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Developing a Derivative Model for the Environmental Flow Index and Exploring its Applications in Modern Urban Contexts

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Abstract. This study develops a derivative model for the Environmental Flow Index (EFI) to evaluate the relationship between urban porosity and environmental flow in high-density urban areas. The model was applied to Sadr City in Baghdad, focusing on the city's unique challenges, such as overcrowding, poor ventilation, and environmental degradation. Using computational simulation tools such as ENVI-MET 5.7 and AutoLISP, the study analyzed environmental variables, including wind speed, temperature, relative humidity, and radiant heat, under two scenarios: the current state with 30% urban porosity and a modified state with 40% porosity.The results demonstrate that increasing urban porosity significantly enhances environmental flow, reflected in improved wind circulation, reduced thermal stress, and better outdoor thermal comfort. For instance, wind speed increased from 2.798 m/s to 6.2361 m/s, while relative humidity decreased by 0.394%, showing a positive correlation with higher porosity levels. The EFI model effectively integrates these variables, offering a standardized and scalable metric for measuring environmental flow. The research contributes valuable insights for urban planners and policymakers, supporting the development of sustainable and livable cities in Baghdad and similar urban contexts.

Keywords: Environmental Flow Index, Environmental flow, Urban porosity, Urban context.

1. INTRODUCTION

Cities around the world are growing at an unprecedented rate, and this rapid urbanization is transforming natural landscapes in ways that have significant environmental consequences. As urban areas become more crowded, the spaces for green infrastructure, like parks and vegetation, and blue infrastructure, such as rivers and ponds, are shrinking. This not only changes the look and feel of cities but also disrupts important environmental systems, including air circulation, heat transfer, and water flow. These disruptions have a direct impact on outdoor thermal comfort, making many cities less livable, especially in regions with extreme climates [1], to address these challenges, urban designers and researchers are paying closer attention to urban porosity. This concept describes how open or permeable an urban area is to environmental flows like air, heat, and light. Higher urban porosity generally allows for better ventilation and thermal regulation, while lower porosity can trap heat and worsen urban heat islands. These effects are particularly noticeable in places like Iraq, where intense heat and dense urbanization create harsh outdoor environments (Oke 1988, 733–746), This paper introduces the Environmental Flow Index (EFI), a new tool for measuring and understanding the relationship between urban porosity and environmental flows. The EFI combines several key factors, such as wind speed, relative humidity, outdoor temperature and urban porosity, to give architects, urban planners, and researchers a simple but effective way to evaluate the environmental performance of any given area. This approach is not just theoretical—it's designed to be practical and easy to use, making it accessible for professionals and students alike, to demonstrate how the EFI works, this study applies it to Al-Sadr City in Baghdad, Iraq. With its dense population and harsh climate, Al-Sadr City serves as a perfect example of why understanding environmental flows is so critical. By exploring how urban porosity affects outdoor thermal comfort in this context, the study aims to highlight practical solutions for creating more sustainable and livable urban environments.

In the end, the goal is to provide a new framework that not only advances research on urban porosity and environmental flows but also equips professionals with the tools they need to design better cities.

2. DEFINITION OF URBAN POROSITY CONCEPT

According to Arabic dictionaries and lexicons, porosity linguistically refers to a property or characteristic of objects represented by pores or openings that serve as channels for movement, transfer, and absorption within a material or specific medium. It also denotes the ratio of void spaces to the original volume of the mass. Scientifically, as per physics and the IMM Laboratory, porosity is defined as the measure of void spaces ("empty") within a material. It is expressed as the ratio of void volume to the total volume, ranging between 0 and 1, or as a percentage between 0% and 100%. Porosity represents a layered arrangement of volume, voids, and transfer links. For example, a sponge illustrates porosity through the water it can hold in its void spaces. Porosity also reflects the strength and cohesion of a material, as high porosity generally reduces material strength and durability (Valva, 2016, p. 61). Furthermore, it highlights the permeability properties in different tissues, emphasizing the importance of the shape, size, and distribution of pores and their connectivity, which collectively affect the strength and cohesion of various structures and materials.

