations, and percentages) observed between the discrete elements of urban morphology to describe the morphology, geometry, and typology of the built environment. UMIs are used in diverse fields of study. The present study focuses on the smallest scales: the canyon and the neighborhood. Several studies have highlighted the associations between UMIs and discrete environmental conditions to obtain the most suitable UMIs for specific environmental issues. In fact, most of the extant research has attended to the environmental approach for the study of different building blocks to exemplify the connections between urban UMIs and different microclimatic conditions.

A study investigated in a compact Mediterranean city to identify the most suitable indicators for the analysis of solar energy availability on façades. They found that Gross space index GSI, Façade to site ratio (VHurb), and Sky view factor (SVF) were the most effective means of predicting the solar performance of different urban layouts. (Wei et al., 2016) altered (VFand density values to evaluate how urban morphology parameters affected microclimate variables [28]. Moreover, (Bobkova et al., 2017a) reviewed a theoretical framework to establish the fundamental morphological parameters of plot systems [16], and space syntax has been employed the as an analytical tool for the investigation of the relationships between integration, movement, and accessible building density, and to ascertain the correlation between accessible plots and diversity indicators [29]. Space syntax is a theory developed to study the spatial morphology of building and streets [30]. As is evident, previous studies have primarily evinced interest in studying urban morphology in terms of performance. The current investigation, however, collects the different indicators used in these studies and further postulates a classification of the indicators based on the elements of urban morphology.

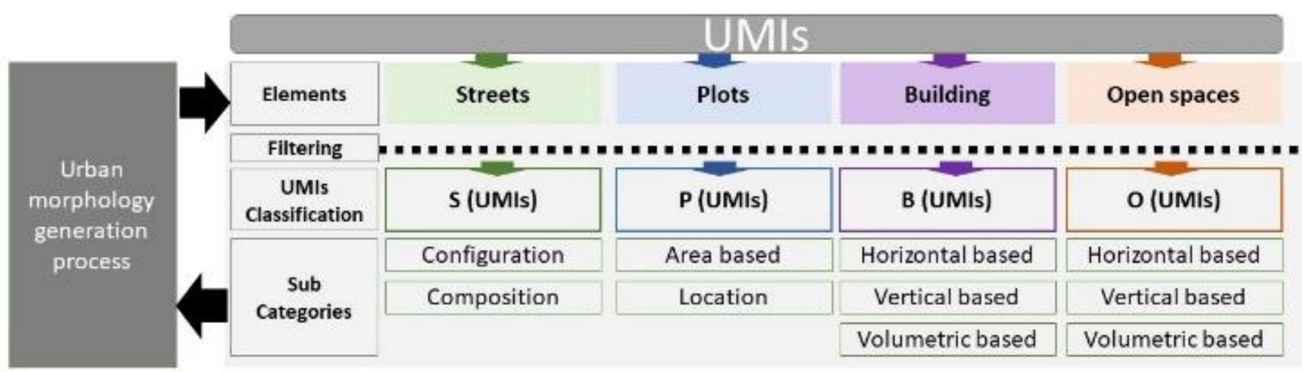


Figure 4: Urban morphology Indicators Classification Strategy (by researcher)

The present study is inclined to focus on the classification of the indicators rather than on performance measures such as environmental (solar radiation, wind speed) or social (enclosure, imageability, legibility) functioning. This study posits that the classification of indicators must denote the first step for the study and creation of urban morphology.

