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Research Article:

The role of urban fabric in climate adaptation to achieve a resilient urban city: Sulaymaniyah city as a case study

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Abstract

The aim of this paper is to establish an empirically based, interdisciplinary framework that integrates vernacular urban morphology with climate-responsive technological interventions to enhance resilience, sustainability, and community engagement in developing urban centers, using Sulaymaniyah as a case study, using a mixed-methods approach, this study investigates Sulaymaniyah's urban fabric and climate resilience. Climate, social, and urban features were evaluated by field surveys in Sabwnkaran and Mallkandy, an expert input on resilience tactics was acquired using questionnaires. Traditional, contemporary, and integrated solutions were assessed, along with implementation challenges and adaption tactics, using descriptive-analytical techniques with Excel and SPSS. Both quantitative and qualitative analysis were assisted by visual and spatial technologies such as AutoCAD and Photoshop. Structured expert interviews supported conclusions and directed useful, situation-specific suggestions for resilient and sustainable urban development in Sulaymaniyah. This was achieved through a detailed study of selected neighborhoods within the Sabwnkran and Mallkandi districts, analyzing their key urban characteristics in terms of building materials, building orientation, height-to-street width ratio, ratio of open and built spaces, ratio of green spaces, winding and straight streets, and ratio of shade and trees. According to linear regression analysis, Green Space played a crucial role in the urban environment under study. It had a good explanatory power ($R2 = 0.855$) and a significant positive association with the dependent variable ($B = 0.070$, $Beta = 0.924$, $t = 4.200$, $p = 0.025$). While Straight Grid Streets neared significance ($B = -0.047$, $Beta = -0.843$, $t = -2.711$, $p = 0.073$), other indicators were not statistically significant ($p > 0.05$), and factors like Building Materials showed minimal explanatory power ($R^2 = 0.008$).

1. Introduction

Rising temperatures, unpredictable rainfall patterns, and a decline in the quality of the urban environment are just a few of the difficulties that cities have to manage as caused by of the escalating effects of climate change. As the past few years have demonstrated, traditional planning systems are really no longer equipped to manage severe climatic disturbances on their own, no matter their historical endurance. once it comes to social acceptance and contextual fit within the conventional urban fabric, technically competent solutions may not always be effective. A global movement that advocates combining traditional urban morphology with climate-responsive technology solutions has come into being as a way to improve sustainable urban resilience. This study investigates the quantifiable effects of traditional urban fabric solutions on climate adaptation in Sulaymaniyah's urban core, examines how new technical solutions can be incorporated to enhance urban morphological adaptability and architectural resilience, explores the measurable synergistic effects of technology and vernacular approaches on urban resilience planning, identifies a methodological framework capable of effectively integrating these techniques within Sulaymaniyah's urban environment, and determines the design guidelines and evidence-based policy frameworks required for successful implementation and increased climate resilience in cities. This study hypothesizes that systematic integration of local urban design solutions with modern technological advancements enhances urban resilience by optimizing contextual flexibility and innovative design responses to climate-induced disturbances. This research is significant as it offers a practical scientific basis that might be applied in urban areas by:

1. Morphology Integration To present an effectively planned layout towards integrating smart technology into Sulaymaniyah's current urban structure while preserving its historical morphological traits and spatial links.
2. Adaptive to Technology To set out quantifiable principles to get using climate-sensitive technology with conventional architectural designs which maximize environmental usefulness and retaining cultural integrity.
3. Optimizing Performance using assessment metrics to evaluate how effectively conventional and contemporary approaches complement each other to spike urban climate resilience.
4. Application of Policies to offer lawmakers and urban planners' context-specific recommendations that help the mixing of smart technology with conventional urban features.
5. Economies need to offer monetary frameworks to ensure long-term sustainability when applying technological innovations in conventional urban environments.
6. Involvement in Community to provide methods for community involvement that ensure the integration of modern technology within conventional urban settings.

2. Literature review

Since about 10,000 years, Earth's climate stayed mostly stable, creating ideal circumstances for human growth, agriculture, and habitation (1). But since the Industrial Revolution, greenhouse gas concentrations have quickly grown due to human activity, especially the burning of oil and gas, raising climate change beyond natural variability (30,31,13). The must environmental conditions that support life have come under danger due to this change (25). The built environment, such as infrastructure, transportation, and buildings, greatly contributes to global emissions, highlighting how urgent it is to address the effects of climate change (25).The IPCC (2014) describes climate change adaptation as the process of adapting to existing or anticipated climatic consequences, including transformational and gradual methods. Because climate risks increased, adaptation became more important even though early climate policy was almost entirely aimed at mitigation (21). Because of long-term environmental changes, socioeconomic changes, in addition uncertainty in future climate forecasts, adaptation is still challenging to implement. According to Schmidt-Thomé (2017), the IPCC (2014) divides adaptation into three categories: structural/physical, social, and institutional solutions. It emphasizes that community involvement, realistic "no-regret" measures, and integration with disaster risk reduction are all needed for successful adaptation as illustrated in Table (1). Holling (1973) defined resilience as the ability of systems to absorb perturbations while preserving fundamental functions. Resilience having strong origins in mechanics (1858) and later ecology. Resilience in architecture encompasses quantifiable elements such environmental effect, energy efficiency, and structural performance in addition to cultural, symbolic, and aesthetic characteristics which affect the way buildings are perceived (11). Resilience has been used in each discipline as the capacity to withstand setbacks, adjust to change, and carry on with business as usual (17). According to Levy (1999), Capel (2002), and Oliveira (2016), urban form is the physical configuration of streets, plots, buildings, and open spaces that forms the structure of the urban fabric. The idea of dimension is expanded into seven dimensions by Lynch (1981), consisting of architectural structures, movement patterns, natural aspects, and perceptual attributes. Connectivity, land use patterns, density, and physical layout all have an effect on the urban fabric (12). Cities have become more vulnerable to climate-related stressors as global urbanization takes up speed, particularly in emerging nations. As a result of cities to effectively adapt to climate change, they need a robust and sustainable urban fabric (8) Fig. (1). As global urbanization rises, urban resilience is being recognized as a key component of sustainable city development (20). Originally based on ecological and engineering principles, resilience is now employed to explain how cities can take in, adapt, and recover from shocks such economic upheaval or climate change. A city's resilience is directly impacted by its urban fabric, which is made up of its streets, buildings, public areas, and infrastructure. Based to research, social cohesiveness, environmental quality, economic performance, and energy consumption are all impacted by a city's physical layout (15,16,23) As a way to create adaptable and sustainable urban settings, resilience and urban form must work together. Urban resilience can be defined in a multitude of ways, but Meerow et al. (2016)'s definition, that emphasizes the ability of urban socio-ecological and socio-technical systems to preserve or swiftly restore desired functions, adapt to change, and transform while current systems limit adaptive capacity, best captures its multifaceted nature. Resistance, recovery, adaptation, and transformation are the four pillars that Ribeiro and Gonçalves (2019) use to further construct urban resilience, emphasizing how urban systems react to disruptions. When viewed overall, such viewpoints demonstrate that urban resilience includes allowing cities to endure damage, minimize disruptions, continuously adapt, and maximizing their potential for long-term adaptation. Fig. (2). The large number of urban resilience indicators reported in the literature highlights the ongoing complexity of urban systems. Citing Tyler and Moench (2012), a number of research focus on physical and environmental factors like infrastructure resilience, ecological health, and preparedness for disasters. Some highlight on socioeconomic factors such as economic stability, ability of institutions, social capital, and governance (20). likewise, Zeng et al. (2022) divide resilience capacities into three categories: absorptive, adaptive, and transformative. Each of these elements deals with a different aspect of urban response. Given their differences, these indicators show the need for an integrated, context-specific framework for urban resilience.

