Research Paper

Integration of urban resilience and human resilience evaluations for health promotion

using Voxel Base Assessment (VBA)

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Abstract

City, as the most crucial context of human work and life, has everchanging layers and dimensions which are exposed to many socio-ecological threats. Due to its multipurpose perspective, the study of urban and human resilience can be considered a practical approach to urban health promotion criteria. In this context, managing all aspects of human health under the notion of urban and human resilience requires new approaches that integrate the knowledge about resilience assessment methods and related procedures to urban development management and maintains a balance between social, individual, and ecological urban performances. Based on the interdisciplinary implication of these studies, the general use of resilience assessment results requires formulating and preparing a methodical and computational database for this purpose. Hence, we introduce an integrated methodological assessment model and systematic approach based on qualitative and quantitative evaluations with two main parts: Voxel Base Assessment (VBA) and Zone Base Assessment, with the more focus on VBA by its unique characteristics and potential for identifying advantages and disadvantages of very intricate parts of urban zones. The application of VBA to identify health promotion factors has been expressed in the form of statistical analyses and visualization evaluations.

Keywords

Urban resilience, Human resilience, Voxel Base Assessment (VBA), Resilience assessment, Health promotion

1. Introduction

Cities present a unique multilayer system comprising the integrated components of ecological, socio-economic systems, sub-systems, and components that originate from an exchange, interaction, and interdependency operations (Bacchin *et al.*, 2014). An urban area is a consensus spot of a significant number of people, industry, and wealth, and it is the foundation of the working and living of people(Bloom, Canning and Fink, 2008). the complex system of the city has a significant impact on people's lifestyle and well-being through its components and their function. Human resilience and health would be correlated to the components of the city by the roots in the salutogenesis orientation, which contains health promotion approaches and urban design guidelines. Socio-ecological characteristics of urban resilience play an important role in citizens' mental, physical, and social health ,which Has a direct link to the individuals' resilience by intensifying or healing the internal and external stressors.

1.1. Urban resilience

In the 1990s, for the first time, *resilience* was introduced to urban management(Tobin, 1999). The urban system consists of interconnected networks with various physical and social components. Cities are vulnerable in various aspects, including infrastructure, transportation, supply of resources, and energy. According to the growth and prominence of numerous urban problems, Urban resilience research aims to improve cities' capacity to deal with diverse natural disasters and socio-economic hazards against climate change, globalization, and urbanization (Kong *et al.*, 2022). This notion has also been implemented as a guideline for urban planning techniques in the past few years. Cities become more dynamic when an urban resilience strategy is used for urban planning, resulting in considering

cities as an intricate socio-economic system(Datola, Bottero and De Angelis, 2019). (Sharifi and Yamagata, 2015) explained resilience as a part of urban sustainability that facilitates social, economic, and environmental relations between humans and their surroundings over time. Resilience is associated with systems' ability to self-sufficiency, learning from experiences, and adaptation when there is a socio-ecological perspective.

1.1.1. Ecological resilience

Ecology is the study of relations between the organism and their environment, which is impacted by various elements. According to the ecological definition of resilience, it is "the magnitude of disturbance that can be absorbed before the system changes its structure by changing the variables and processes that control behavior" (Holling and Gunderson, 2002). Resilience is a transdisciplinary and multifaceted notion. The concept of resilience is widely used in ecology and studies related to the development of ecosystem stability. (Bhamra, Dani and Burnard, 2011). According to the ecological definition of resilience, The Intergovernmental Panel on Climate Change (IPCC) defined resilience as "a system's ability to anticipate, absorb, accommodate, or recover from the impact of a hazardous event."

1.1.2. Social resilience

The dynamic system of human-environment interaction is referred to as social resilience(Folke, 2006). Various factors define the resilience of communities. In the face of disaster, when other indicators are constant social resilience plays a key role in resilience. Communities can rebuild after a calamity due to a variety of capacities and traits; hence social structure should be regarded as a vital component of resilience(Drabek *et al.*, 1981). A resilient community can adapt to change and continue to carry out its functions under stress. The built environment goes beyond simple physical structures. Instead, it is a "social construct" containing different physical and non-physical components (such as stocks of buildings and infrastructure, transportation networks, etc.)(Sharifi *et al.*, 2017). The layout and design of the environment have a significant impact on social interactions. The offering of transportation, safe play spaces, suitable housing, greenery, street cleaning, and suitable illumination encourages social interactions(Baum and Palmer, 2002).

1.1.3. Human resilience

Scholars first regarded resilience as a personality attribute, but more recent research represents it as a dynamic development process(Luthar and Cicchetti, 2000). The process of dealing, managing, and adjusting to internal and external stressors or trauma is referred to as resilience (Windle, Bennett and Noyes, 2011). (Redman, 1999) Argued that resilience is a multi-dimensional concept influenced by human interactions with the environment and systematic capabilities.

1.2. Health Promotion

Physical and social characteristics of the environment that are socially created and regulated may directly or indirectly support health by opportunities they offer humans to make healthy lifestyles(Macintyre and Ellaway, 2000). Landscape as a health resource elevates physical, mental, and social health. (Abraham, Sommerhalder and Abel, 2010). (Kaplan and Kaplan, 1989) introduced the theoretical foundations for the potential of the relation between cognitive attention restoration and landscape. They established four properties for *Restorative environments*. First, a *Restorative environment* allows people to be away from their daily lives. Second, they attract people's attention without being exhausting. Third, they enable the discovery of new experiences for individuals. Fourth, they enable users to do what they want to do.

1.2.1. Salutogenesis and Human Resilience

Understanding resilience is becoming the focus of study in humanitarian contexts, following the salutogenic model of human resilience, which is a turning point from the adversities (pathogenic) model to the strengths model(Almedom, 2008). The first introduction of salutogenesis was defined by Aaron Antonovsky (1979), which consists of two main subcategories, including Sence of coherence (SoC) and Resistance Resources (RR). Sense of Coherence is the core construct of the salutogenesis model (Mittelmark and Bauer, 2017) and consists of three main indicators, including comprehensibility, manageability, and meaningfulness, which consist of characteristics directly leading to physical, mental, and social health. The salutogenesis orientation is based on health origins and sources; hence is associated with stress management to health archiving (Luyckx *et al.*, 2012). The prevailing impression is that sense of coherence is a comprehensive and ultimate idea that incorporates resilience and hardiness (Windle, Bennett and Noyes, 2011). The primary sources of human and social resilience are rooted in social and individual mental health and coherence. As(Mccraty, 2015) defined, social interaction problems give rise to incoherence and stress for humans.