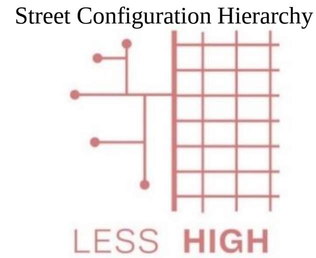
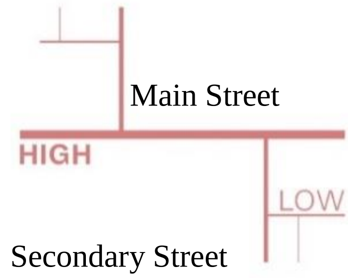
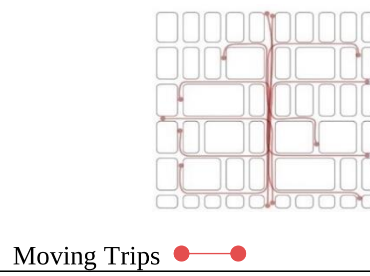
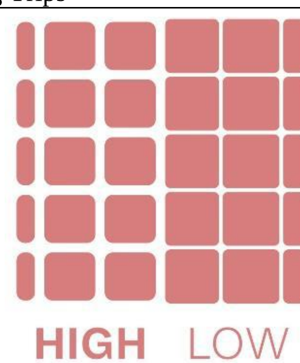
Consequently, it moots two levels of classifications: a primary position dependent on the vocabulary of urban morphology, and a secondary echelon that includes sub-categorizations for each element. For instance, the secondary levels of the street system include configuration, composition, area, and location of the plot system, while the secondary levels of the blocks and open spaces classification include vertical, horizontal, and volumetric indicators. Street configuration indicators encompass connectivity, integration, and choice, and are used to study the street grid, axial line, or segments of streets. Besides, street composition indicators are utilized for the study of the permeability of a street, a component that incorporates accessibility and visibility. Plot area indicators may be applied for the study of the compactness and openness of plot systems through the calculation of building and plot areas. Plot location indicators are employed to study the diversity of plot systems. Vertical indicators of building blocks facilitate the study of vertical surfaces (façades): for example, the façade-to-site average, the frontal area index, and the vertical height average. Horizontal indicators for building blocks help the calculation of gross floor index and floor space index and the determination of building distribution factors. Volumetric indicators assist in the measurement of the volume-area ratio and building aspects that represent the compactness of shape. Vertical indicators of open spaces are used to study the vertical associations of building façades and to study the open spaces between building façades. These measures include the SVF, the urban canyon indicator, and the rugosity indicator. Horizontal indicators of open spaces help the study of the horizontal relation between buildings to examine the Occlusivity and Sinuosity of the open spaces between buildings. Volumetric indicators assist in the assessment of the porosity of open spaces.

UMIs classification strategy depends on filtering the huge number of Indictors according to three aspects urban morphology elements, generation process, and spatial relations. At first, the research chooses the UMIs, which can be used in the urban morphology generation process. Then, four main categories of UMIs will be introduced, which will be explained in detail in the next part. The four main categories target streets, plots, buildings and open spaces as urban morphology elements. Then, UMIs will be classified according to their spatial relations, the spatial relations indicate the relations between urban morphology elements. The strategy of classification is shown in Figure 4.

5.1. Street indicators S(UMIs)

The classification of street indicators is based on the configuration and simplification of spaces (urban morphology) in a manner more convenient for analysis. (Marshall, 2005) developed the concept of the structure of a street network as a characteristic set of indicators that he named the route structure analysis. This system categorized streets on the basis of their configuration and composition [12]. Additionally, (Hillier and Hanson, 1984) proposed that axial lines and segments could be employed to measure the configurations of streets [31]. Several approaches in space syntax units according to Application scale, the axial line can be used in different scales [30]. One of the most common criticisms of axial space syntax analysis concerns its general discounting of physical distances and its assumption that the preference of people toward straight movement prevails over the choice of the shortest distance. Critiques should be aimed at the analysis of an existing urban morphology. The present study focuses on the process of the generation of urban morphology. Such a process of generation initially depends on the measurements of spatial configurations using axial lines and other features that influence the composition of streets to create street width. S (UMIs) is the first category of UMIs will be explained in **Table 2**.