From an architectural and urban planning perspective, porosity refers to integrating voids into the built

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environment to enhance ventilation, lighting, and connectivity, reflecting a balance between nature and the built environment. This concept emerged as a reaction against rigid, solid architectural forms, emphasizing openness and interaction between humans and cities. In their article *Naples* (1925), Benjamin and Lacis explored porosity by studying Naples, Italy, describing the intertwined relationship between the built environment and nature, stating that "architecture is as porous as rock." This highlights the blending and merging of spaces without clear boundaries, fostering social interaction (Naples and Lacis, 1925, 165-166).

The roots of porosity trace back to traditional architecture, where elements such as courtyards and mashrabiyas were introduced to improve environmental conditions (Bianca, 2000). In the modern era, architects like Le Corbusier advocated for "open plans" to create more permeable structures (Frampton, 1992). In urban planning, concepts like Ebenezer Howard's Garden City emphasized environmental balance (Howard, 1965). Wolfrum et al. (2018) presented porosity as an urban agenda promoting interaction between physical and social spaces, calling for more open and interconnected cities. Similarly, Sennett (2018) emphasized porosity as a tool for urban integration.

In recent decades, porosity has been redefined to address challenges like urban heat islands, incorporating perforated facades and green roofs to enhance thermal comfort and reduce the carbon footprint. Projects such as *Sendai Mediatheque* by Toyo Ito and *8 House* by BIG showcase innovative applications of architectural porosity (Ito, 2009; BIG, 2010).

Physically, porosity refers to the appropriate ratio of voids within high-density urban fabrics, both horizontally and vertically, and their capacity to accommodate public uses and flows that affect the area and its surroundings. Strategically, porosity is an urban strategy for addressing issues of urban fragmentation and connecting areas of varying urban morphology. It activates urban spaces through flexible, connected edges and proportionate density. Socially, porosity enhances social and economic synergy within specific areas, providing spaces for people to meet and interact. Environmentally, it serves as a morphological indicator of environmental performance, alongside roughness and urban density, aiding in the enhancement of environmental flow.

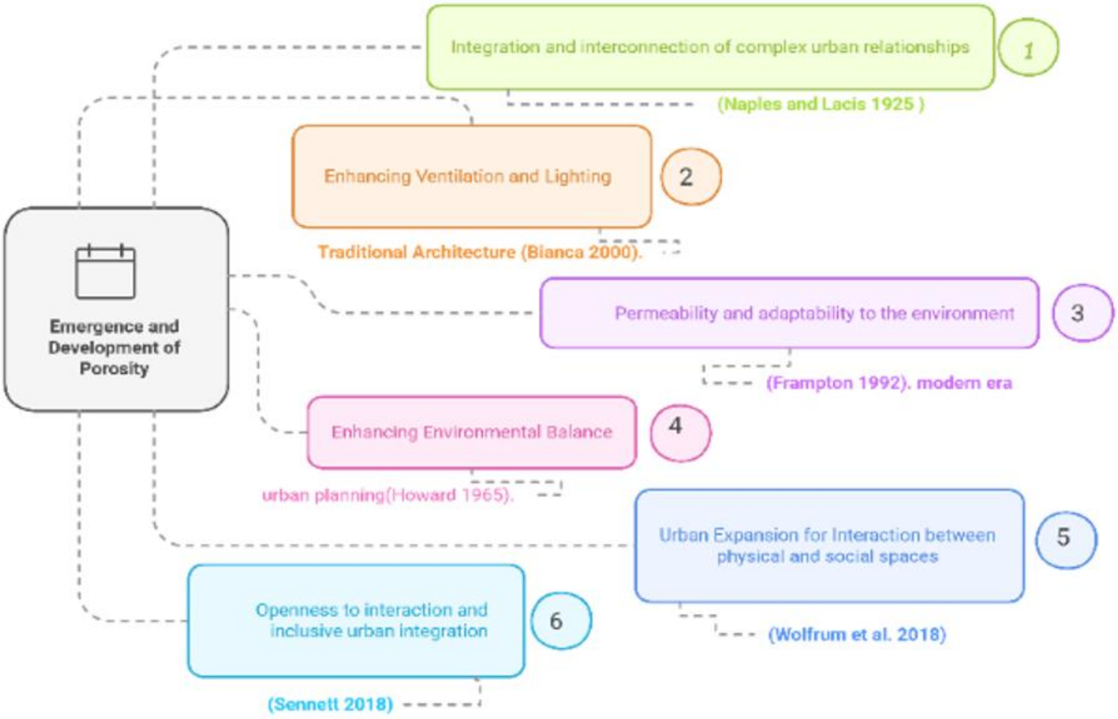

Figure 1: Emergence and development of porosity.