3. Urban Resilience Framework

Urban resilience is the capacity of a city to persevere, change to, and overcome social, economic, and environmental challenges. The second part splits resilience choices into two groups: active technological interventions and traditional passive solutions, with an objective of creating a dual framework that integrates low-energy, natural ways with modern smart technologies (19,2). Fig. (3)

a) Traditional Passive Solutions:

Conventional passive systems depend on low-energy techniques, local materials, and natural forces. Using raising ventilation, minimizing energy use, and minimizing heat absorption, they highlight climate adaption.

- **Natural Ventilation**

Cross ventilation, single-sided ventilation, stack effect, wind towers, atriums, plus optimal inlet/outlet size are examples of natural ventilation ways which help with cooling, indoor air quality, and less dependence on mechanical HVAC systems. Climate, building shape, and wind conditions all affect its efficacy (3, 1,9).

- **Shading Devices**

shading enhances pedestrian comfort and may use photovoltaic technology to generate electricity. Because to Alzahran and Gadi (2024), Elnabawi and Hamza (2020), and Middel et al. (2016), their performance varies depending on geometry, orientation, and urban surroundings.

- **Vegetation and Greenery**

Greenery in cities allows to mitigate UHI, minimize air pollution, sequester carbon, reduce noise, boost biodiversity, and improve psychological well-being. Using shade and evapotranspiration, green areas help cool cities (10,26, 22).

- **Water Management**

By minimizing flood risks and boosting water security, water management techniques such as stormwater control, nature-based solutions, wastewater recycling, and decentralized greywater systems improve resilience (14, 28).

- **Earth and Local Materials**

In addition to minimizing embodied energy, earth-based materials also promote thermal massing, enhance indoor air quality, minimize carbon emissions, and promote biodiversity. Based on Life Cycle Assessment (LCA) studies, the CO2 effects of conventional materials are far less (6,27).

- **Urban Form and Street Network**

Walkability, microclimate, connection, and disaster response all have been affected by street width, edges, orientation, and layout. Solar access, natural ventilation, and safe mobility have been improved by well-designed street canyons (24,7).

b) 4.2 Active Sustainable Solutions:

The active solutions allow flexibility and quick reaction to climatic concerns by utilizing contemporary technology to add to passive techniques.

- **Renewable Energy Systems**

CO2 reduction, energy independence, and resilient micrograds are supported by incorporating solar pavements, PV canopies, solar street furniture, and piezoelectric devices within urban infrastructure (18, ,4).

- **Smart Urban Infrastructure**

IoT-enabled technologies control utilities, keeps an eye on the environment, and help early warning systems. In the opinion of Shan et al. (2020), Di Marco et al. (2020), and Rai et al. (2023), smart grids, smart lighting, automated water/waste management, and real-time monitoring all boost resilience and efficiency.

- **Electric Vehicles (EVs)**

Using vehicle-to-grid (V2G) technology, EVs lower emissions, raise air quality, and build resilient energy systems. These raise grid stability in times of crisis and store excess renewable energy (29).

4. Research Methodology:

Using a hybrid method which mixes theoretical and empirical research, study Sulaymaniyah's urban structure and climate change resistance.

Phase One – Field Survey:

Study Sabwnkaran and Mallkandy areas to assess climatic, social, and urban characteristics.

Phase Two – Questionnaires:

Sustainability, urban planning, and architectural experts analyze proposed resilience criteria.

Phase Three – Data Analysis:

Arithmetic means, percentages, standard deviations, frequencies, and graphical representations have been determined using Excel and SPSS as a part of a descriptive-analytical approach.

Important conclusions include:

- **Traditional strategies**: Water features scored lowest, whereas building orientation and material choice (Mean = 2.7) were the most effective. Fig (4)
- **Modern technologies**: IoT systems received the lowest

grade, while green infrastructure and renewable energy systems received the best (Mean = 3.13). Fig (5)

- **Integration strategies**: Maintenance requirements ranked highest (Mean = 3.9), followed by community acceptance and heritage preservation; technical feasibility ranked lowest. Fig. (6)
- **Implementation barriers**: Regulatory constraints and lack of funding were most significant (Mean = 3.89), while heritage protection conflicts were least critical. Fig. (7)
- **Adaptation strategies**: Vernacular materials achieved the highest rating (Mean = 4), while water-based cooling features received the lowest. Fig. (8)
- **Modern technological contributions**: Modern insulation technologies scored highest (Mean = 4.3), whereas IoT sensors recorded the lowest values. Fig. (9)

Phase Four – Urban Planning Recommendations:
Develop climate-responsive, sustainable, and resilient urban plans specific to Sulaymaniyah.

Visual and Spatial Analysis Tools:

• AutoCAD: Accurate measurements of open areas, roadway widths, building footprints, and spatial densities.

• SketchUp: 3D modeling for visual patterns, building-void interactions, street canyon ratios, and volumetric analysis.

• Adobe Photoshop: Albedo calculations to evaluate thermal characteristics, surface color analysis, and material identification.

• Documentary photography: on-site verification of pedestrian conditions, vegetation, shade, and facades.

• Satellite imagery: aerial views to assess neighborhood morphology, impermeable surfaces, and green areas, Fig. (10,11,12).

Expert Consultation:
Data has been verified, technical indicators are being reviewed, and structured interviews are used to assess the feasibility of suggested therapies. In the conclusion, the research provides strong scholarly conclusions and useful, locally applicable recommendations to improve urban resilience in Sulaymaniyah. The impact of several urban design indicators on the variable that is dependent (Y) has been studied applying a linear regression analysis. Unstandardized coefficients (B), standardized coefficients (Beta), t-values, significance levels (Sig.), and the coefficient of determination (R^2) for each indicator are displayed in the table that summarizes the findings. From all of the indicators, Green Space had a strong explanatory power (R2 = 0.855) and a significant positive connection with the dependent variable (B = 0.070, Beta = 0.924, t = 4.200, p = 0.025). This suggests that green infrastructure plays a critical role in the urban environment under study, since locations with larger percentage of green spaces greatly contribute to the result examined. The following indicators did not show statistically significant impacts ($p > 0.05$): Open Space, Building Height, Building Materials, Orientation, Narrow/Winding Streets, Permeable Surfaces, Reflective Surfaces, Straight Grid Streets, Tree Canopy, and W/H Ratio. From all of these, the results for Straight Grid Streets came close to significance (B = -0.047, Beta = -0.843, t = -2.711, p = 0.073), indicating a possible adverse effect that could call for more research. A large number of non-significant indicators provided comparatively low R2 values, suggesting that these particular variables had little explanatory ability. Building Materials, for example; they had an R2 of 0.008, indicating a negligible contribution to the dependent variable.