2. Methodology

Urban resilience assessment leads to methodically comprehending the notion of resilience and maintaining a balance between research and practice(Sun, Zhen and Xie, 2021). The first stage in developing urban resilience is to evaluate its existing state(Kong *et al.*, 2022), to Recognize its advantages and disadvantages. Methods of evaluating urban resilience are now under development. According to various research fields, the assessment methods of urban resilience gradually diversified, including simulation models, optimization models, network analysis, and spatial analysis(Kong *et al.*, 2022). By focusing simultaneously on qualitative and quantitative assessment methods and Using simulation and evaluation systems, this research applies the data as a guide tool for its framework. by offering a new approach that consists of two key components, it is possible to form an integrated and coherent framework by the combination of these two parts. The research method has two main stages: First, according to the research literature in the field of resilience and its correlation with mental health, this research achieved its evaluation method framework by the combination of related studies. In the next step, modeling and preparing a database of existing urban information and converting selected zones into voxels were done. conceptual framework of the resilience assessment method of this research is available in figure 1.

2.1. Case Study

By focusing on urban lost spaces components such as safety, maintenance, activity, public uses, facilities, design, management, usable places, neighborhood attractiveness, and connectivity (Li, 2021)(Khalid, 2020) location of study areas was selected, of which both consist similarities and differences in urban function, human behavior, and land use in order to have an accurate assessment method and conceptual framework.

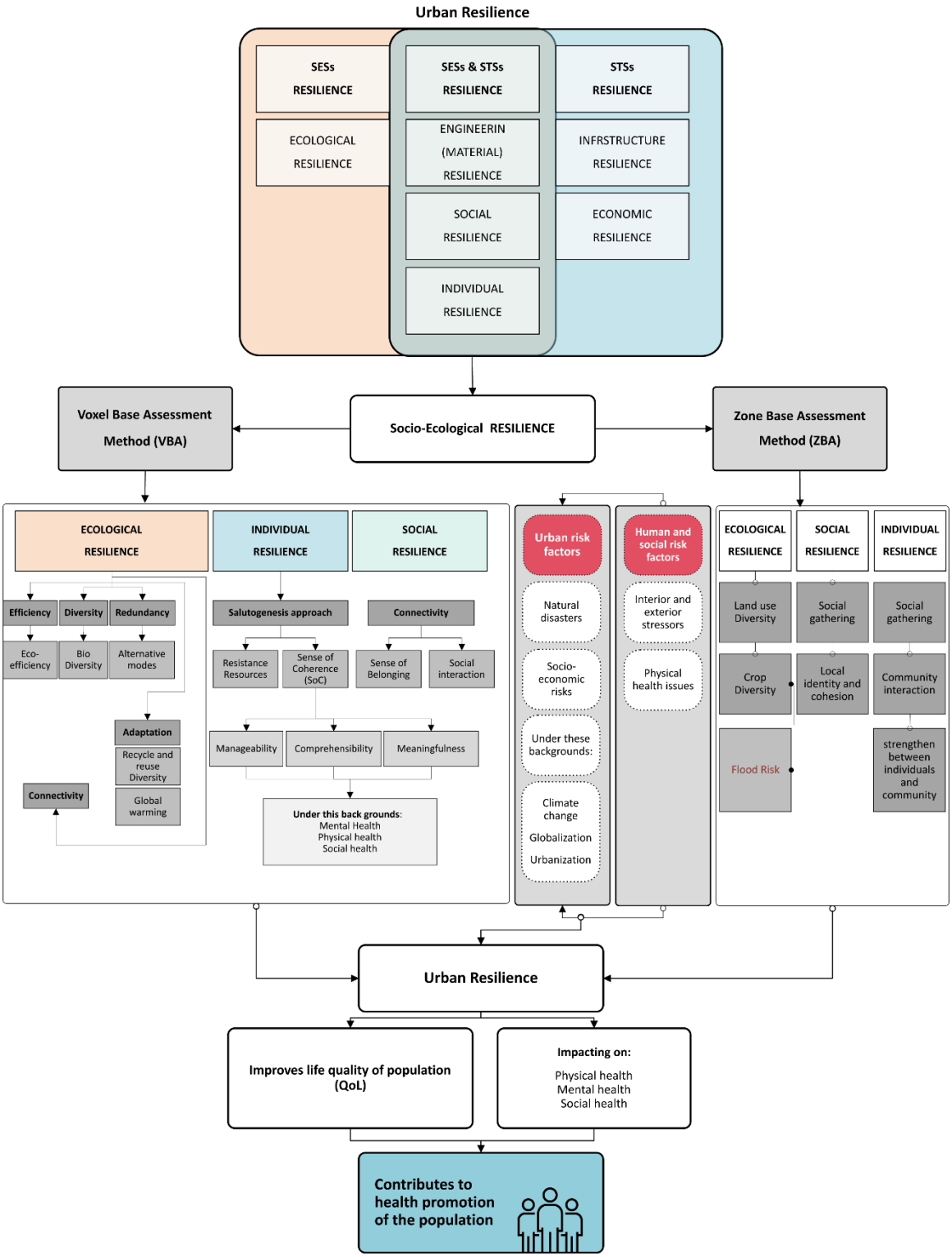

Figure 1. Research process focusing on urban and human resilience studies to achieve health promotion

The first selected zone is one of the most significant urban transport and service zones and one of the high-frequency places of people presence in Shiraz city. Beside some structural similarities, second zone has urban and behavioral differences, by comparing these two zones, a practical analysis can be achieved. These two selected zones have shown differences in more detailed physical features such as the type of urban morphology, available natural resources, social spaces, adjacent uses, dominant materials, and level of urban traffic.

2.2. Voxelization process

each voxel considers the smallest 3D part of a spatial unit of the selected zone in this research. The Voxelization concept, rather than pixelization, provides scholars with a detailed 3D spatial behavior analysis of spatial development. (Shirowzhan *et al.*, 2018) voxelization is a multi-step process in this method, so a reliable database can be used. Two selected zones were transformed and shaped to a **250*250**-meter area with the **3*3*3**-meter voxels.