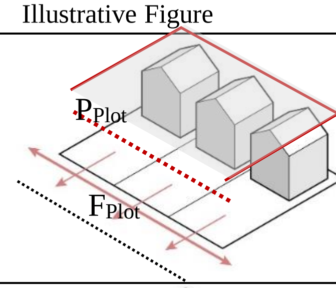
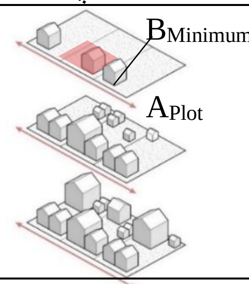
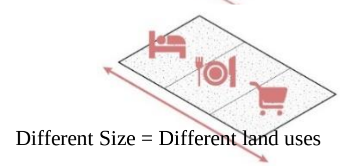
Table 2: Street Indicators: Classification, Definition and Calculation, Adapted from: [8;30;32;33].

S (UMIs)	Definition and Calculation	Illustrative Figure
Configuration Degree of centrality (connectivity)	The ratio of the number of links to the number of nodes in the network is the connectivity index. Links are street segments, while nodes are intersections **[32]**. $$Conn_A = \frac{S_t}{S_c} \quad (1)$$ S_c: the number of connected segments S_t: the number of total segments	
Configuration Closeness centrality (integration)	Closeness centrality represents the average distance, or average shortest path, to all other vertices in the network. $$Int_A = \frac{1}{Depth_A} = \frac{S_t}{\sum_0^n S_{C}*R} \quad \textbf{(2)}$$ Int: the integration value of segment A Depth A: the total depth of segment A St: the total number of segments S_C: the number of connected segments to segment A R: radius of analysis.	
Configuration Betweenness centrality (choice)	Betweenness centrality indicates how many times a vertex is located on the shortest path between two other vertices [33]. .	
Composition Permeability (Per)	Permeability can be defined as the extent to which an urban morphology is pervaded with publicly accessible space. This feature refers to the ease of travel between any two points through an urban area as well as the multiplicity of route choices. Low AwaP scores indicate high permeability within the measured area [30]. $$\text{AwaP} = \sum_{i=1}^{n} p_i * \frac{A_i}{A_t} \quad \textbf{((3)}$$ N: is the number of blocks Pi and Ai: the perimeter and area of each block i, AT: the total area of all blocks.	
Composition Accessibility (Ac)	Movement permeability: explains how the environment allows people to choose routes through and within it. In general terms, it is a measure of the opportunity for movement.	
Composition Visibility (VI)	Visual permeability: refers to the disability of the destination routes through an environment [8].	

5.1. Plots Indicators P(UMIs)

Plot indicators are based on the theoretical review introduced by (Bobkova et al., 2017a), who measured the structures using geometric terms such as openness and compactness (area-based indicators) and by the accessible number and variety of plots in configurational terms **[16]**. P (UMIs) is the second category of UMIs will be explained in **Table 3**.

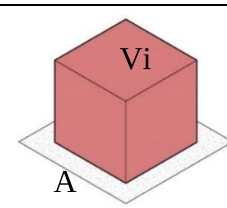
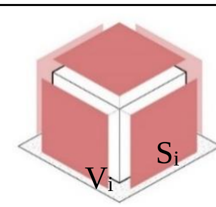
Table 3 Plot Indicators: Classification, Definition and Calculation, Adapted from [16]

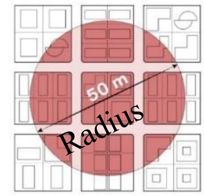
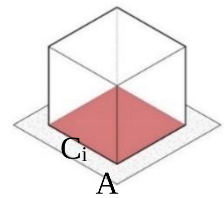
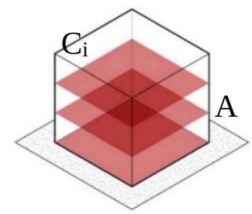
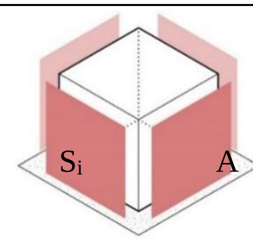
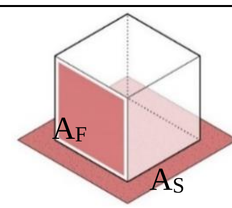
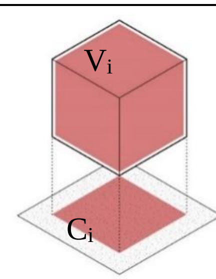
P(UMIs)	Definition and Calculation	Illustrative Figure
Area-based Plot openness	The degree of openness of each plot, for which the notion of plot frontage is essential. $O_{Plot} = \frac{F_{plot}}{P_{plot}}$ **(4)** O_{plot}: the plot openness. F_{plot}: the street frontage. P_{plot}: the plot perimeter.	
Area-based Plot compactness	The urban fabric's ability to adapt to land-use changes is related to the extent that plots can amalgamate into bigger plots or divide into smaller ones. $C_{Plot} = \frac{A_{plot}}{B_{Minmum}}$ **(5)** C_{plot}: plot compactness. A_{plot}: plot area. $P_{Minimum}$: Minimum boundary rectangle area.	
Location-based Plot diversity	The ability to incorporate difference, the measure of the number of plots and the diversity of plots in terms of sizes.	