3. DEFINITION OF ENVIRONMENTAL FLOW CONCEPT

The term "flow" linguistically refers to the concept of continuous and homogeneous movement, characterized by regularity and directionality. This movement occurs seamlessly and involves the consistent transfer of energy or materials in a coordinated and smooth manner. It represents the transition of objects from one point to another in a fluid and organized way. From a terminological perspective, flow appears as a multidisciplinary concept that refers to the continuous movement of materials, energy, or information across different environments or media. In Earth sciences, flow is defined as the movement of water or chemicals through rocks or soil, such as groundwater flow, which is essential for understanding geological phenomena like erosion (Freeze and Cherry, 1979). In physics, flow relates to the continuous movement of particles or energy, such as the flow of heat, electricity, or fluids, measured by the amount of material or energy passing through a unit area over time (Landau and Lifshitz, 1987).In chemistry and fluid mechanics, flow is understood as the movement of particles or fluids under the influence of forces, often described using equations like the Navier-Stokes equations to study the motion of viscous fluids (Batchelor, 2000). In engineering, flow is used to understand the transfer of fluids or gases within mechanical systems or air ducts, as well as to study hydraulic flow in dams and water channels and thermal flow in structures (White, 2016). In medicine and biology, flow refers to the dynamic movement of blood or bodily fluids through blood vessels or tissues, essential for understanding blood circulation and pressure (Hall, 2015). In sociology, flow refers to the movement of individuals or ideas, including the transmission of information and cultural values, and how they influence social dynamics (Castells, 2010). In art, flow represents the sense of movement and fluidity depicted in artwork, such as through flowing lines or colors (Arnheim, 1974).

Moreover, flow, as defined by Mihaly Csikszentmihalyi, is a psychological state characterized by high concentration and productivity, occurring when an individual becomes fully immersed in a challenging and engaging activity. Flow represents a harmony between the challenges faced by the individual and their skill level and is based on several core models.

The Flow Model (Csikszentmihalyi, 1990) focuses on achieving a balance between task challenges and the individual's expertise, where flow occurs when skill levels and challenges align. The Dualistic Model (Swann and Pittman, 1995) links flow to the balance between internal experiences and external environmental demands, emphasizing the importance of feedback in enhancing performance. The Cognitive Model (Nakamura and Csikszentmihalyi, 2009) highlights the role of attention and focus on the task, identifying components such as challenge-skill balance, clear goals, immediate feedback, loss of self-consciousness, and time transformation, all of which contribute to full engagement in an activity.

Lastly, the Self-Determination Theory (Ryan and Deci, 2000) proposes that flow occurs when an activity aligns with an individual's values and interests, fostering a sense of autonomy and intrinsic motivation. Thus, flow is a deeply enjoyable experience that enhances creativity and productivity.

Given that certain environmental factors exhibit flow characteristics, the transfer, interaction, and transformation of these factors in response to urban changes can be referred to as environmental flow. These factors will be further elaborated upon in the following paragraph.

4. ENVIRONMENTAL ELEMENTS ASSOCIATED WITH THE CHARACTERISTIC OF FLOW, TRANSITION AND MOVEMENT

Based on the linguistic and technical concepts of flow mentioned above, in addition to previous theories and studies, environmental elements with the property of continuous movement and transition are linked to the concept of environmental flow, which will be adopted in later measurements of [wind speed, temperature, relative humidity] as follows:

a. Wind speed (W): refers to the rate at which air moves in the environment, typically measured in meters per second (m/s) or kilometers per hour (km/h). Wind influences thermal comfort by providing a cooling effect in warm environments through increased evaporation and convective heat loss. Conversely, high wind speeds in cold environments amplify heat loss from the body, intensifying the sensation of cold, especially in winter when wind chill becomes more noticeable (Givoni 1998)

b. Temperature (T): is a key factor in thermal comfort, directly affecting the body's ability to maintain thermal balance through physical processes such as radiation, conduction, and evaporation. High temperatures increase sweating, which can lead to heat stress in humid environments. Conversely, low temperatures cause heat loss through vasoconstriction and shivering. The optimal temperature range for thermal comfort is between 20°C and 24°C, though it varies with physical activity and clothing. High humidity reduces the body's ability to cool itself through evaporation, increasing the sensation of heat, while wind enhances cooling. Radiant heat from surrounding surfaces further amplifies the perception of heat (Oke 1987).