This model categorizes voxels by their physical features such as color, function, material, voxel type, code type, and static or dynamic. Two main categories of dynamic or static voxels define a group's potential for obtaining activity. Therefore, Dynamic voxels are considered environmental objects that have the potential for the activity of people or vehicles. Six main categories are classified by their functional identities, such as buildings, soft material surfaces, hard material surfaces, vehicle surfaces, and vegetation (figure 4).

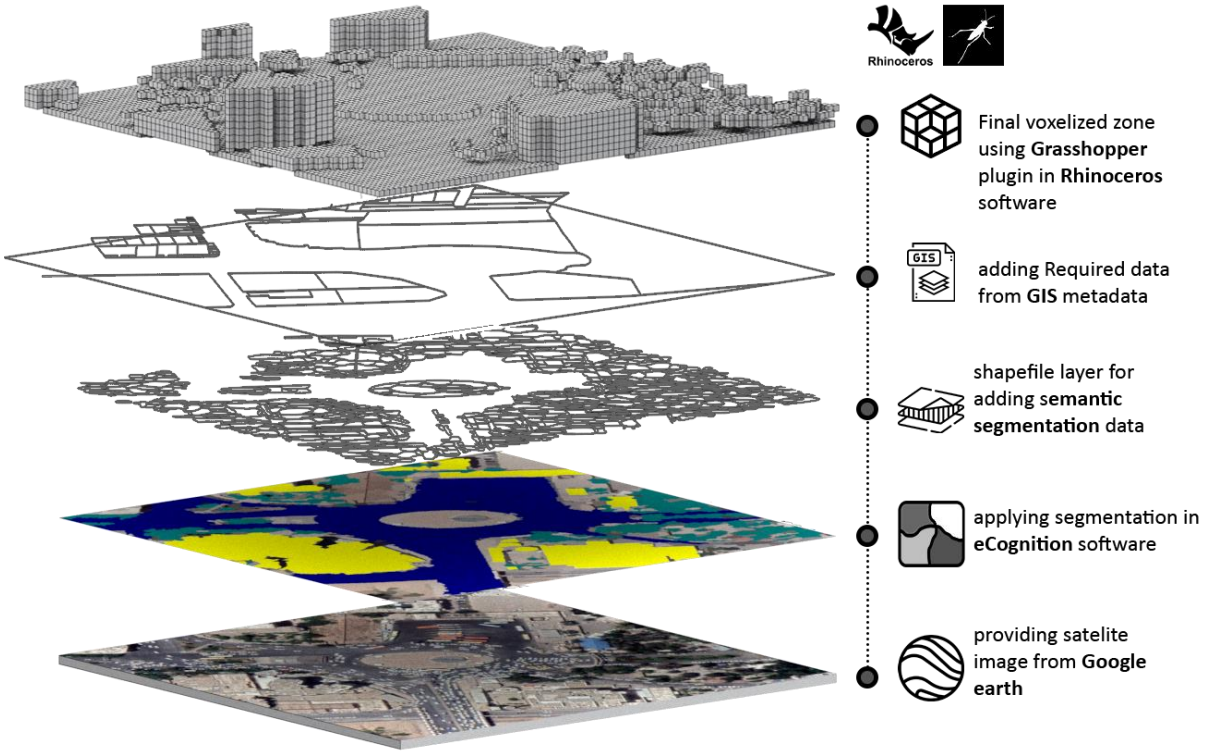

Figure 2. Process of collecting and implementing data to a voxelized map

In order to collect features of each zone, In the first phase, geographic data was captured from the shapefile and used city metadata to determine the function and number of floors for each building. By writing voxel

feature data to **Excel** format and reading the collected database from an Excel file, this study's reading and writing processes were applied in the **Grasshopper** plugin of **Rhino**. Implementing various remote sensing techniques has been a frequently used procedure in urban research. In this project, image processing in the **eCognition** software has been carried out to execute semantic segmentation(Onim *et al.*, 2020), which will be used to verify the different information layers of city objects. This procedure contributes to categorizing surfaces, buildings, and vegetation information and locations. The required data for voxelization is carried out by superimposing the various information layers in the GIS of Shiraz city (Figure 2).