5.2. Building indicators B (UMIs)

This study proposes three classifications for building indicators: the horizontal, vertical, and volumetric approaches, all of which are affected by building height. Horizontal indicators measure the horizontal morphological connections between the elements of urban morphology that are affected by the built areas. Vertical indicators measure the vertical morphological relation between the components of urban morphology. Volumetric indicators measure the volumetric morphological relation between the vocabularies of urban morphology. B(UMIs) is the third category of UMIs will be explained in **Table 4**.

Table 4 Buildings Indicators: Classification, Definition and Calculation ,Adapted from: [27;34; 35;36]

B (UMIs)	Definition and Calculation	Illustrative Figure
Volumetric based Indicators Volume area ratio (V/A)	The volume-area ratio expresses the building density in terms of volume units. It is measured as the ratio of the building's volume to the area of the urban site [27]. $V/A = \frac{\sum_{i=1}^{n} Vi}{A}$ **(6)** Vi: the building's volume. A: the size of the land lot. N: is the total number of buildings on that lot.	
Volumetric based Building aspects (S/V)	Building aspects (S/V) are more related to the compactness of the shape of a single building; this term defines the amount of exposed envelope per unit volume [27]. $\frac{S}{V} = \sum_{i=1}^{n} \frac{S_i}{V_i}$ **(7)** Si: the total area of building outer skin. Vi: the Building's volume. N: the total number of buildings on the lot.	

