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The impact of urban morphology and energy demand of a residential buildings in Hebron city

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The impact of urban morphology and energy demand of a residential buildings in Hebron city

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In partial fulfillment of the requirements for the Master’s degree in Renewable Energy & Sustainability.

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The impact of urban morphology and energy demand of a residential buildings in Hebron city
Aseel Ishaq Abu Daba't

ABSTRACT

A comprehensive understanding of the urban form is a prerequisite for sustainable development, especially in cities where urban growth is confined to a limited geographical area, such as Hebron City, which faced rapid urban growth, increased density, as well as population growth and migration to the city in the last several decades, and where efforts focused mainly on optimizing land as an economic asset instead of taking into account its energy demand. Despite the fact that urban form is considered a major discourse in urban studies, little work has been done at the urban level in Hebron.

This thesis examines the impact of urban morphology in the city on residential building selected in Hebron, West Bank. The energy building was examined in different urban patterns, which were classified using GIS. The urban variables, which are: built intensity, compactness, building height, and open space ratio, were identified at the urban level to express the differences in the urban fabric. The performance was assessed regarding energy demand (heating and cooling), using Design-Builder simulation software on a typical building, which was located by the Mean Center in GIS. Moreover, the obtained results were compared with values of CFD analysis aimed at improving energy demand to determine how far these results are from sustainability.

This thesis demonstrated that the urban form plays a significant role in determining the performance of the building and its energy demand. It has also reached some general recommendations such as greenery which assist engineers and maker- decisions in the planning process and urban design. Moreover, it will help decision-makers understand the influence of these constraints of the urban form (urban variables) on the city development in terms of energy demand. It can further reveal important information about problems, and possibilities to be expected under different density conditions with better energy demand to cope with the challenges of a rapidly growing urban population through the equations that has been got.

Keywords: Energy demand,GIS, Urban tissues, Floor space index (FSI), Ground space index (GSI), simulation software, Open space ratio (OSR), urban parameter, Ancient morphology science.

تأثيرالتشكل الحضري والطلب على الطاقة في المباني السكنية في مدينة الخليل

اسيل ابو الضبعات

الملخص

يعد الفهم الشامل للشكل الحضري شرطًا أساسيًا للتنمية المستدامة ، لا سيما في المدن التي يقتصر فيها النمو الحضري على منطقة جغرافية محدودة مثل مدينة الخليل ، والتي واجهت نموًا حضريًا سريعًا ، وزيادة في الكثافة فضلاً عن النمو السكاني والهجرة إلى المدينة في العقود الماضية ، وحيث ان الجهود تركزت بشكل أساسي على تحسين الأرض كأصل اقتصادي بدلاً من مراعاة أداء الطاقة فيها. بالاضافة الى أن الشكل الحضري يعتبر خطابًا رئيسيًا في الدراسات الحضرية ، ولكن فقد تم إنجاز القليل من العمل على المستوى الحضري في الخليل.

تبحث هذه الأطروحة في تأثير الشكل الحضري في المدينة على مبنى سكني تم اختياره في الخليل في الضفة الغربية، تم فحص المبنى في مناطق حضرية مختلفة لنفس المدينة حيث تم تصنيفها باستخدام نظم المعلومات الجغرافية ، بالاضافة الى تحديد المتغيرات الحضرية ، وهي: (الكثافة المبنية ، والاندماج ، وارتفاع المبنى ، ونسبة المساحة المفتوحة) على المستوى الحضري للتعبير عن الاختلافات في النسيج الحضري حيث تم تقييم الأداء للمبنى النموذجي فيما يتعلق بالطلب على الطاقة (التدفئة والتبريد) ، باستخدام برنامج محاكاة Design-Builder في المبنى المستهدف، والذي تم تحديده بواسطة Mean Center في برنامج (GIS) علاوة على ذلك ، تمت مقارنة النتائج التي تم الحصول عليها مع قيم تحليل اداء طاقة الرياح على المستوى الحضري(CFD analysis) وذلك لتحقق من دقة النتائج والتي تهدف إلى تحسين الطلب على الطاقة لتحديد مدى بُعد هذه النتائج عن الاستدامة.