c. Relative humidity (RH): is the amount of water vapor in the atmosphere and is an environmental factor influencing environmental flow and human thermal comfort. Humidity affects the body's ability to cool itself; high humidity hinders sweat evaporation, increasing the feeling of heat, while dry air enhances natural cooling. Humidity levels vary based on climate, vegetation, and soil conditions, being higher in coastal areas and lower in deserts. The ideal humidity range is between 30-60%, as lower levels cause dryness and increased thirst. Humidity impacts heat transfer through convection and supports cooling through sweating and evaporation (Kuismanen 2008)

From the above, it is evident that environmental factors do not operate independently but interact with one another in shaping the environment. For instance, wind facilitates the distribution of heat and solar radiation, while relative humidity can limit the effectiveness of these factors in enhancing thermal comfort. Thermal comfort, as a crucial metric for evaluating environmental flow in urban settings, is significantly influenced by air circulation and heat distribution. These dynamics directly impact individuals' sense of comfort in their surroundings, which in turn affects their movement and presence in urban spaces.

5. LITERATURE REVIEW

5.1. Previous Studies

The study by Ameijde and Song (2018) explored the design of a pedestrian-oriented city using generative methodologies focusing on porosity to enhance urban quality of life. The city incorporated mixed functions (embassies, companies, housing) and balanced building density with open public spaces to support social and economic interactions. Using "Octopus" software, urban blocks were analyzed and designed based on sunlight exposure, land use, and block geometry, creating hybrid activity zones. The study emphasized the importance of distributing spaces and functions to foster interaction and achieve flexible, multifunctional urban design.

The study by Du, Mak, and Tang (2018) investigated the impact of building heights and porosity on wind flow and thermal comfort for pedestrians using CFD simulations. Nine buildings in high-density Hong Kong were studied. Results showed that increased building heights improved wind speeds in side areas but reduced them in sheltered zones, while greater porosity enhanced wind comfort. The study recommended varying building heights and increasing porosity to improve outdoor thermal comfort.

Tadi and Zadeh (2017) examined porosity as an intrinsic morphological feature of urban systems, integrating volume and void to balance ecological sustainability and energy performance in urban fabrics. Using the IMM laboratory model, they analyzed four components (built environment, urban spaces, spatial functions, access routes) and six spatial properties (porosity, diversity, accessibility, exterior surfaces, effectiveness, proximity). Mathematical equations defined porosity values between 0% and 1%. The study, conducted in Lombardy, Italy (historic core, surrounding zones, and suburbs), found strong correlations between porosity and urban morphology, highlighting its influence on connectivity, pedestrian flow, functional distribution, and traffic patterns. The city's morphology was likened to a "DNA" encoding its spatial characteristics, while in Stevens (2022) analyzed urban porosity as a metaphorical tool to study the interaction between urban spaces and social integration. Focusing on the Congolese Matongé district in Brussels, the study combined historical and spatial analyses, tracing urban development from the 11th century to modern times. It showed that urban porosity fosters flexibility and connectivity in urban spaces through galleries and corridors, supporting diverse uses and inclusive urban interactions.

The study by Lee, Jusuf, and Wong (2015) explored how varying building heights in residential complexes impact airflow, wind speed, and ventilation quality using CFD simulations. Focusing on Singapore housing estates, the study found that staggered building heights improved airflow at mid-levels and enhanced thermal comfort, while excessive variation at ground level caused turbulence, reducing ventilation and increasing heat accumulation. The study recommended staggered building designs to optimize urban airflow.