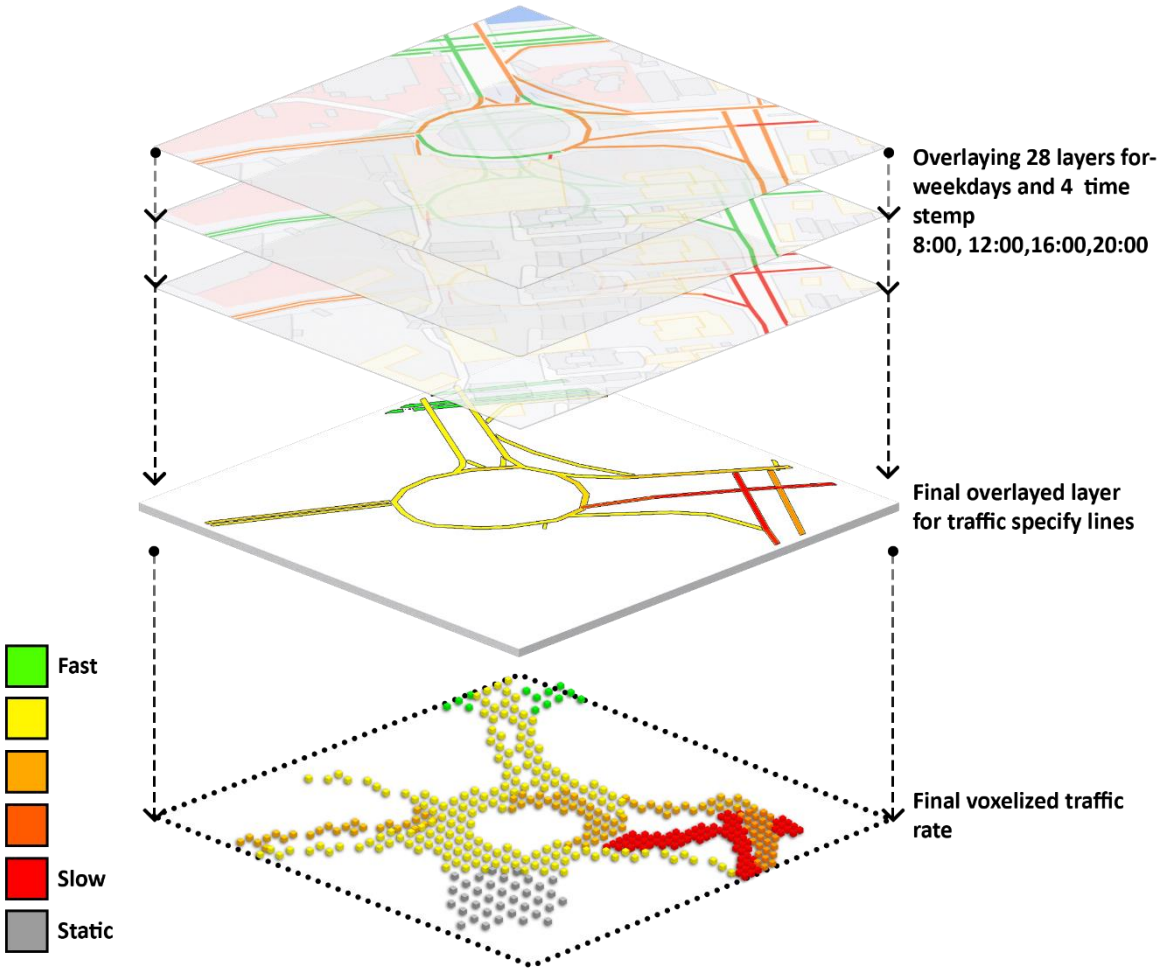

Figure 3. Steps of creating a voxelized traffic map based on Google Map traffic data

The next phase is the construction of dynamic voxel layers, representing the ratio of vehicle density and redundancy as shown in (figure 3). Creating this set of voxels, a typical urban map of the weekly traffic at 8 a.m., 12 p.m., 4 p.m., and 8 p.m. of each zone in the Google map database was prepared. Then, a new traffic map was generated by superimposing these layers, which are colored based on vehicle density, traffic volume, and change in velocity. The vehicle objects were classified as voxels based on the traffic color ratio obtained from the zones.

2.3. Voxel base assessment of resilience

Identifying the dimensions and indicators is the first stage of evaluating urban resilience. (Kong *et al.*, 2022) in this research, three dimensions of resilience assessment have been presented, including ecological, individual, and social resilience, and five indicators, including diversity, redundancy, efficiency, adaptation, and connectivity. Because the resilience approach in urban planning has a systematic view, As(Godshalk, 2003) mentions a resilient city as a network of physical systems and human communities, this research presents a voxel base framework, and the assessment basis is according to the detailed properties of voxels. All the applicable dimensions and indicators of resilience were used, which could measure in this framework, to show each voxel's role and importance. according to the physical features classification, in the zone A, there 26 voxel groups and 29 voxel groups in zone B. The scoring process is based on research in the literature review to have the most practical and accurate data based on scientific facts. Details of dimensions and indicators of the voxel base assessment and scoring basis is visible in figure1.

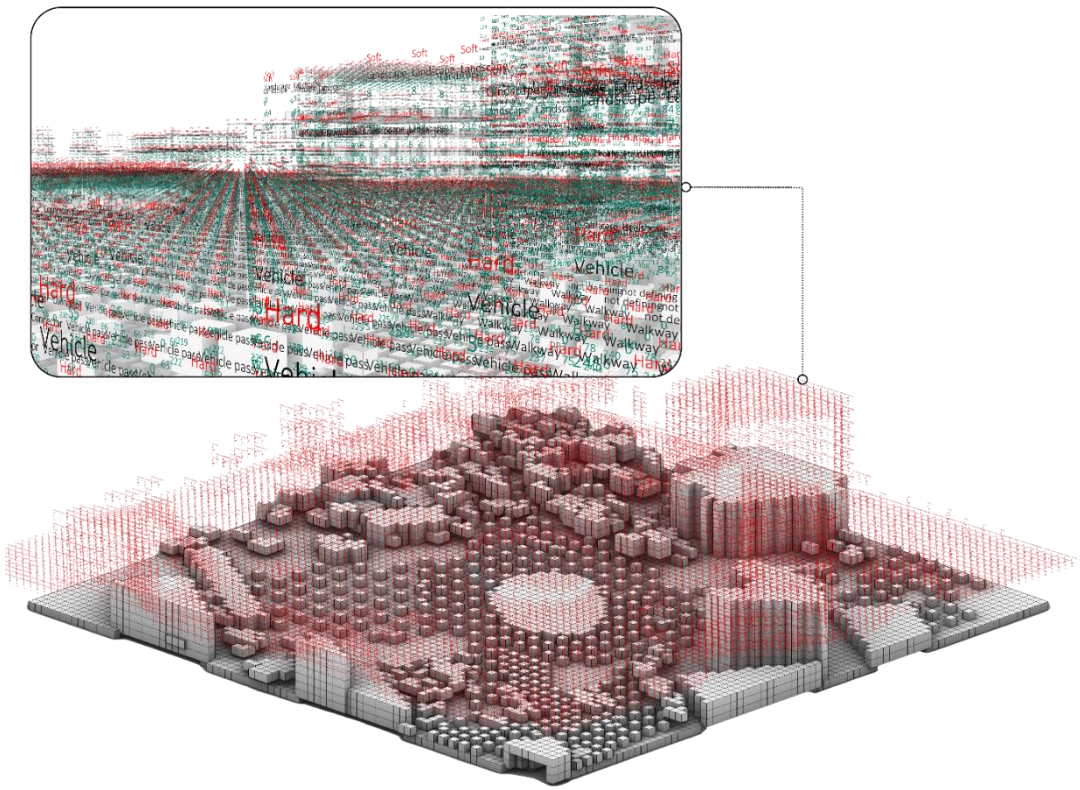

Figure 4. Conceptual model of data classification and visualization

The scoring range is between -1 and 1, and some scoring items are floating while others are constant for all the voxel groups according to Table 1. For instance, the scoring basis for vegetation, trees, and natural elements differs from artificial elements such as surfaces, buildings, and vehicles, while constant items are related to all voxel groups. With the same argument, it can be stated that the most significant score or impact that a voxel or group of voxels can have on the environmental condition and resilience is directly dependent on its physical features. as (Adger, 2000)mentions, the resilience of materials is correlated with its structure and ability to absorb damages and adaptation after disturbance. Besides Voxel base Assessment, evaluating resilience in ecological, individual, and social categories needs a holistic and systematic viewpoint. Hence also, there is a Zone Base Assessment (ZBA). Indeed, this type of assessment considers a supplement for voxel base assessment by making an analytical balance in the scores.