6. Discussions and recommendations

- Considering urban resilience is modified through environmental, social, physical, and infrastructure factors, resilience is a complex concept that calls for integrated approaches opposed to one-dimensional solutions.
- The accuracy and usefulness of resilience evaluations could possibly be significantly increased through the combination of quantitative climate indicators with urban morphology studies.
- Upgrading Conventional Passive Solutions: This is suggested that you continue using climate-responsive and nature-based design techniques, for example plants, shading devices, and natural ventilation. These tactics enhance urban biodiversity, improve air quality, and reduce heat.
- Developing Active Sustainable Solutions: As a way to raise resource efficiency and real-time responsiveness across sectors including energy, transportation, water, and waste management, the research supports the integration of smart infrastructure made possible by IoT with renewable energy technologies like solar and wind.
- Toward Sustainable Mobility: The adoption of electric vehicles (EVs) can be a part of proactive strategies that support low emissions and strengthen the resilience of urban energy systems via the application of mobile storage and flexible grid interaction.
- Integrated Approach: The results highlight how crucial it is for urban planning to incorporate both passive and active solutions. Active solutions contribute to the creation of cities that lessen vulnerabilities, increase sustainability, and improve urban quality of life, whilst passive techniques offer long-term environmental sustainability.
- Boost Traditional Design: In both new and renovated projects, maintain courtyards, shaded streets, and local materials.
- Encourage Modern Technologies: Consider cost and viability when implementing green roofs, reflecting surfaces, and renewable energy solutions in new districts.
- Integrated urban planning ensures community involvement by combining modern and traditional

approaches with cultural and heritage awareness.

- Building Capacity: Educate planners, architects, and municipal employees on sustainable technology and climate-responsive architecture.
- Solve Barriers: Establish legislation, funding sources, and political support to make adaptation efforts possible.
- Community Support: Take part communities to make programs more socially acceptable and sustainable.
- Monitoring and Evaluation: Use both qualitative and quantitative indicators to evaluate effectiveness and guide improvements.
- The findings highlight the dominant influence of Green Space in the urban context under study, reinforcing the importance of integrating natural elements in city planning to enhance environmental and social outcomes. While other physical design factors were not statistically significant individually, their combined effect or interaction with other variables may still play a role, and further multivariate analysis could provide additional insights. The near-significant effect of Straight Grid Streets suggests that street patterning could influence urban performance and deserves further exploration in future research

7. Conclusion

Urban climate resilience needs a mix of mitigation and adaptation strategies, comprising both long-term planning and quick actions.

A city's ability to take on, adapt from, and adapt to climate change is highly affected by its built environment, including its roadways, blocks, buildings, and green areas.

Resilience-based urban planning raises recovery, reduces vulnerabilities, and fosters sustainable urban growth.

Coordinated technical, social, and environmental initiatives, active stakeholder engagement, and context-specific techniques are all necessary for effective adaptation.

It is not enough to rely just on passive (nature-based design, shade, ventilation, vegetation, water management) or active (renewable energy, smart infrastructure, electric cars) solutions.

By combining traditional passive solutions using modern technology, mixed methods provide cultural compatibility, historical preservation, and raised urban resilience.

Community involvement, institutional support, and capacity building are essential for removing obstacles.

Conclusions from the practical section

Open Space to Buil Mass Ratio:

Nearly every region comprises a constructed mass that is larger than the suggested ratio (40–60%), so there are few open spaces. This suggests a comparatively high construction density, which could be having an impact on thermal comfort and natural ventilation.

Building Height:

Each area complies with the basic urban planning height standards, falling between the suggested range of 15 to 20 meters.

Building Orientation:

60–70% of buildings have an orientation of north-south (N–S), which is in line with suggestions for optimizing natural light and reducing direct solar heat gain.

Building Materials:

Although recommendations call for the use of exclusively low-mass materials, the majority of buildings use low thermal mass (>60%) materials with modest reflectivity (30–40%). It also means that certain materials might not perform as well thermally as they could.

Green Spaces and Tree Canopy:

Most areas fall within the recommended range (25–30% for green spaces, 20–30% for tree canopy), with some minor gaps, reflecting a need to enhance green spaces to reduce surface heat and improve thermal comfort.

Reflective and Permeable Surfaces:

Although certain regions (especially Sabwnkaran Zones 1 and 2 and Mallkandy Zones 5) lacked permeable surfaces, reflective surfaces only partially meet regulations (40–50%). This could raise the danger of stormwater runoff and decrease heat absorption.

W/H Ratio:

There is a rather excellent balance between height and breadth because all regions are more than the minimum (>1). nonetheless, some regions with extremely high values (e.g., Zone 2 Sabwnkaran: 2.6) may require adjustments since they could lead to temperature discomfort.

Street Design (Street Patterns):

Straight grid-line streets do not exist in all places, and narrow, twisting streets have rare or nonexistent in others, suggesting a lack of efficient design allowing better ventilation and temperature regulation.

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دور النسيج الحضري في التكيف مع تغير المناخ لتحقيق مدينة حضرية مرنة: مدينة السليمانية كدراسة حالة