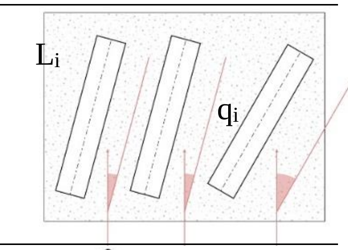
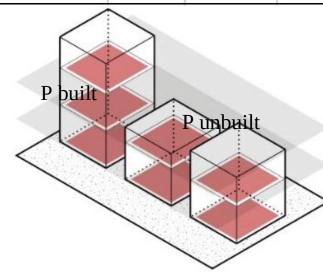
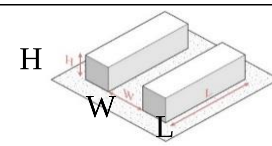
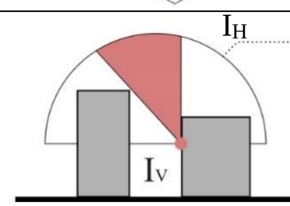
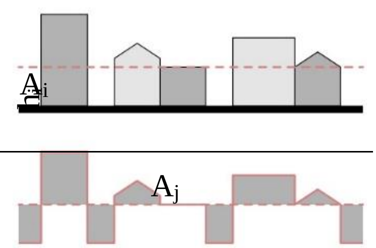
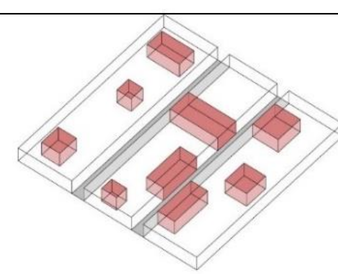
Horizontal slice-based Building distribution factor	The calculated number of buildings inside the cover radius of 50 meters [36]. $$BDF(\%)\left(1-\frac{\text{Ncluster }(d=50)-1}{100}\right)*100 \quad (8)$$ BDf: Building distribution factor	
Horizontal slice-based Gross space index (GSI)	The gross space index is defined as the ratio of the built-up area to the area of the urban site [27]. It reflects the area of a building's footprint over the area of the site [34]. $$GSI=\frac{\sum_{i=1}^{n} C_i}{A} \quad (9)$$ Ci: the building coverage area A: the size of the land lot N: the total number of buildings on the lot	
Horizontal slice-based Floor space index (FSI)	The floor space index is defined as the ratio of the area of a building's total floor space to the size of the piece of the land [27]. $$FSI=\frac{\sum_{i=1}^{n} C_i * L}{A} \quad (10)$$ Ci reflects the coverage area of building L: the number of floors A: the size of the land lot N: number of buildings.	
Vertical -based Façade to site ratio (VHurb)	The façade-to-site ratio is an index of vertical density for the urban texture. It is the ratio of the total façade area of the building to the area of the urban site. VH_{urb} is proportional to the extent of vertical surfaces in the urban area [27]. $$VHurb=\frac{\sum_{i=1}^{n} S_i}{A} \quad (11)$$ A: the size of the land lot Si: total Surface Area	
Vertical -based Frontal area index (FAI)	The frontal area index alludes to a building's frontal area over the area of a site and is calculated [34] . $$FAI=\frac{A_F}{A_S} \quad (12)$$ AF: the total area of frontal façade. As: total area [35].	
Vertical -based Average building height (Hbuild)	The average building height (verticality) is calculated as the ratio of the buildings volume to the built-up area [27]. $$Hbld=\frac{\sum_{i=1}^{n} Vi}{Ci} \quad (13)$$ Ci: reflects the coverage area of building i Vi: the building's volume N: the total number of buildings on a land lot [34].	

5.3. Open Spaces Indicators O(UMIs)

This study proposes three classifications for the indicators of open spaces: the horizontal, vertical, and volumetric approaches, all of which are affected by building height. Horizontal indicators measure the horizontal morphological connections between the elements of urban morphology that are affected by the built areas. Vertical indicators measure the vertical morphological relation between the components of urban morphology. Volumetric indicators measure the volumetric morphological relation between the vocabularies of urban morphology.

Table 5 Open Space Indicators: Classification, Definition and Calculation Adapted from: [27;37;38;39;40;41;42]