Table 1. Voxel Base Assessment of resilience based on scientific studies in ecological, individual and social resilience

Ecological resilience	Floating items Scoring basis	Ecological resilience	Constant items Scoring basis
Diversity bio diversity (Ribeiro and Pena Jardim Gonçalves, 2019)	Ability or disability of a voxel for being a habitat for local animal	**Redundancy** (Ribeiro and Pena Jardim Gonçalves, 2019)	If the voxel have or have not alternative components
crop diversity (Ribeiro and Pena Jardim Gonçalves, 2019)	Relation of voxel to the diversity of local plants	**Adaptation** (Zabalza Bribián, Valero Capilla and Aranda Usón, 2011)	Influential items of a voxel which leading to global warming or influencing the air pollution / purification
Eco-efficiency (Dhar and Khirfan, 2017)	If the voxel have/have not harmony with environmental condition	Environmental pollution (air/water) (Freedman, 1995)	If the voxel Leading to water/air pollution or purification
Water demand /consumption (Zabalza Bribián, Valero Capilla and Aranda Usón, 2011)	Referring to amount of irrigation demand of a natural voxel ,ranging from: zero to a high-water demand plants	**recyclable or able to recovery** (Ismail, Halog and Smith, 2017)	Ability or disability of the voxel to being recycled or reused
Human resilience		**Maintenance** (Amin, 2014)	Appropriate or unfit maintenance of a voxel
Stagnation (Gad and Catalunya, 2021)	Resulting in waste time in the car		
Memory reminiscence (Meléndez *et al.*, 2015)	If the voxel is Related to representing positive or negative values or memories due to the function of the building or area	**Connectivity** Physically interconnected landscape (surfaces) (Dhar and Khirfan, 2017)	According to the harmony of the voxel material to the landscape
Mental safety (Gad and Catalunya, 2021)	Related to the Issues of a voxel type in wayfinding or making Crowdedness	**Human resilience**	
		Mental health Stress reduction and attention restoration (Kaplan and Kaplan, 1989)	If the voxel leads to a positive impact by Being a natural element or giving rise to negative impacts by being a source of sound pollution
Physical safety (Gad and Catalunya, 2021)	Due to voxel properties providing a safe way for people with disabilities, children, and elderlies	**Physical health** (Gad and Catalunya, 2021)	If the voxel leads to air pollution or air purification

Human resilience	Floating items	Social resilience	Constant items
	Scoring basis		Scoring basis
Physical activity (Gad and Catalunya, 2021)	If the voxel contributes to ease of mobility	**Neighborhood attractiveness** (Khalid, 2020)	If the voxel has elements related to being a lost space or a restorative urban space
Social resilience			
Social interaction **Walkable pathways** (Maass, Lillefjell and Espnes, 2017)	If the voxel type leads to walkability	**Sense of belonging** (Nowicki, 2008) (Adams *et al.*, 2006)	If the voxel group creats a multisensory or uni-sensory sence in the user(human) Or enhances or reduces being in charge
Blue and green items /gray items (Yen, Chiu and Huang, 2021)	In the voxel type belonges to blue and green items or gray items		

Table 1.The scoring basis of Voxel Base Assessment according to indicators and dimensions ecological,individual and social resilience

3. Result

Resilience evaluation scores have been prepared in Voxel Base Assessment (VBA) and Zone Base Assessment (ZBA). Each voxel has exclusive features in many categories, which makes it a relational database. The number of generated voxels in zone A is 10611. All voxels are among the influential objects in urban and human resilience items. The ratio of building voxels is 39.17%, voxels belonging to hard surfaces is 25.91%, soft surfaces and greenery are 14.54%, vehicle surfaces is 16.31%, and 4.04% of the total voxels belong to vehicle objects. In zone B, there are 10915 voxels, which Among them, 39.17 % belong to building voxels, 25.91% to hard surfaces, 14.54% to natural surfaces and vegetation, 16.31% to vehicle surfaces, and 4.04% of the total voxels belong to vehicle objects.

3.1. Physical features analysis

Classified data illustrated in physical features were obtained in 3D voxelized heatmaps for the first step of analysis and comparisons. Voxel frequency ratio in different physical items for both zones is shown in (figure 5). These numbers indicate a significant absence of vegetation. Another criterion that can provide a suitable classification for analyzing urban based on visual features would be evaluating the blue-green landscape elements. In zone B, 11.44% of the voxels have blue or green natural indices, and in zone A is 12.67%. However, classification of functionality has been done for the existing buildings as a part of the physical features in each zone. It provides an accurate evaluation of possible behaviors in each zone that

facilitates decision-making. In zone A, 9.37% of building voxels belong to voxels for residential occupancy, 12.05% for educational functionality, and 78.03% for service functionalities.

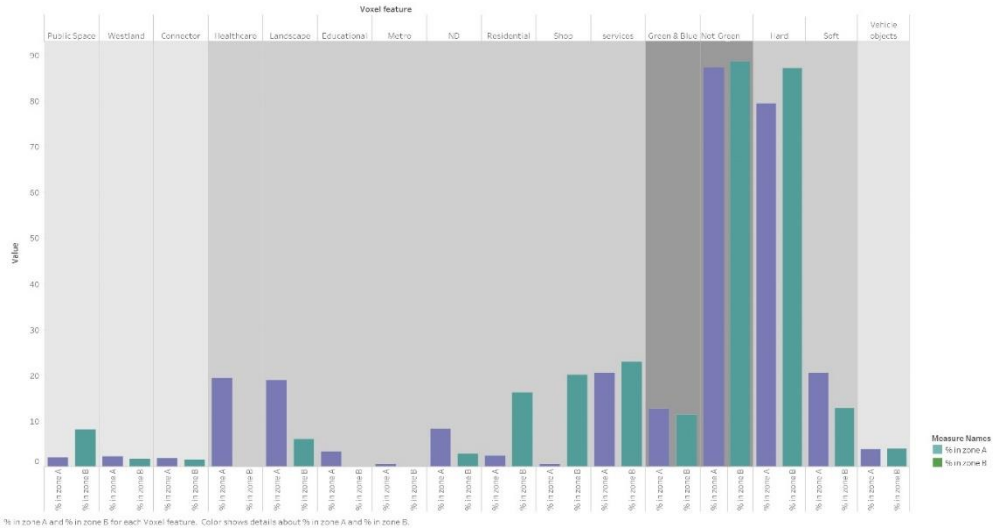

Figure 5. Voxels frequency ratio based on physical features classification

3.2. Resilience Assessment analysis

The first layer of evaluation is the knowledge-based assessment used to achieve a qualitative analysis of urban zones from the resilience perspective. The 3D voxelized result maps of resilience assessment are presented in two sections: urban resilience assessment and human resilience assessment. This visualization method provides general and partial primary data of each zone. Accordingly, each voxel and the expressed physical features can obtain a deeper layer. The second layer considers the precedents of the environment and the unique features of that substrate in the zone-based Assessment (ZBA) layer. These scores added to the scoring of all voxels to refine the results from a comprehensive point of view.