الملخص

تهدف هذه الورقة البحثية إلى وضع إطار عمل تجريبي متعدد التخصصات تدمج ما بين مورفولوجيا المدن المحلية والتدخلات التكنولوجية المستجيبة للمناخ لتعزيز المرونة والاستدامة والمشاركة المجتمعية في المراكز الحضرية النامية، وذلك باستخدام السليمانية كدراسة حالة. عن طريق استخدام منهجية بحثية مختلطة، تُؤدي التداعيات المتزايدة لتغير المناخ إلى مواجهة المدن لمجموعة أوسع من المشكلات، بما في ذلك ارتفاع درجات الحرارة، واضطراب أنماط هطول الأمطار، وتدهور جودة البيئة الحضرية. وعلى الرغم من مرونتها التاريخية، لم تعد أنظمة التخطيط التقليدية قادرة على التعامل مع الاضطرابات المناخية المعقدة بمفردها، كما أظهرت العقود الأخيرة. وقد لا تنجح الحلول السليمة تقنياً في بعض الأحيان من حيث القبول الاجتماعي أو التوافق مع النسيج الحضري التقليدي. وكوسيلة لتحقيق مرونة حضرية مستدامة أفضل، نشأت حركة عالمية تُشجع على دمج التخطيط الحضري التقليدي مع الحلول التكنولوجية المُستجيبة للمناخ. تبحث هذه الدراسة في النسيج الحضري للسليمانية وقدرتها على التكيف مع تغير المناخ. وقد تم تقييم السمات المناخية والاجتماعية والحضرية من خلال مسوحات ميدانية في منطقتي صابونكاران وملكندي، كما تم جمع آراء الخبراء حول استراتيجيات التكيف باستخدام استبيانات. وتم تقييم الحلول التقليدية والمعاصرة والمتكاملة، إلى جانب تحديات التنفيذ واستراتيجيات التكيف، ب SPSSوExcel تقنيات التحليل الوصفي وقد تم دعم التحليل الكمي والنوعي بتقنيات بصرية ومكانية مثل AutoCAD و SketchUp و Photoshopالتصوير الفوتوغرافي, وصور الأقمار الصناعية. وقد دعمت المقابلات المنظمة مع الخبراء الاستنتاجات وقدمت اقتراحات مفيدة ومحددة من أجل تنمية حضرية مرنة ومستدامة في السليمانية. وقد تحقق ذلك من خلال دراسة تفصيلية لأحياء مختارة ضمن منطقتي سابونكران وملكندي ، حيث تم تحليل خصائصها الحضرية الرئيسية من حيث مواد البناء، واتجاه المباني، ونسبة ارتفاع المباني إلى عرض الشوارع، ونسبة المساحات المفتوحة إلى المبنية، ونسبة المساحات الخضراء، والشوارع المتعرجة والمستقيمة، ونسبة الظل والأشجار. وقد وفر هذا التحليل فهماً عاماً للاستراتيجيات التقليدية المتبعة، ودليلًا على كيفية تحسين هذه الاستراتيجيات بإضافة تقنيات حديثة.

الكلمات الافتتاحية :

النسيج الحضري؛ المرونة؛ التكيف؛ التغييرات المناخية.

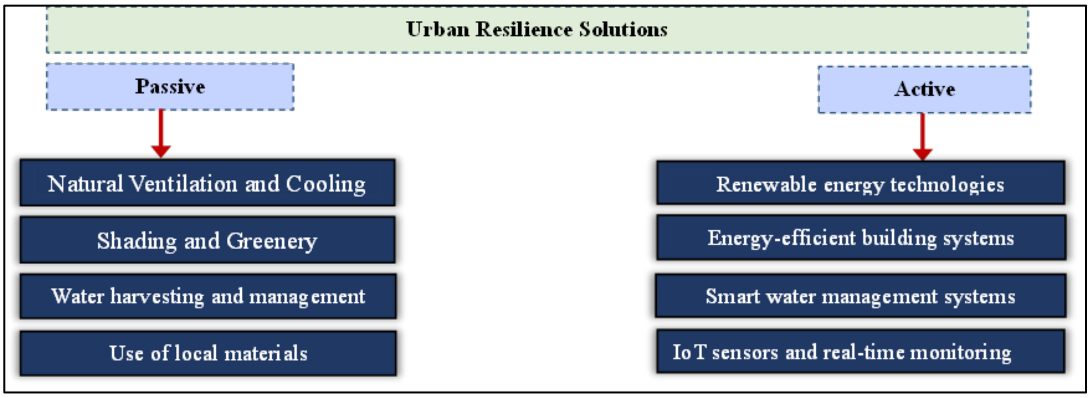


Fig.1: Urban resilience solutions(Researcher)

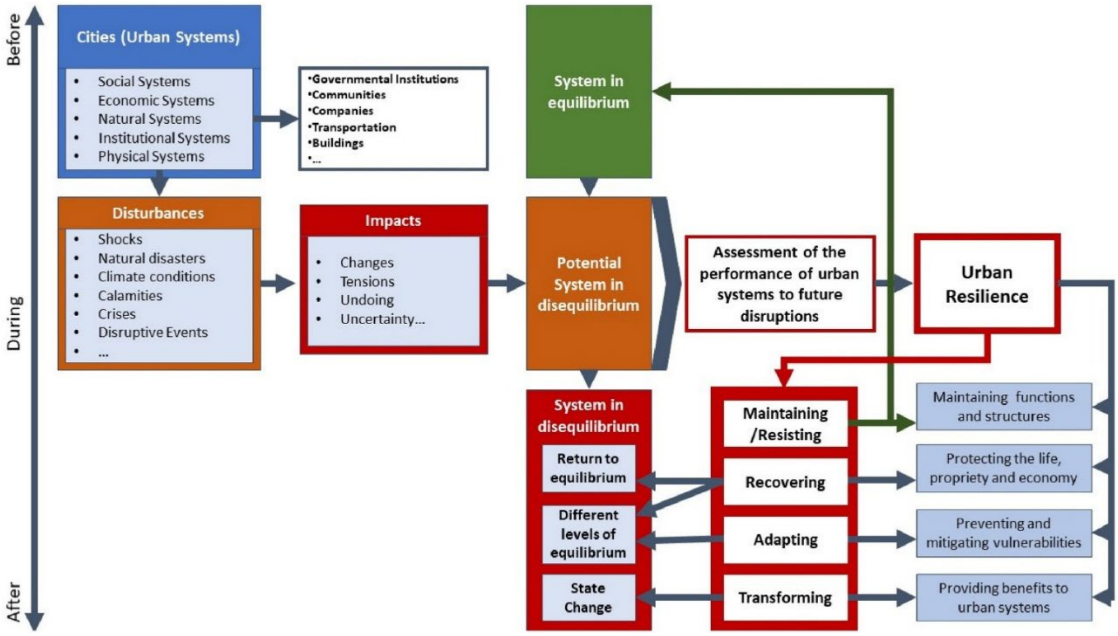


Fig.2: The concepts of Urban resilience are explained in terms of four pillars (Ribeiro & Gonçalves, 2019)