أثبتت هذه الدراسة أن الشكل الحضري يلعب دوراً هاماً في تحديد أداء المبنى والطلب على الطاقة فيه، كما توصلت إلى بعض التوصيات العامة لمساعدة المهندسين في عملية التخطيط والتصميم الحضري، بالاضافه الى انه سيساعد صانعي القرار على فهم تأثير هذه القيود على الشكل الحضري (المتغيرات الحضرية) على تنمية المدينة من حيث الطلب على الطاقة. يمكن أن تكشف كذلك عن معلومات مهمة حول المشاكل ، والإمكانيات المتوقعة في ظل ظروف كثافة مختلفة مع طلب أفضل على الطاقة لمواجهة تحديات النمو السريع لسكان المناطق الحضرية.

الكلمات المفتاحية: الطلب على الطاقة، الأنسجة الحضرية، مؤشر المساحة الأرضية (FSI)، مؤشر المساحة الأرضية (GSI)، برمجيات المحاكاة، نسبة المساحة المفتوحة (OSR)، المعلمة الحضرية، علم التشكل القديم.

DECLARATION

I declare that the Master Thesis entitled" The relationship between urban morphology and energy demand in Hebron" is my own original work, and I do hereby certify that unless stated, all work enclosed within this thesis is my own independent research and has not been submitted for the award of any other degree at any institution, except where due acknowledgement is made in the text.

Aseel Abu Daba't

Signature:________________________ Date:________________

DEDICATION

This work is heartily and proudly dedicated to the people who serve as an inspiration to me.

To the one who taught me the meaning of persistence, and that nothing is impossible with the power of faith... to my mother.

To the one whom I'm honored to hold his name. To my father.

To my husband who has been the best support throughout my path.

To my Instructor, Dr. Shireen Al-Qadi, who enlightened me on the path of science.

To those who were like a mother and father to me. my in-laws

I dedicate this humble achievement to all of my siblings and friends who were always there to support me.

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List of Abbreviations

H1	Hebron 1 (Palestinian Government)
GIS	Geographical Information System
GMM	Gaussian Mixture Model
FSI	Floor Space Index
GSI	Ground Space Index
OSR	open space Ratio
L	Average number of floors
OSMnx	Open Street Map Network x
GHG	Green House Gases
UHI	Urban Heat Island
HHD	Highest Heating demand
HCD	Highest cooling demand
BEI	Baseline Emission Inventory
IEC	Israel Electric Corporation
LOD1	Level of Detail (1)
Avg.	Average
U value	Transmittance value.
Sc	Scenario
ASHRAE	The American Society of Heating, Refrigerating and Air-Conditioning Engineers

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Chapter 1
Introduction

1.1 Preface

The link between buildings and their built environments is a multidimensional challenge for architects and planners. It is not enough to only focus on individual buildings; it is also essential to expand the analysis to urban form (Sanaieian et al., 2014). The cities' spatial structure and their relationship with the urban environment have recently been the subject of theoretical, empirical, and policy research (Anderson et al., 1996). In addition, understanding the urban environment and urban context is important before starting the planning process. Urban environment includes the interactions of population growth, city management, and the built environment with the natural environment (Shaheen, 2006). The energy demand depends upon the geometric and dimensional characteristics of the local urban form: the orientation, the plots, the blocks, the open spaces, and so on. All combined to determine the performance of buildings, which should be analyzed within the system of urban morphology to be fully understood, so the urban form influences require more exploration, considering many differences, and deeper investigation to preserve the access of natural resources such as air and light within buildings.

The main responsibility for current urban morphology is the perception of the patterns within the urban form (Fleischmann, 2017). Christopher Alexander explained that a city comprises an unlimited number of overlapping patterns at all resolution scales (Alexander, 1965) .The most visible feature of urban dynamics is the appearance of irregular or amorphous settlement patterns (Frankhauser, 1997). Therefore, the structure of cities cannot be understood without exploring the urban tissue, especially in Hebron, where it is difficult to find references for describing the urban form.