From the above studies and their applications, it can be concluded that the concept of urban porosity is an urban strategy and a key principle in modern urban design that aim to create more interconnected, accessible and breathable cities while the environmental flow refers to the movement and exchange of natural elements such as air, heat, water, and light within an urban or architectural context. It encompasses the dynamic processes that influence thermal comfort, ventilation, and ecological balance in urban environments, According to previous discussions and studies, environmental flow is affected by factors such as urban porosity, building heights, relative humidity, wind speed, and spatial configurations. It plays a critical role in mitigating urban heat islands, enhancing outdoor thermal comfort, and improving overall environmental quality in dense urban areas & it's considered an applied mechanism on the presence of porosity.

6. “EFI” EQUATION AND ITS DERIVATION

- Initially, the method for measuring urban porosity will be presented. Urban porosity can be measured mathematically using the IMM model through the following equation:
- Porosity = (A_open / A_total)
- Where A_open represents the area of open spaces such as parks, vacant lots, and urban voids, while A_total refers to the total measured area of the urban fabric within the case study.
- It can also be calculated programmatically using various software, such as Geographic Information System (GIS), QGIS, and ArcGIS, as well as through automation using AutoLISP to automate the process of identifying areas and calculating urban porosity. The resulting value is unitless, represented either as a plain numerical value or as a percentage.
- The Environmental Flow Index (EFI) can be determined by integrating factors related to flow, such as wind speed, air temperature, thermal comfort, and humidity levels. A potential simplified formula can be expressed as follows:

$$\underline{EFI=(P,RH,W,T)}$$

- The Relationship Between Urban Porosity and Environmental Flow: Urban porosity directly affects wind circulation and thermal comfort by increasing air movement and enhancing cooling through green spaces (positively correlated). Therefore, it can be hypothesized that a higher porosity value (P) increases environmental flow. It is also assumed that combining flow factors and multiplying them by the porosity ratio results in the environmental flow for those factors within the specified porosity. An increase or decrease in flow factors will be reflected accordingly, as indicated in the theoretical framework. The proportional relationships can be summarized as follows: (Wind — Positive correlation), (Temperature — Negative correlation), (Relative Humidity — Negative correlation), and so on. This will be tested in the third chapter of the scientific study.

- Since the values of the factors in the above equation are expressed in different units (e.g., porosity is dimensionless as a ratio of open space; W = wind speed in meters/second; T = temperature in Celsius or Kelvin; H = humidity as a percentage or absolute value), it becomes essential to normalize each factor [T, W, H] into unitless values. This is achieved using Linear Normalization, as described by Hwang and Yoon (1981), and is represented as follows:

$$x_{norm} = \frac{x - x_{min}}{x_{max} - x_{min}}$$

- Range of EFI Values:

Since this equation relies on environmental variables that vary based on climatic and geographical conditions, EFI values can range widely, typically falling between 0-1 after mathematical normalization using the Linear Normalization equation. The ranges are defined as follows:

- Minimum Values: Occur when wind speed is at its lowest levels, and urban porosity is low (below 0.3).
- Maximum Values: Occur when these factors are at their highest levels, with high urban porosity (above 0.7).
- Moderate Acceptable Values: Typically range between 0.4-0.6.

- The Environmental Flow Index Equation:

$$EFI = P\,(RH+W+T)$$

7. METHODOLOGY AND APPLICATION

a. The case study of Al Sadir City: it's located in eastern Baghdad, spans approximately 30 km² and housed an estimated 2.99 million people in 2012 (Central Bureau of Statistics/Iraqi Ministry of Planning), with higher estimates by the United Nations in 2018. It is a densely populated district characterized by limited infrastructure and predominantly low-income residents, facing challenges such as poverty, unemployment, and inadequate services. The urban fabric reflects a mix of rural and modern cultural influences, with informal development being common. Construction often occurs gradually, leading to uncoordinated growth, a lack of public spaces, and deteriorating infrastructure. Many older buildings suffer from overcrowding, poor maintenance, and substandard construction, with insufficient sanitation, unreliable electricity, and limited access to healthcare and education contributing to poor living conditions. Recent urban renewal projects have aimed to improve infrastructure, housing quality, and public spaces, but the imbalance between housing demand and urban quality persists.The urban design of Al-Thawra City consists of 80 modern sectors, each covering around 200,000 m². Each sector is divided into two residential neighborhoods with 28 to 32 housing blocks and about 1,000 houses per sector. Houses have a standard area of 144 m² (7m × 20m) (Alaqili, 2010). The sectors are designed as integrated units with essential services and a low skyline. Building heights range from two-story residential houses to three- or four-story mixed-use buildings (commercial-residential) (Alousi, 1980).