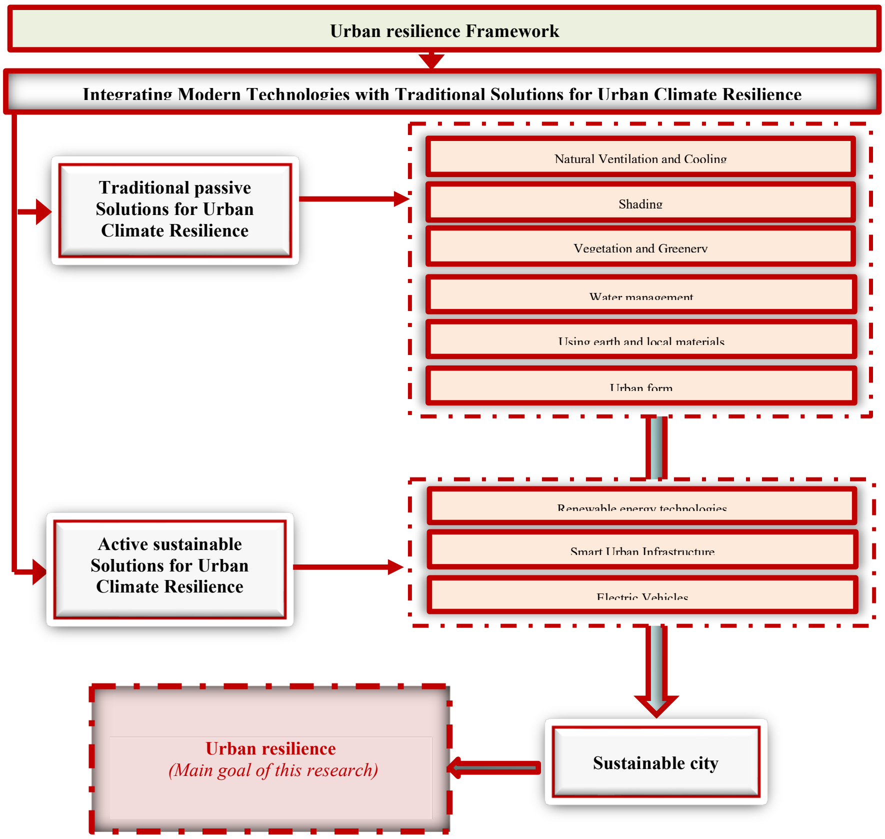


Fig. 3. Urban resilience Framework (Researcher)

Table 1: Adaptation categories (researcher)

Category	Type	Examples
Structural/ physical	Engineered and built environment	Flood and cyclone shelters, sea walls, coastal protection structures, etc.
	Technological	Water-saving technologies, early warning systems, etc.
	Eco-system based	Afforestation and reforestation, green infrastructure, etc.
	Services	Social safety nets and social protection, public health services, etc.
Social	Educational	Knowledge sharing and learning platforms, awareness raising, etc.
	Informational	Early warning and response systems, community-based adaptation plans, etc.
	Behavioral	Livelihood diversification, migration, crop-switching, etc.
Institutional	Economic	Financial incentives such as subsidies and taxes, weather insurance, etc.
	Laws and regulations	Water regulations, disaster risk management laws, etc.

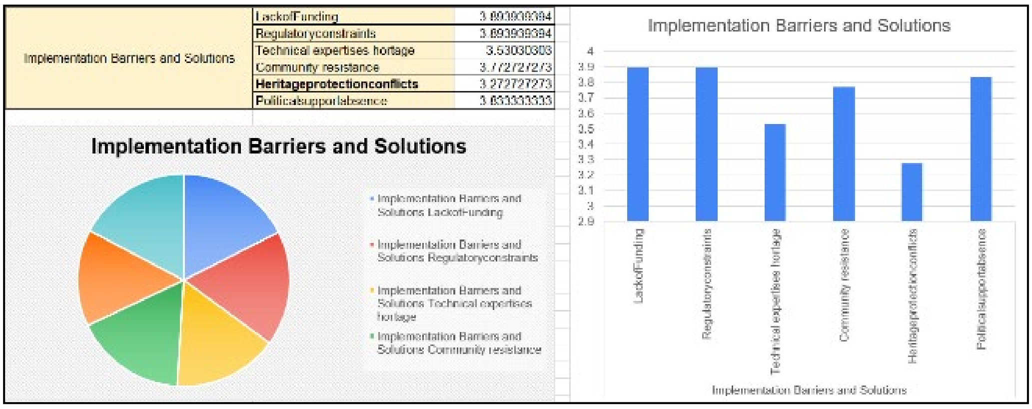


Fig. 4. Average responses on the role of Traditional Urban Fabric in addressing climate challenges in Sulaymaniyah. (Researcher)

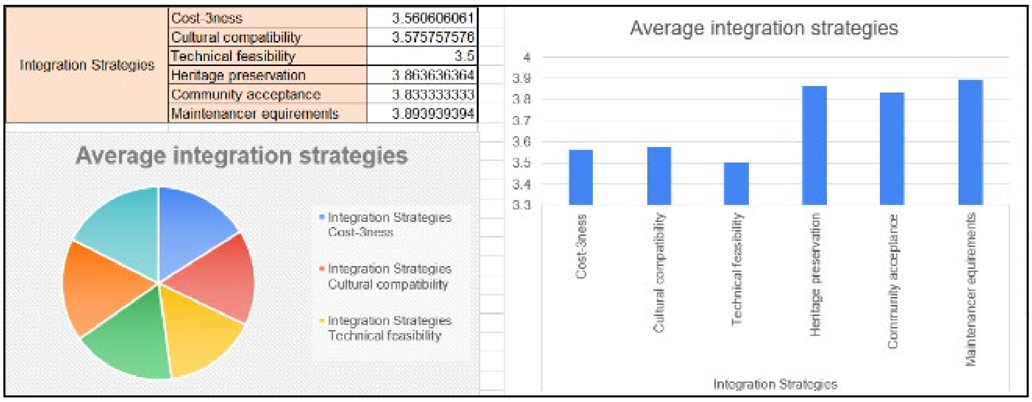


Fig. 5. Average responses on the role of modern technological solutions addressing climate challenges in Sulaymaniyah. (Researcher)