This thesis provides a methodology to evaluate the energy demand of buildings in certain urban forms to understand and improve cities.

1.2 Problem statement

Cities are the main cause of the depletion of large amounts of energy resources;50% of the world's population has resided in a city and this percent will reach up to 80% by 2030. (Sanaieian et al., 2014) . More than 60% of the world’s growth in population is happening in Asian cities (Lai et al., 2018), So it is regarded as the main cause of social and environmental problems, which are reflected in its urban forms (Bin Sulaiman et al., 2017). Jabareen (2006) said that many environmental problems are due to the form of the contemporary city.

The Palestinian-occupied territory faces significant difficulties identified by population growth rates, rapid urbanization, and scarcity of land (Shaheen, 2006). Due to restrictions imposed by the Israeli occupation and the lack of an effective Palestinian planning institution, urban development in the cities did not follow studied planning schemes, which led to deterioration of the urban structure of cities and negatively affected land use, urban services, and the quality of the living environment (Shaheen and Salim, 2012). Moreover, the current pattern of urban growth and urbanization cause many difficulties that might lead to serious environmental degradation (Shaheen, 2006).

The population growth rate in the city of Hebron reached 2.3%, and it is estimated to reach (23,858) in 2025, which means more demand for land for housing purposes (Shalaldeh,2020). Hebron city is becoming a highly dense city since horizontal urban development is restricted (Muallem, 2020). This is due to the high prices of land, and Israel confiscation of large areas of land belonging to the city for the construction of settlements; Thus, the population is forced to expand vertically. The city has started to lose its traditional physical characteristics from the mid-twentieth century. These changes in urban form were similar to other changes in many developing countries that have been transformed into a modern style, it also has changed the spatial and physical characteristics of urban form; which neglect the harmony with environmental factors of Hebron city. Figure (1.3) shows the 3D description of buildings in H1 area in the city of Hebron.

Figure 1.1: 3D description of buildings in H1 area in Hebron city (Shalad, 2020).

1.3 Research significance

The majority of populations are living in urban areas these days, which has led to the need for more buildings and more space. As a result of population growth and land scarcity due to political situation, urban spaces are growing at an unhealthy rate which has led to various problems. The scarcity of studies on the morphology at a precise spatial level limits knowledge on the formation and development of such areas and the ability to develop useful policy and urban planning in the context (Mottelson and Venerandi,2020). The desire to study and measure the city can help treat its enormous complexity, as the vast growth of cities and energy demand, through identifying its parts and abstracting the various layers that compose it, particularly if our aim is to plan and design a better-built environment. This study assists specialists and decision-makers and provides them with a clear insight into the spatial patterns of residential buildings in the city of Hebron. help them make appropriate decisions to solve problems, especially in a dense urban environment, and it can strongly influence a building's energy demand. It also contributes to making the city more vital with healthy residential areas.

1.4 Theoretical Background

During the last 20 years, the major development has been the great awareness of cities' morphology to fit with buildings (Strømann-Andersen and Sattrup, 2011). Hence , researchers began to shift their focus from individual buildings to neighborhoods and attempt to simulate the influence of the environmental performance on buildings since 1990s (Y. Jabareen, 2006), and the environment consequences of human activities have been increasingly interesting (Anderson et al., 1996). In particular, the urban form is affected by the environmental, economic, social and political aspects of the cities. Also, human activities are affected by the physical form of the city (Charehjoo, 2013), and there is a large amount of effort that applies the physical aspect of urban form and human activities.