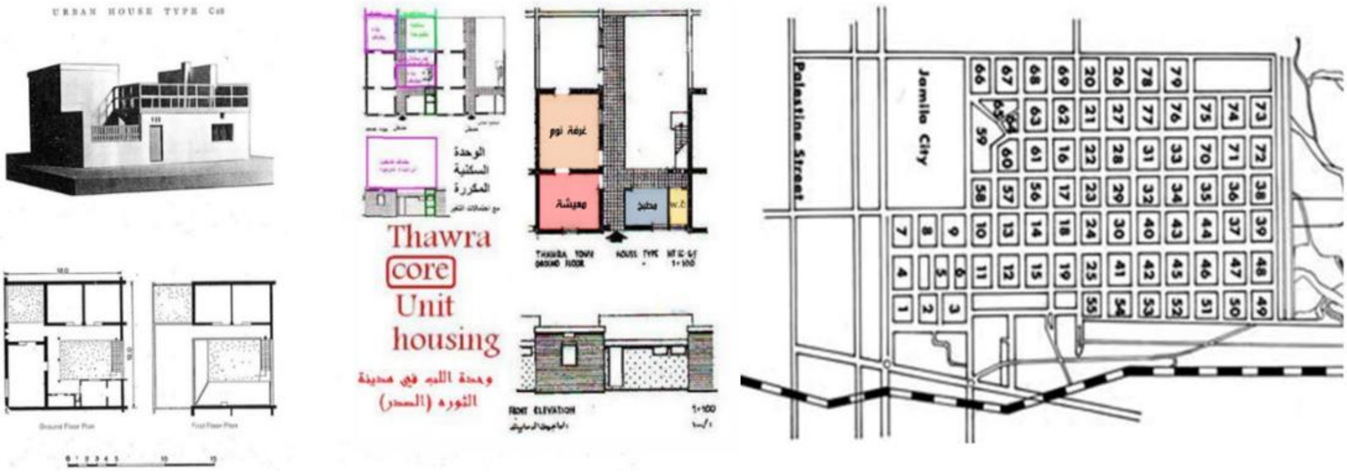

Figure 2: The layout of a single sector in Sadr City and the proposed plan for residential units. Source: Pyla, Panayiota. "Back to the Future: Doxiadis's Plans for Baghdad." *Journal of Planning History* 7, no. 1 (2008): 3-19.

- The site selection includes the following coordinates:
- The area chosen is Sector 10-71, specifically (Souq Al-Oura within Sector 71).
- Site coordinates (CF46+63 Baghdad):
- Longitude = 44.460227° (E), Latitude = 33.405566° (N)

- The residential block area for measurement is 205m × 300m, including residential blocks, a mosque, and primary and secondary schools.
- Measurements are taken for September 22, 2024 (Fall/Autumn Equinox), when day and night become nearly equal in length.
- The site is characterized by the presence of Souq Al-Oura, known for its congestion and the closure of most streets in the area and residential block.

Souq Al-Oura: Located within Sector 71, Souq Al-Oura is a prominent market in Sadr City, Baghdad, Iraq. The history and development of this market are closely tied to the growth and changes in Sadr City itself. It originally emerged as an informal, self-organized market established by local residents along the main street of the sector. Over time, it expanded gradually, consisting of temporary stalls and shops with simple structures and poor infrastructure, causing (urban-environmental) pollution in the street and surrounding area. The Baghdad Municipality has since reopened the previously closed street by clearing Souq Al-Oura and removing illegal structures. However, the market is currently under threat of removal.

- The area defined below is 300m × 300m, including residential units, Souq Al-Oura, and the surrounding internal and peripheral streets.