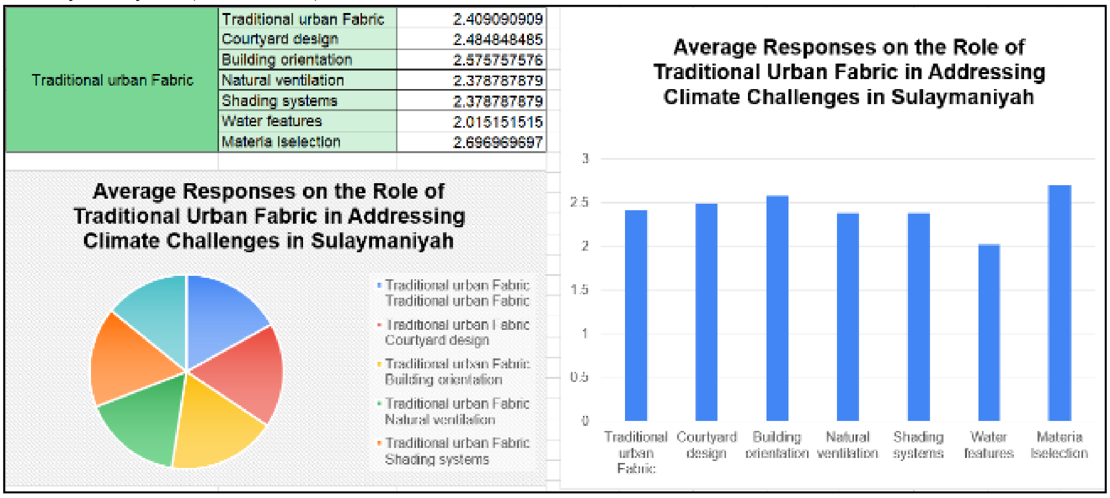
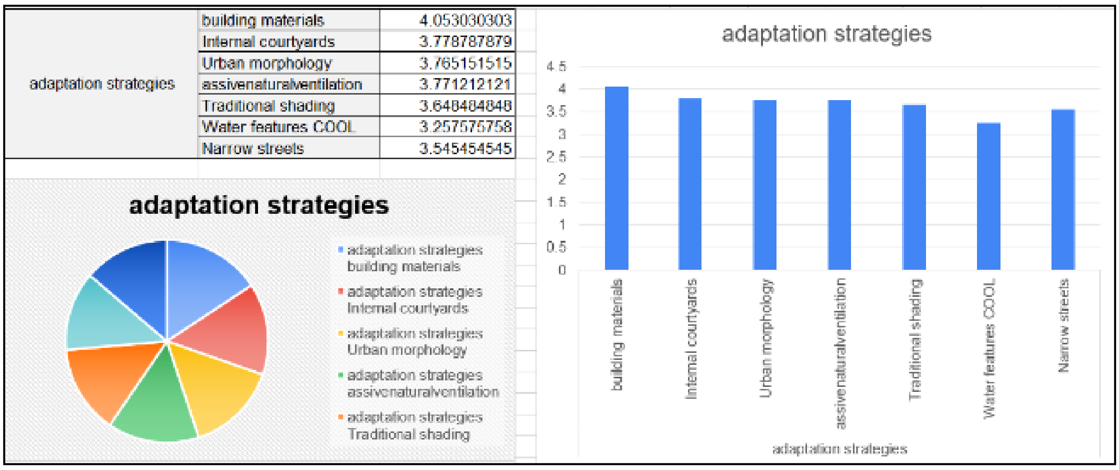
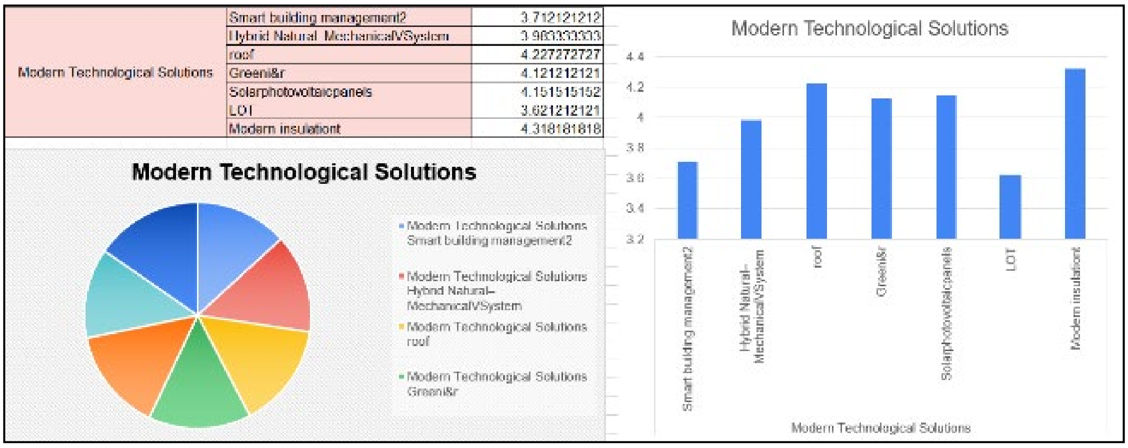


Fig. 6. Average responses on the role of integration strategies addressing climate challenges in Sulaymaniyah. (Researcher)

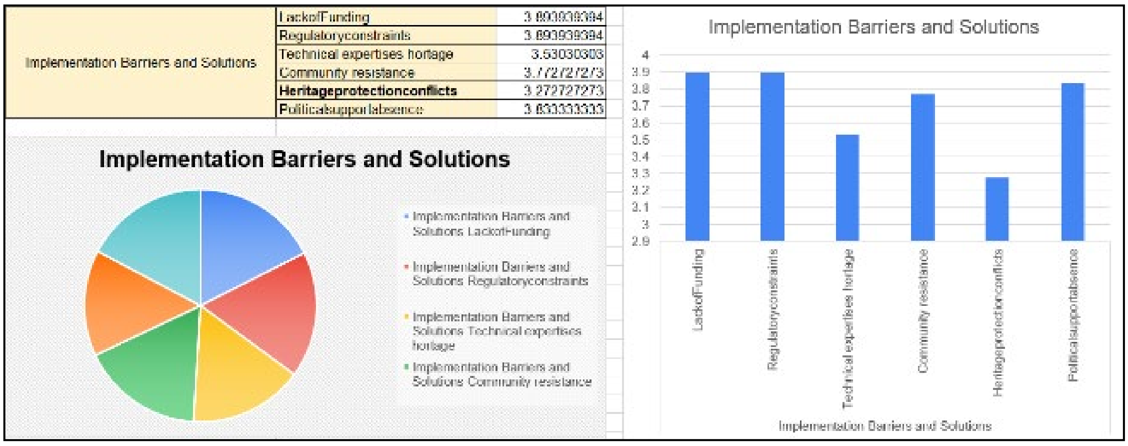


adaptation strategies	building materials	4.053030303
	Internal courtyards	3.778787879
	Urban morphology	3.765151515
	assivenaturalventilation	3.771212121
	Traditional shading	3.648484848
	Water features COOL	3.257575758
	Narrow streets	3.545454545

Fig.7. Average responses on the role of Implementation Barriers and Solution. (Researcher)



Modern Technological Solutions	Smart building management2	3.712121212
	Hybrid Natural- MechanicalVSystem	3.983333333
	roof	4.227272727
	Greeni&r	4.121212121
	Solarphotovoltaicpanels	4.151515152
	LOT	3.621212121
	Modern insulationt	4.318181818



Implementation Barriers and Solutions	LackofFunding	3.893939394
	Regulatoryconstraints	3.893939394
	Technical expertises hortage	3.53030303
	Community resistance	3.772727273
	Heritageprotectionconflicts	3.272727273
	Politicalsupportabsence	3.833333333

Fig.8. Average responses on the role of Implementation Barriers and Solution. (Researcher)

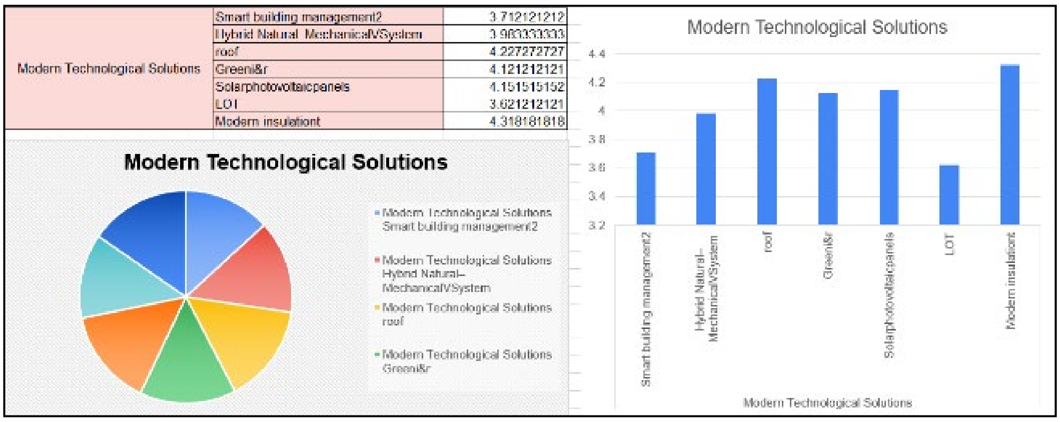


Fig.9. Average responses on the role of modern technological solutions. (Researcher)