Methods have been adopted in the investigation of the link between urban form and environmental and energy demand. Many studies describe the environmental quality of urban open spaces, which involves an extensive range of qualitative aspects of the built environment like daylight availability, thermal comfort, and access to solar energy ,etc(Zhang et al., 2012) (Aghamolaei, 2020). Other studies have discussed the environmental implications of high-density urban context from several aspects; such as the correlation between different built forms and spatial arrangements on urban daylight availability and ventilation (Zhang et al., 2012), thermal comfort (Luo et al., 2020), urban climate

(L. Katzschner,et al , 2009) (Xu et al., 2017) and acoustic environment (L. Silva et al., 2017). Another aspect described the environmental quality of building façades because it is directly or indirectly linked to achieving good internal environmental quality that has implications on human comfort, building performance and perception, in terms of energy demand (Zhang et al., 2012). There are many studies done in the last years on the impact of complex environmental interactions occurring in the urban context that develop methods and techniques for energy simulation at this scale (Ratti et al., 2005).

Several studies analyzed a parametric urban performance by using a hypothetical uniform and non-uniform urban block (Natanian et al., 2019a) ; used a hypothetical urban models under a parametric evaluation approach, to examine the relationship between design parameters, density and environmental performance (Natanian et al., 2019a). Cheng (2009) examined the relationship between built form, density and solar potential in both uniform and irregular 100×100 m models (Cheng et al., 2006). Vermeulen (2018) used a non-uniform urban block to evaluate the relationship between urban morphology and solar potential on facades by an evolutionary shape optimization method(Vermeulen et al., 2018). Saratisis (2016), tested indoor daylight for five different typologies in New York city , each in ten various density scenarios (Saratsis et al., 2016). Javanroodi (2018) explored the impact of building typology on ventilation potential and cooling loads in a high-rise urban bloc.(Javanroodi et al., 2018).

Many urban form studies present full analysis, quantification and description of urban environments, offering various methods to classify urban form to obtain urban patterns to provide a better understanding of the characteristic of the city form (Gil et al., 2012). Braulio and Gonzalo(2020) show a methodology that describes the urban taxonomy to determine the urban form patterns of residential buildings using (GIS) technology to the Castellón de la Plana city in a Span(Braulio-Gonzalo et al., 2020). Boeing explores urban fabric patterns and spatial systems depending on the theoretical framework of visual cultures in urban planning and morphology using OSMnx (Open Street Map network -web page) and its data.(Boeing, 2021). Venerandi and Mottelson (2021) present a taxonomic study at a fine level of spatial granularity of the urban form of five major cities of Sub-Saharan Africa by applying k-means clustering at eight indicators of urban form computed at the block level(Venerandi and Mottelson, 2021). Al-Saaidy and Alobaydi (2021) study urban block structures by using metric and computational methods. They determined three important variables of urban blocks - perimeter, size, and dimension, that are selected to identify the blocks' features and differences in Baghdad, Iraq by using different statistical methods linked with computation techniques and a geographical information system (Jasim Essa Al-Saaidy and Alobaydi, 2021).

The findings from the literature illustrate both; a common focus on environmental performance and measuring cities or identifying urban patterns of cities. More research efforts are essential to understand the relationship between different urban morphology.

1.5 Research question

The main research questions are as follows:

What is the relationship between energy demand of the residential building and the urban morphology in Hebron city?

Sub-questions:

1. What are the urban patterns for the residential building in Hebron and how to access them?
2. How does the urban pattern affect the energy demand of the individual building?

1.6 Objectives

The main objective of this thesis is to evaluate the impact of the urban form of different urban morphologies in Hebron on the demand of an individual residential building (prototype). This aim is supported by the following research objectives:

1. Identify the characteristic of urban patterns of residential buildings in the city of Hebron using GIS software.
2. Identify the basic parameters of the urban form that affect the energy demand of building in Hebron.
3. A reference to the energy demand of urban models under different density conditions.

1.7 Methodology

To reach the objective, descriptive, quantitative and analytical means must be considered. It is necessary to implement four main phases to form the research methodology as shown in Figure 1.2

1. Literature review: The stage of preliminary studies and the collection of information include: concepts and terms of the thesis idea, international standards and index of

urban parameters, limitations of sustainable residential buildings in the Mediterranean and international standards of energy demand.