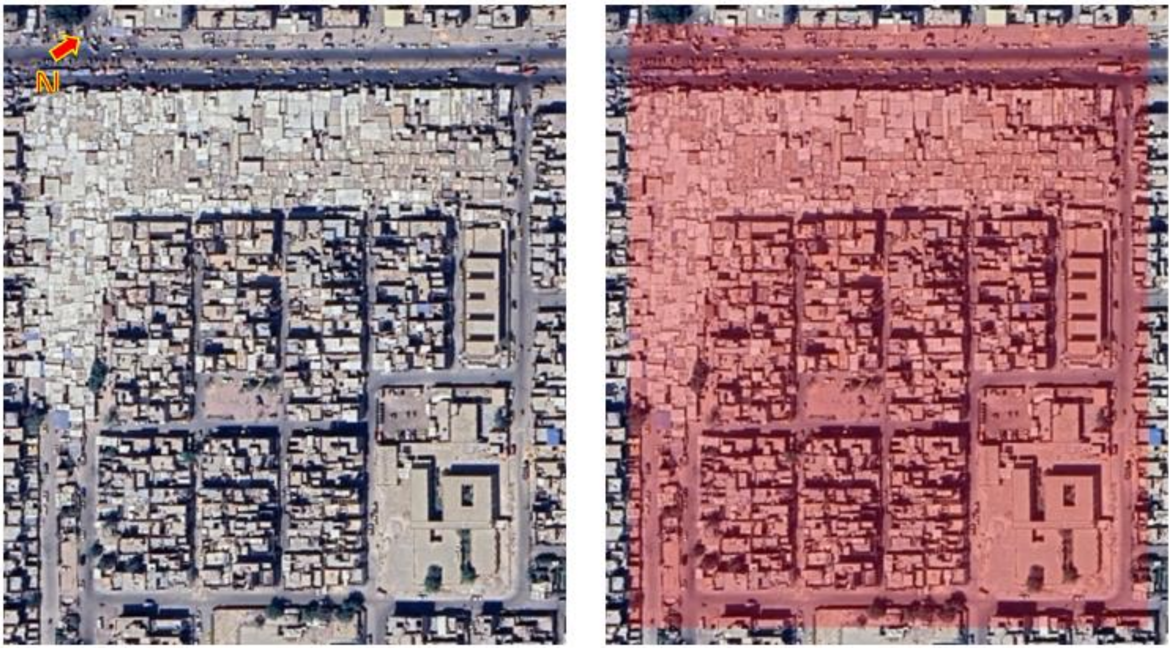

Figure 3: Aerial view of the study sample from Sadr City.
Source: (https://earth.google.com/).

7.1. Calculating The Urban Porosity Percentage And (EFI) Application Before

- P= The measured porosity of the current state using automation and simulation programs (AutoLISP) for the study sample = (30%).
- The sample was simulated environmentally using the (ENVI-MET 5.7) software, yielding values for [temperature, wind speed (W), relative humidity (RH), mean radiant temperature (MRT), and wind flow in various directions and dimensions (flow u, v, w)]. This was achieved by inputting site parameters, including coordinates, measurement area, date and time as mentioned above, and specifying the measurement height within the program inputs (k=3.5m) to assess the aforementioned indicators at the pedestrian level in the outdoor environment.
- The environmental flow equation will now be applied based on the calculated environmental results and data obtained from the software.

$$EFI = P_{before}(RH + W + T)$$

$$EFI = 0.3(0.549 + 0.137 + 0.052)$$

$$= 0.3(0.738) \longrightarrow = 0.221 \longrightarrow EFI \cong 0.2$$

7.2. Calculating The Urban Porosity Percentage and (EFI) Application After

- Porosity factors at the building, street, and urban void levels in the case study will be modified using specific mechanisms like: Multi-story rectangular buildings (2-3 floors) will be added, aligned with the prevailing wind direction to enhance airflow and reduce thermal stress, while green spaces and trees will improve air circulation and the sky view factor. Informal market buildings will be removed to create urban voids, addressing urban and environmental distortions, and replaced with multi-purpose buildings to restore commercial functionality. These interventions are minimal and cost-effective, designed to activate the area after removing informal structures. The increased openness will enhance the sky view factor, contributing to environmental and aesthetic benefits. The market area will be transformed into a transitional zone, maintaining its activity while facilitating a gradual shift from residential to commercial uses and connecting surrounding blocks with main streets. Additionally, the internal square within the residential area will be revitalized through landscaping and tree planting, improving its environmental and urban functionality. This approach aims to balance sustainable regeneration with environmental and functional improvements.