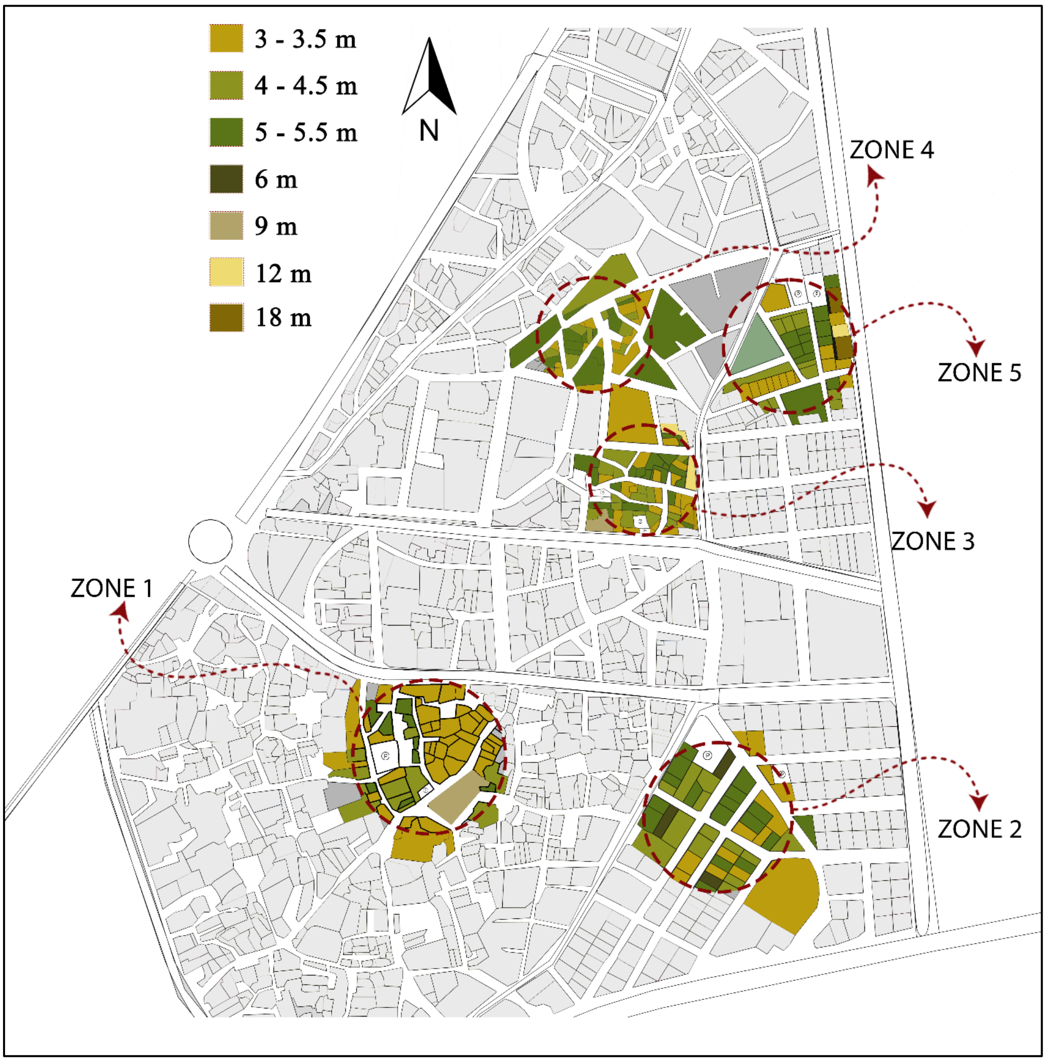


Fig. 10. Selecting Case Study Area(Researcher)

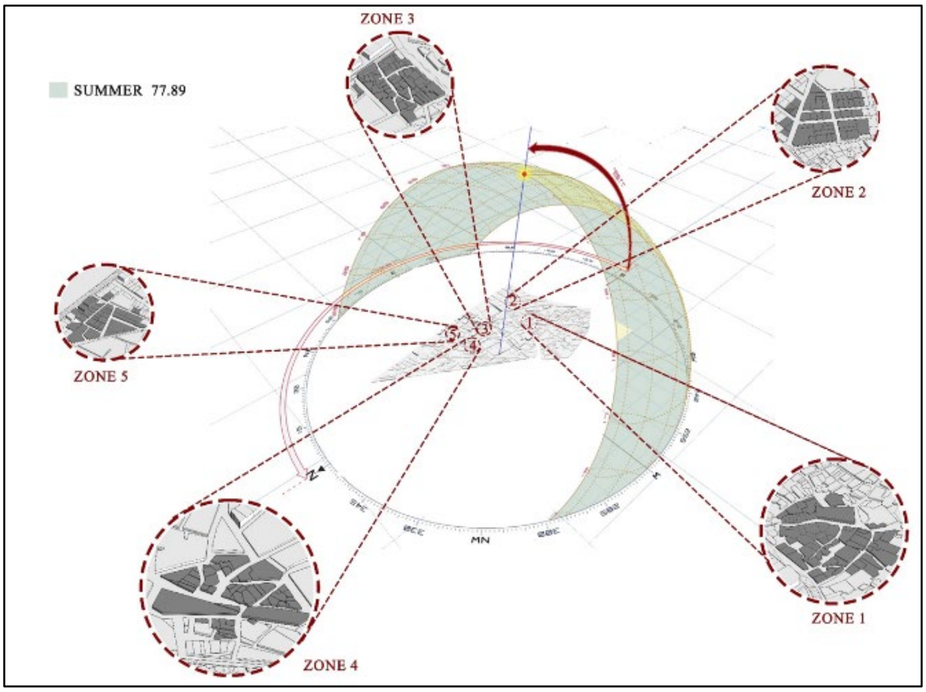


Fig. 11. Explanation of the sun's path relative to the case study areas: A: Summer (Researcher)