2. Analysis of the urban context of Hebron city using the GIS system through spatial analysis. a multivariate approach in the analysis of building fabric morphology by cross-analysis of different dimensions of urban density (built intensity, compactness, open space ratio, and building height) to identify the shapes of urban blocks for residential areas. This method is used to define the shapes of urban blocks in contemporary cities.
    - GIS system: A Geographic Information System designed to store, retrieve, display, manage and analyze all kinds of geographic and spatial data. GIS software produce maps and other graphic displays of geographic information for analysis ("Maptitude GIS Software," 2003).
3. Determining the main characteristics of the residential buildings. Information about a prototype residential design building is gathered by literature review, which will determine the parameters of predicting sustainable housing in the Mediterranean climate such as Orientation, window to wall ratio, and so on.
4. Analysis of the energy demand of different scenarios within the urban fabric. The simulation will be carried out on the whole proposed building by using the Design builder simulation program.
5. Analysis of simulation results to identify the basic parameters of the urban form that affect the energy demand, which was obtained by heating and cooling calculations, and CFD analysis of buildings in Hebron city.

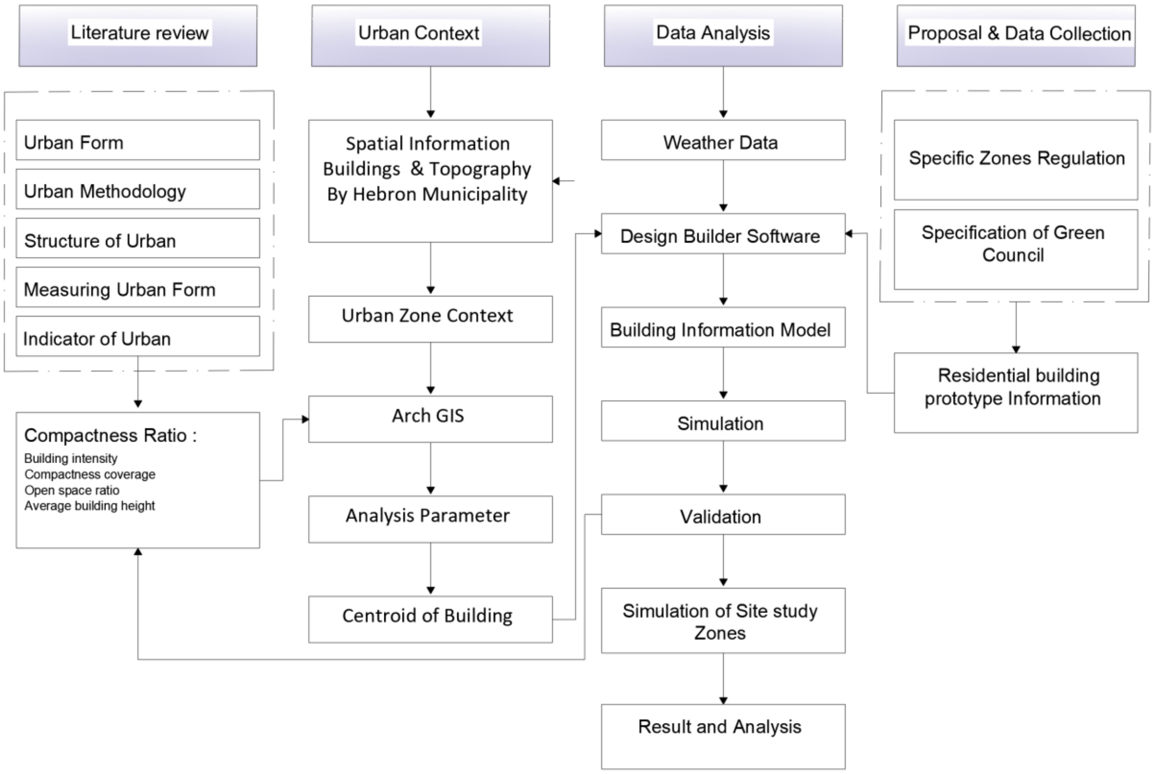


Figure 1.2: Research Methodology.