O(UMIs)	Definition and Calculation	Illustrative Figure

Horizontal slice-based Sinuosity (SI)	The angle of change of space denotes sinuosity. In the case of a flow normal to the street, the sinuosity is equal to zero, which is consistent with the fact that this street can be the azimuth of the linear segment I [39]. $SI = \frac{AL_i * cos^2 q_i}{AL_i}$ **(14)** Li: the length of the linear segment i Qi: the angle between the given azimuth (of flow)	
Horizontal slice-based Occlusivity (Oc)	The average of urban spaces openness to the sky [40]. The distribution of built elements against the height above ground, It is calculated by way of a series of horizontal cuts of the urban fabric. $Oc = \frac{1}{N_H} \sum_N \frac{P_{built}}{P_{unbuilt}}$ **(15)** N_H: the number of horizontal cuts P_{built}: the built perimeter for the current cross section. $P_{unbuilt}$: the unbuilt perimeter for the current cross section [41].	
Vertical slice-based urban canyon (UCI)	The ratio of building height to road width (H/W). It is a simplified model for the study of urban geometry [42].	
Vertical slice-based Sky view factor (SVF)	SVF is calculated as the mean value of the ratio of the solid angle of the visible sky from each point of the façades to the sky vault [27]. $SVF = \frac{I_V}{I_H}$ **(16)** I_V: the ratio of the solid angle of the visible sky I_H: the sky vault.	
Vertical slice-based Rugosity (RU)	Absolute rugosity represents the average height of the urban canopy. Relative rugosity describes the variance of the average height of the urban canopy (including constructed and non-constructed elements) from the given direction. $\boldsymbol{H_m} = \frac{\sum_{built} \boldsymbol{A_i h_i}}{\sum_{built} \boldsymbol{A_i} + \sum_{nonbuilt} \boldsymbol{A_j}}$ **(17)** H_m :absolute rugosity Ai :area of building element i Hi: height of building element i A_j: area of non-building element j $R_\alpha = \frac{\sqrt{\sum_i (h_j - h_\alpha)^2 * I_i^2}}{\sum_i I_i}$ **(18)** $\boldsymbol{h_\alpha}$:average height of urban canopy of from the direction α $\boldsymbol{R_\alpha}$:relative rugosity $\boldsymbol{h_i}$:height of urban canopy (including construction and non-construction elements) $\boldsymbol{I_i}$:average height of urban canopy from the direction of i $\sum_i I_i$: equivalent diameter of urban canopy	
Volumetric indicators Porosity (Po)	Porosity is the ratio between the open volume and the total volume of a certain area [38]. A further indicator of porosity measures the ratio of the open space against the total urban area [37]. $Po = \frac{\sum_{openspaces} \pi r_{hi}^2 * L_i}{\sum_{openspaces} V_j + \sum_{built} V_i}$ **(19)** Li: Length of the open space i. r_{hi}: Equivalent hydraulic radius of the open space i. Vi: Mean volume of the built volume j. Vj: Mean canopy volume above open.	