3.2.1. Urban Resilience Visualization and Comparative Comparison

The findings of the urban resilience discussion for each ecological and social field are shown in the form of 3D voxelized heatmaps in (Figure 6). The Final generated 3D heatmap of urban resilience assessment is

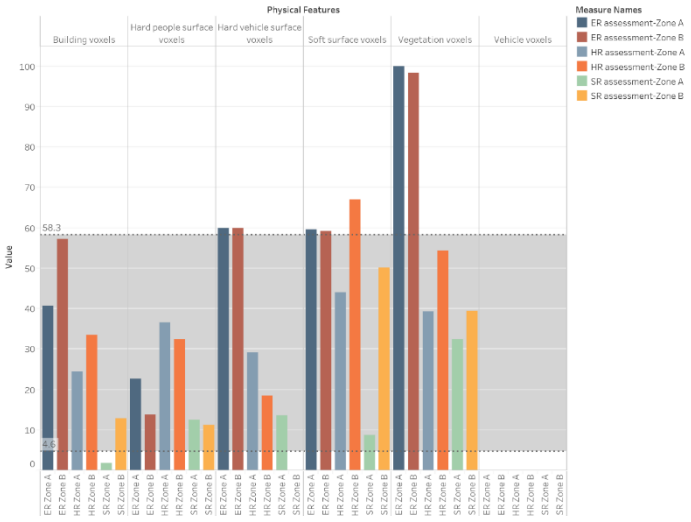

Figure 6. Comparison of ecological,human and social resilience according to the physical features classification

shown in (figure 7). The average points obtained from the assessment of ecological resilience in zone A, vegetation has obtained the highest possible score in this zone and has performed optimally in increasing the ecological resilience of the zone.

Soft surfaces and vehicle surfaces score effectively in this zone. Also, Voxels of buildings, vehicles, and soft

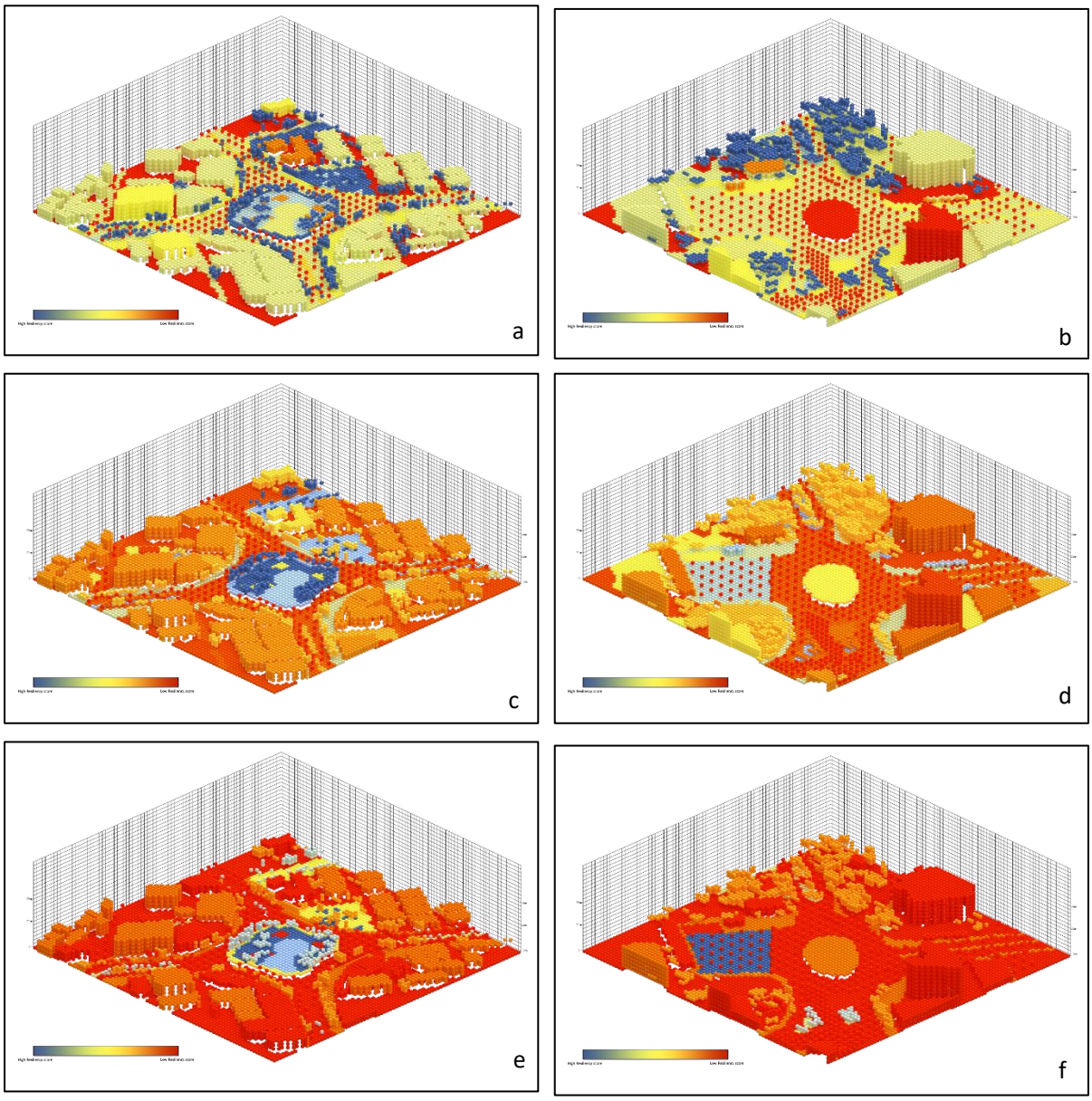

Figure 7. Final generated voxelized heatmaps based on Voxel Base Assessment of resilience in three dimensions of ecological, human, and social. a) Human resilience heatmap in zone B, b) Human resilience heatmap in zone A, c) ecological resilience heatmap in zone B, d) ecological resilience heatmap in zone A, e) social resilience heatmap in zone B, f) social resilience heatmap in zone A

surfaces have the highest impact on increasing ecological resilience. In the case of social resilience, a significant discrepancy has emerged between voxels of buildings and soft surfaces. Furthermore, in zone A, soft surfaces have received a negative score, which is considered a risk factor for this zone, and thus it negatively impacts resilience indicators.