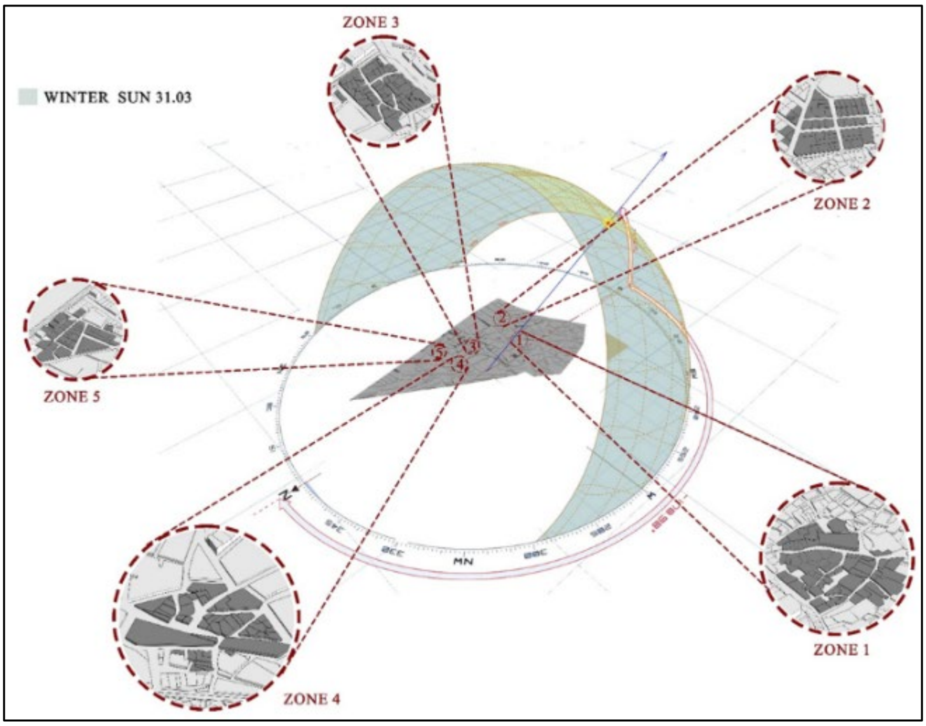
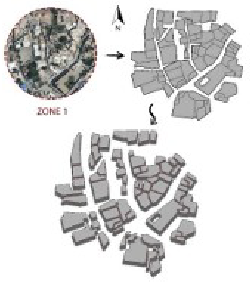
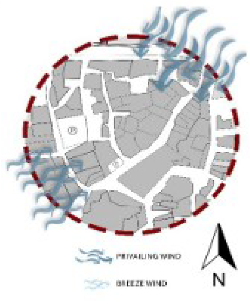
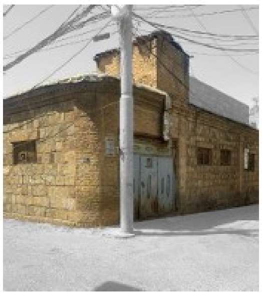


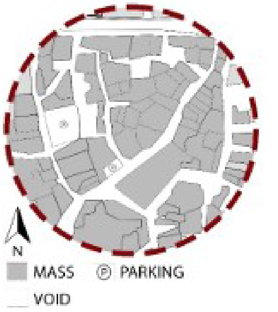
Fig. 12. Explanation of the sun's path relative to the case study areas: B: winter

Table 2: Regression results for each indicator (Researcher)

Indicator	Constant (B)	X_Score (B)	Std. Error	Beta (Std.)	t (X_Score)	Sig. (X_Score)	R^2
Open Space	3.330	-0.040	0.055	-0.386	-0.725	0.521	0.149
Building Height	2.895	-0.035	0.051	-0.371	-0.692	0.539	0.138
Building Materials	4.072	-0.006	0.037	-0.088	-0.153	0.888	0.008
Green Space	3.050	0.070	0.017	0.924	4.200	**0.025**	0.855
Narrow/Winding Streets	3.515	0.025	0.037	0.360	0.667	0.552	0.129
Orientation	2.700	-0.025	0.028	-0.464	-0.908	0.431	0.216
Permeable Surfaces	2.870	-0.055	0.037	-0.647	-1.468	0.238	0.418
Reflective Surfaces	3.210	-0.042	0.044	-0.481	-0.951	0.412	0.231
Straight Grid Streets	3.203	-0.047	0.017	-0.843	-2.711	0.073	0.710
Tree Canopy	3.168	-0.022	0.029	-0.391	-0.736	0.515	0.153
W/H Ratio	3.173	-0.015	0.030	-0.277	-0.499	0.652	0.077

Table (3): An analysis of Zone No. one within the Sabwnkaran district (Researcher)

No.	Indicator	Description & Measurement Method	Sabwnkaran district	Measured Value (Study Area)	Standard/Recommended Value	Assessment
			Zone one			
1	**Open Space to Built Mass Ratio**	Ratio of open/void spaces to built structures. Measured using AutoCAD area calculations and SketchUp volume analysis.		Total Area:44262 m² Mass:30370m² %68.6 Void:13892m² %38.2	40:60 to 50:50 (Open: Built) *Optimal for ventilation and heat dissipation*	2
2	**Building Orientation**	Predominant building orientation relative to sun path and prevailing winds. Analyzed using AutoCAD compass and solar studies.		%62	N-S orientation: 60-70% *Minimizes east-west sun exposure in hot climates*	4
3	**Building Materials**	Type and thermal properties of predominant materials. Documented through site photos (Google Images) and material surveys.		78% low thermal mass; 30% reflective	Low thermal mass materials: >60% Reflective materials: 30-40% *Light colors preferred for heat reflection*	4

4	**Green Space Percentage**	Percentage of area covered by vegetation (parks, trees, green roofs). Calculated using AutoCAD area analysis and satellite imagery.		15%	25-30% minimum *WHO recommends 9m² per capita; 30-40% optimal for heat mitigation*	1
5	**Tree Canopy Coverage**	Percentage of ground area shaded by tree canopies. Measured from aerial imagery analysis and field surveys.		15%	20-30% *Provides natural cooling and reduces surface temperatures by 2-5°C*	1
6	**Reflective Surfaces (Albedo)**	Percentage of surfaces with high solar reflectance (light-colored roofs, pavements). Measured via material surveys and Photoshop color analysis.		%36	40-50% of horizontal surfaces *Albedo >0.6 for roofs, >0.4 for pavements*	2
7	**Permeable Surfaces**	Percentage of ground surfaces that allow water infiltration. Calculated from AutoCAD site plans and material mapping.	None	0	30-40% *Reduces urban flooding and heat island effect*	0

8	**Street Width to Building Height Ratio**	Ratio for assessing canyon effect and ventilation. Measured in AutoCAD cross-sections and SketchUp street profiles.		W/H ratio=average street width/average Building Hight 10/5.25=1.9	**W/H < 0.5 →** *Deep canyon; poor ventilation; low sunlight* **0.5 < W/H < 1.0 →** *Moderate canyon depth; constrained airflow* **W/H > 1.0 →** *Open canyon; better ventilation and daylight*	5
9	**Narrow & Winding Streets/Alleys Pattern**	Percentage of area with narrow (3-6m), winding, organic street patterns typical of traditional neighborhoods. Measured using AutoCAD Street analysis and Google Earth imagery.		12%	Recommended: 15-25% of total urban area	1
10	**Straight Streets Pattern (Grid)**	Percentage of area with straight, wide (10-20m) grid street patterns typical of modern planned areas. Measured using AutoCAD Street network analysis.	None	0	Recommended: 60-70% of total urban area	0