- P= Measuring the porosity of the sample after urban (morphological) changes and modifications using automation and simulation programs (AutoLISP) for the study sample = (40%).
- The environmental flow equation will now be applied based on the calculated environmental results and data obtained from the software.

$$EFI=P_{After}(RH+W+T)$$

$$EFI=0.4\,(0.795+0.307+0.064)$$

$$=0.4(1.166)\longrightarrow =0.466\longrightarrow EFI\cong 0.5$$

8. RESULTS

Environmental Simulation Results of the (ENVI-MET 5.7) software in the schedule: -

Table 1:

Factors	Before	After
Urban Porosity P	%30	40%
Temperature T	35.947	35.884
Wind speed W	2.798	6.2361
Relative Humidity RH	22.135	21.741
Wind Speed Change(%)	18.48	38.905
MRT	30.859	30.273
Flow u (m/s)	2.283	1.1006
Flow v (m/s)	1.6176	6.1265
Flow w (m/s)	0.0000060002	0.37982

8.1. Temperature(T)

The results showed that air temperatures in the area, specifically at the studied point in Sector 71 of Sadr City (the market) during the afternoon, were 35.947°C before the changes. After increasing porosity, the temperature decreased by 0.063°C, reaching 35.884°C. This reduction was observed across the sample, as illustrated in the thermal simulation images attached in Appendix (A). The decrease is attributed to increased openings, airflow exposure, and additional greenery in the area.

8.2. Wind Speed (W)

The simulation results indicated that wind speed increased from 2.798 m/s to 6.2361 m/s, with an improvement of 3.4381 m/s. This enhancement was observed at the measured point within the market and other points in the site. It is attributed to the increase in openings and porosity, along with the reinforcement of open corridors acting as wind pathways, thereby improving outdoor thermal comfort, as shown in the thermal simulation images in

8.3. Flow Components (Flow u, Flow v, Flow w)

The results for the horizontal wind speed components (flow u) on the x-axis (east-west direction or vice versa) and (flow v) on the y-axis (north-south direction or vice versa), as well as the vertical component (flow w) on the z-axis (representing upward and downward wind flow), showed variations based on urban void configurations and increased porosity. A reduction in wind speed was observed in the horizontal component (flow u), while an increase occurred in the other horizontal component (flow v) due to the influence of urban void formations and prevailing wind patterns. Simultaneously, the vertical component (flow w) experienced a notable increase in wind speed, enhancing wind flow across various axes and improving outdoor thermal comfort.

8.4. Relative Humidity (RH)

The simulation results showed that the relative humidity level decreased from 22.135% to 21.741%, a reduction of 0.394%, during most afternoon hours and the majority of the day across different points of the site. This decrease correlates positively with the reduction in built mass and increased porosity, indicating a favorable effect associated with other environmental factors, such as increased wind speed.

8.5. Mean Radiant Temperature (MRT)

The simulation results showed that the mean radiant temperature (MRT) decreased from 30.759°C to 30.273°C, a reduction of 0.586°C, at the selected measurement point in Sector 71 of Sadr City during the afternoon and most hours of the day. This decrease positively correlates with increased openings and improved airflow due to higher porosity. This strategy represents an effective urban mitigation mechanism that enhances environmental airflow, contributing to a more sustainable and comfortable urban environment.

9. CONCLUSION

After analyzing the practical study results through numerical values and thermal simulation images related to temperature, wind speed, and relative humidity, and comparing the findings between the current state, characterized by a porosity ratio of 30%, and the modified scenario where porosity-enhancing mechanisms were applied—including the removal of informal structures, adjustment of building heights and materials, addition of greenery, and redesign of street setbacks to achieve a 40% porosity ratio—the impact of increased porosity on the studied values became evident.

The results showed a significant improvement in wind speed due to increased porosity, which in turn contributed to lowering temperatures and relative humidity. These effects were measured using the Environmental Flow Index (EFI) equation, where a proportional increase in EFI values was observed with higher porosity. This positively affected outdoor thermal comfort, enhancing environmental flow and revitalizing the area by improving environmental conditions.

These findings represent a key objective of the research, confirming the hypothesis that urban porosity has a direct impact on enhancing environmental flow. Furthermore, a precise scientific measurement method was introduced, relying on clear and accurate equations and simulation programs. This paves the way for future studies to apply this methodology in different areas of Baghdad or even in other countries, achieving precise and rapid results that support sustainable urban planning.

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