3.2.2. Human Resilience Visualization and Comparative Comparison

The evaluation results of human resilience are illustrated in voxelized 3D heatmaps. In the human resilience assessment in zones A and B., two assessment indicators are considered risk factors: hard surfaces and vehicle objects (figure 8). These items are in a Deviation factor from the average for human resilience in zone A. From the comparison of these two zones, it is observed that improving the conditions of the soft surfaces has had a significant impact on enhancing human resilience. The second layer of zone-based

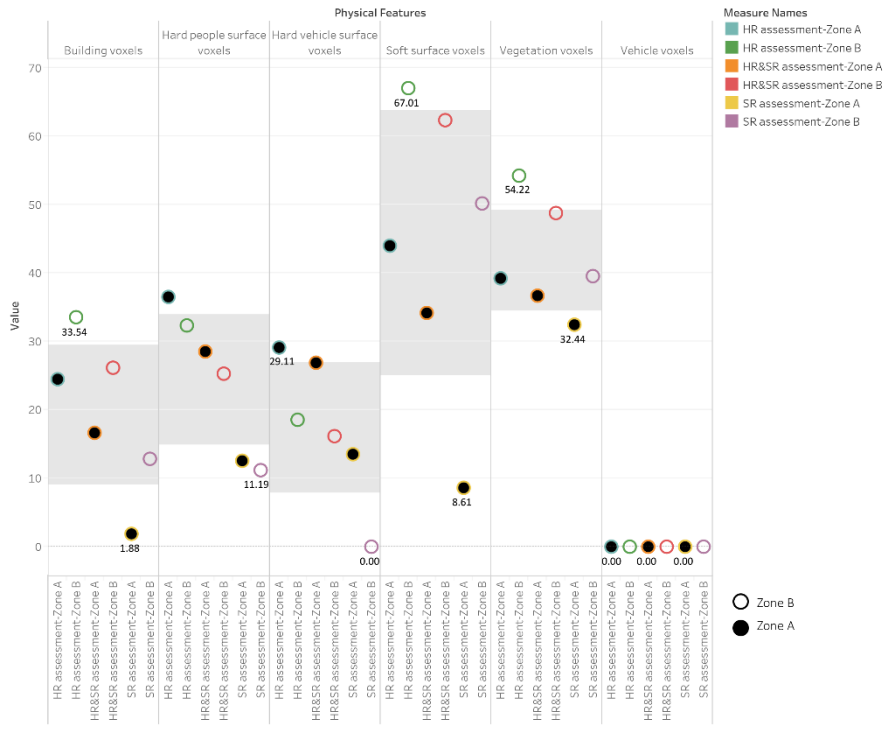

Figure 8. influential physical features on health promotion by aggregation social and human resilience items

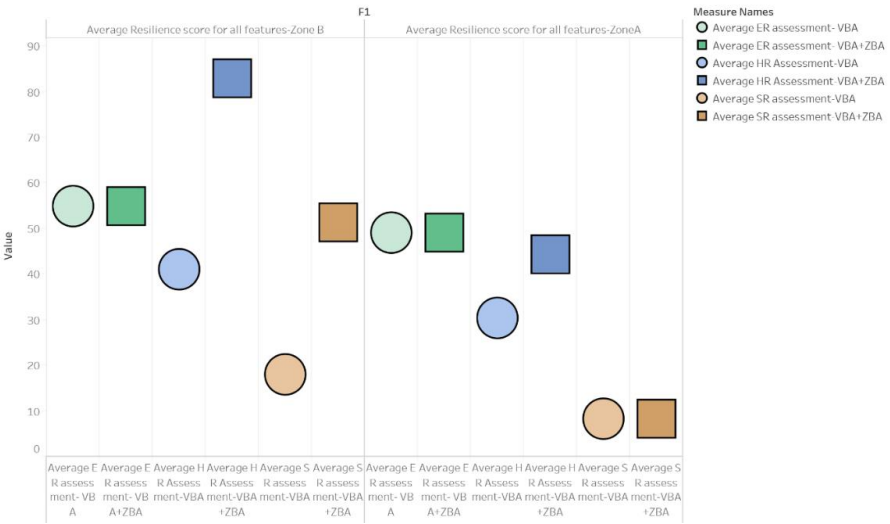

Figure 9. The role of Zone Base Assessment in modification of Voxel Base Assessment of resilience in zone A and B

assessment is crucial in evaluating human resilience. The improvement of human resilience in zone B is after the addition of the second layer, which has resulted in a 25% increase in resilience (figure 9).

3.3. Interconnected analysis for health promotion

In the following evaluation of findings, the focus is on obtaining data contributing to a better comprehension of each feature's role in the health promotion concept. Achieving the goal of health promotion requires more experiments on human and social resilience assessments in connection with physical features. These results state that human resilience has a more positive impact on both zones. However, the main difference between the two zones is based on the impact of public spaces. Creating spatial and behavioral diversity has been neglected in the development plans of these zones.

In this basis of assessment, factors affecting "Health Promotion" include simultaneously considering physical features and social interaction potential. Based on the conducted survey in zone A, the plenty of hard materials and colorless landscapes in Voxel Base Assessment bring about the weakness in creating social interactions (figure 10).