6.DISCUSSION

Although there are several studies interested in using UMIs to test several performance (radiation, wind speed, or thermal comfort), there are a lack of studies which take in to count the the importance of the usage of UMIs in urban morphology generation. The research find that almost of urban morphology generation studies used GSi, and FSi. In addition, several studies used centrality indicators in urban morphology generation.

The most remarkable point to discuss is that the research proposed a classification of UMIs could be used in urban morphology generation. The classification depends on three factors. The first is urban morphology elements, the second factor is urban morphology generation process, and the third is spatial relations between urban morphology elements. As shown in Figure 5, the classification of UMIs includes four main categories:

S(UMIs) are used in the streets generation process, it includes two sub-categories streets configuration (grid system) and street composition which represent the final shape of streets. Streets configuration indicators based on space syntax theory, the street composition is a calculation of streets permeability depends on several equations.

P(UMIs) are used in the Plot generation process, the classification is based on BOBKOVA concept, which classified UMIs in two categories. The first one is area-based, which represents the relationship between buildings and plot or streets and plot. The second category is location-based, which represents the relation between several plots.

B(UMIs) are used in building block generation. The classification is based on the spatial relation

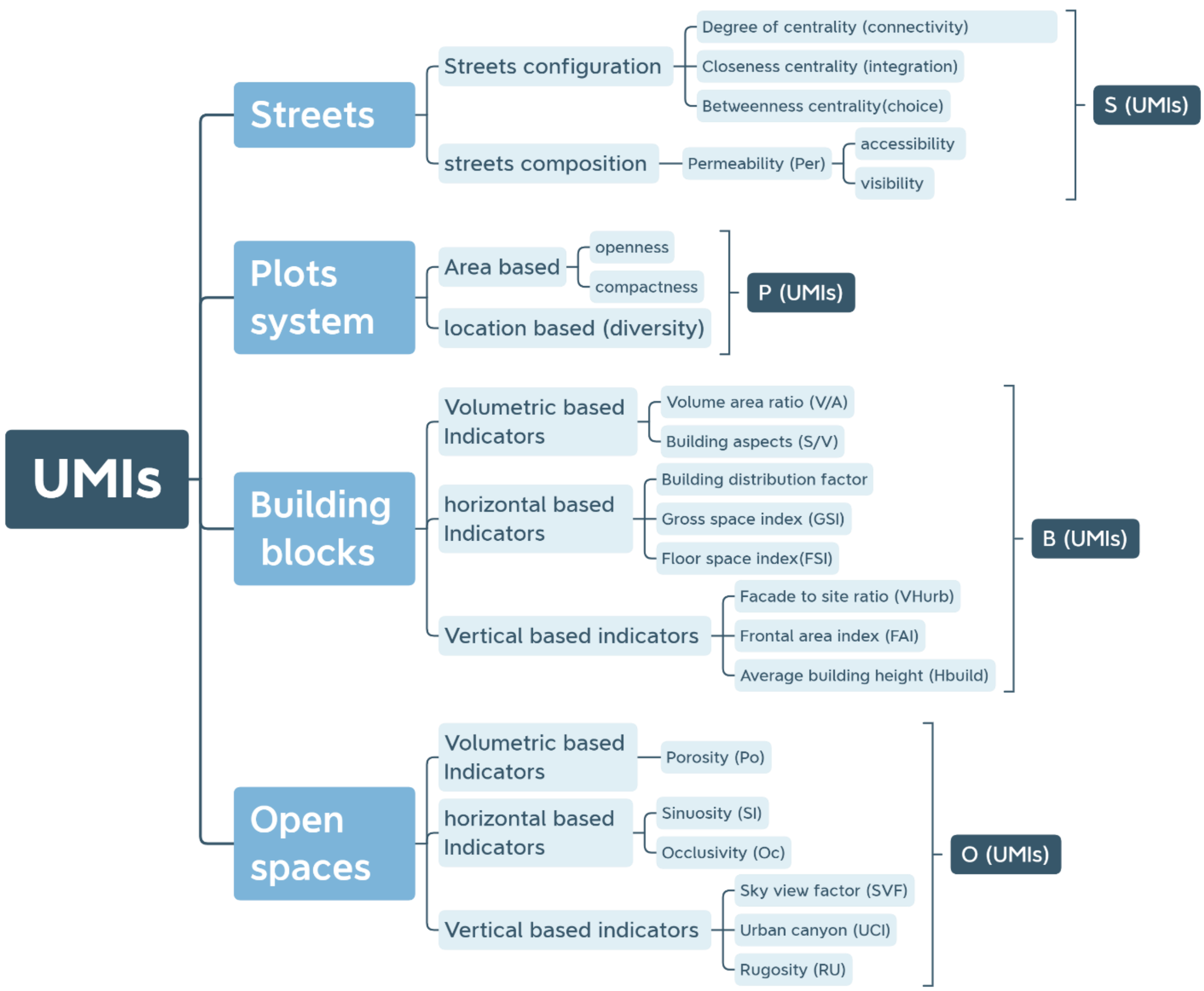


Figure 5: UMIs Classification (by researchers)

between building blocks. Horizontal-based UMIs are used in the general building at a horizontal level as density indicators, the distance between buildings. Vertical-based UMIs are related to building height. Volumetric UMIs represent the relation between building volume and built area or facades area.

O(UMIs) are used in open spaces generation. The classification is based on the spatial relation between open space borders. Horizontal-based UMIs represent open spaces distributions in horizontal. Vertical-based UMIs are related to building height. Volumetric UMIs represent the relation between open spaces dimensions and outer border dimensions.

7. CONCLUSION

As an academic discipline, urban morphology must be subjected to an in-depth analysis to apprehend and recognize the differences and overlaps between this discipline and numerous other converging domains. The generative design facilitates the appropriate addressable of varied urban issues and assists designers in shaping successful solutions for the difficulties through traditional of innovative methods of generation. As previously stated, the present study aims primarily to simplify the generative process of the urban morphology of cities. To achieve this objective, this study outlined a classification of urban morphology indicators used in urban morphology generation. S(UMIs) include connectivity, integration, choice, and permeability. P(UMIs) include Openness, compactness, and diversity. B(UMIs) include V/A, S/V, BDF, GSI, FSI, VHurb, FAI, and Hbuild. O(UMIS) include Po, Si, Oc, SVf, UCI, and Ru.

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Mostafa M. Elzeni: Generating the idea, Collecting data, Methodology & Original draft preparation, **Ashraf A. Elmokadem:** Reviewing & Supervision, **Nancy M, Badawy:** , Methodology ,Validation, Editing, Reviewing & Supervision.

DECLARATION OF COMPETING INTEREST:

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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