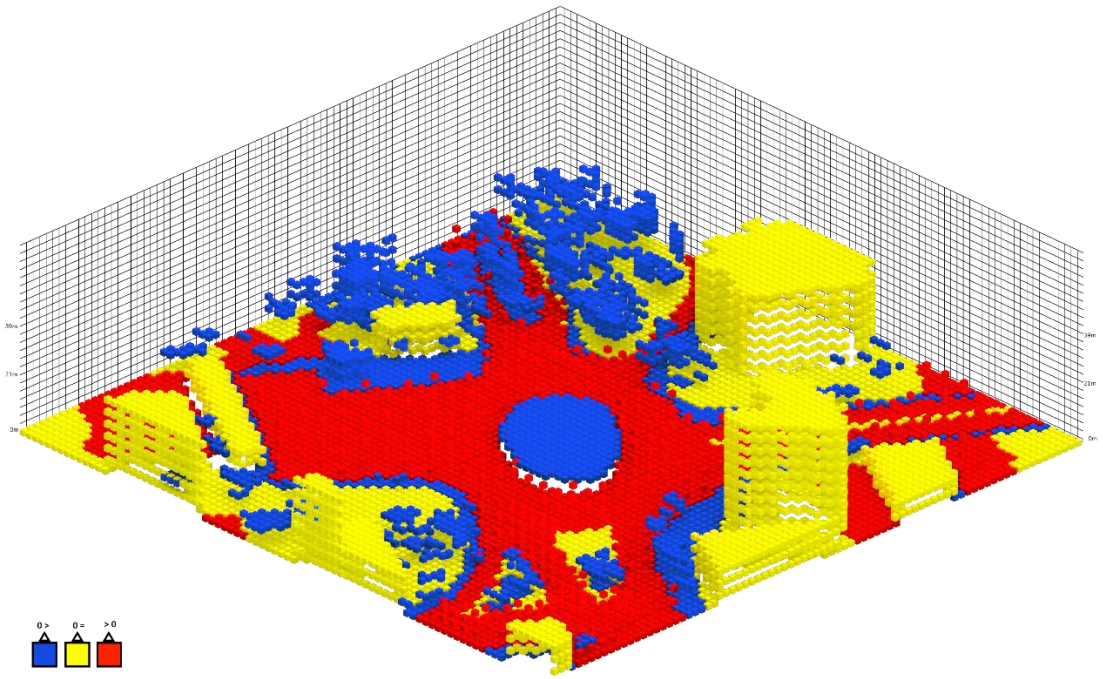

Figure 10. Resilience score voxelized heatmap according to the most influential items for health promotion

4. Discussion

with a practical perspective to this research, considering essential concepts in similar fields can provide experts with valuable knowledge for developing design and making decisions. One of these approaches is called "lost spaces," which always has multiple interpretations**.** It is a topic that can be utilized as an

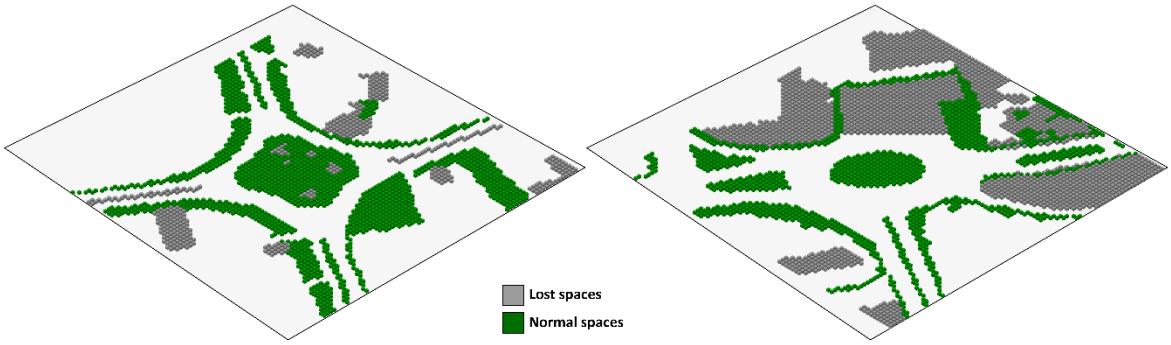

Figure 11. Highlighting lost spaces in the voxelized map using the influential items based on resilience score in zones A and B

example of harmful spaces on the mental health of humans. In this way, if among the human resilience items which refer to physical safety, including "safe ways for people with disabilities" and " safe ways for children and elderlies," or in the social resilience items, "neighborhood attractiveness" was in a risk condition, it is a criterion by which lost spaces are available in the zone. New design arrangements should be considered, and recognizing their positions can modify these issues (Figure 11).

After qualitative evaluation, Among the criteria of human resilience, the vehicle surfaces and traffic rate (calculated in the number of vehicle objects) in the area is known as the risk in both zones. In zone B, the two criteria of soft surfaces and vegetation positively impacted, creating a discrepancy between these two zones regarding mental health. The difference in the public space and landscapes between the two zones is evident from analyzing these two physical feature elements. Public space accounts for a minor amount of the overall green space in zone A, while in zone B, this ratio is completely balanced, leading to more possibility of physical activity. Three items significantly affected human resilience assessment, including safe ways for children and elderlies, ease of mobility, and air quality or air pollution.

In order to develop future research, different methodological ideas will help diversify the results and continue various analyses. One of them would be the development of the initial stages of classifying and writing voxels in fully automatic ways using segmentation semantics in urban images from different views. Another case in developing the introduced methodology will be photogrammetry using depth sensors, automatically forming the voxelization process. Mentioned items are accessible ideas that speed up the process of preparing and creating a database. Another idea would be using 3D Isovist parameters(Chmielewski, 2021), one of the tested ideas in urban user experience studies. It is a type of data derived from agents known as space users that are added to the analytical layers.

5. Conclusion

Regarding the increase of natural hazards and the growth of urbanization, studies of urban development and urban and human resilience significantly increased. With the progress of interdisciplinary studies, new methods led to finding more ways of decision-making. Using computational methods as a functional advantage in interdisciplinary studies can increase the speed and accuracy of studies in the research process.

Resilience impact factors that play an effective role in improving mental health were practically assessed in the research methodology. Based on the classified information of each zone in the voxelized

environment, basic information about the role of urban and social resilience in improving mental health was obtained. The presence of green urban areas with the potential for physical activity and social interactions directly led to mental, physical, and social health promotion. A comparison of zone A and B specifies the lack of adequate safe physical urban pathways for users.

Accordingly, the method of knowledge-based data indicates the critical potential of recognizing destructive elements and contributes to fixing them, such as identifying lost spaces by reviewing a voxelized framework. Finally, using various interdisciplinary scientific methods can be a long step in developing scientific studies, especially in mental health.

6. Acknowledgment

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