Expected result: Access to general recommendations that assist engineers, decision-makers, urban planners and designers in the process of urban planning, design and policy making related to the environmental performance and sustainable development. In addition, it helps decision-makers to determine how the urban form can affect the development of cities from an environmental point of view. It also allows understanding the emerging issues in the urban fabric, so that they can prepare a design for the city or restructure its urban form. At the same time, it provides us with information about the problem under different conditions of density, and in turn, it can help them choose models with better energy performance, and guide urban development towards a more sustainable urban form.

1.8 Research scope and limitations

Scope:

1. Hebron City (Hebron context): Hebron is located in the south of the West Bank. It is regarded as the largest Governorate in size and population. It is one of the oldest cities, it dates back more than 4.000 years (Hebron City Profile 2009).

2. The Mediterranean Climate: Hebron is located in the Mediterranean Climate. It is mostly characterized by clear cold winters and clear, long, arid warm summers, with an average daily high temperature of 27 degrees, several months of the year it is warm to hot at temperatures continuously above 25 degrees and reaches 33 degrees (Weather Spark)
3. Prototype of buildings: multi-story.

Limitations:

1. Limited information about the weather file that describes the micro-climatic in the city of Hebron, so the study will be limited to the weather of Jerusalem.
2. Several simulation methods have been developed to study and describe the environmental and energy demand of buildings; but most of these studies have focused on buildings as individual blocks neglecting the urban context in which the building is placed.

1.9 Thesis outline

This research is divided into five chapters following the introduction chapter as shown in Fig (1.3); thus, subsequent chapters are as follows:

Chapter 1: This chapter presents an overview of the components of the research; introduction, background, research problems and urban issues in contemporary urban forms in Hebron, the main research question, sub-questions, objectives and methodology, besides describing the research strategy and approach. The organization of the dissertation is presented in the last section.

Chapter 2: presents the research on urban morphology, the current literature on energy demand, and a literature review on the various definitions related to urban forms. A new quantitative approach to measuring urban form is addressed in this chapter. Some design concepts, criteria, and international standards and indexes for urban morphology used in this thesis are discussed in further detail, and it investigates the effects of urban structure and density on residential building energy demand, as well as it of residential buildings in Hebron.

Chapter 3: It describes the methodology used in this research to achieve its objectives, and it provides an overview of the research methodology and the analytical framework developed. It also discusses the tools used to collect data and select case studies and simulation trials during the study process.

Chapter 4: presents the analysis of data concerning the urban form of Hebron’s residential area that will be collected from Hebron municipality. It consists of the main subject related to the four density parameters concerning the built intensity, compactness, open space ratio, and building height, which are then analyzed. Finally, it contains a discussion that covers the comprehensive analysis of this stage.

Chapter 5: This chapter synthesizes common design, scenario analysis and energy simulation for evaluating environmental performance across a range of urban forms.

Chapter 6: This chapter summarizes the findings from the previous chapters. It also highlights the significance of the research and its limitations. Finally, it gives general recommendations and suggestions for future research.

Chapter 2: Literature Review:

2.1 preface

This chapter reviews the relevant literature to provide a theoretical foundation for understanding the main concepts and terms. It focuses on the theories, approaches, and main indicators used for urban forms, besides the quantitative analysis which has been conducted. Among the works taken into account, two criteria have been identified: studies related to the identification of physical and spatial patterns that permit a classification of similar urban forms, ultimately relevant to the formulation of general theories; quantitative analysis tools, used to conduct research on case studies.

2.2 Definition of Urban form, Urban morphology and Urban pattern

2.2.1 Urban Form

The form of an urban area can be defined in a number of ways. The most common definition is the physical arrangement of buildings, housing, size, shape, scale, density, urban block layout, distribution of green space and land use - often referred to as its built form(Kamin, 2020) (Shi et al., 2017). It has also been described as the spatial configuration of urban elements(Dempsey et al., 2009), and defined as the ‘morphological properties of urban space at all scales(Živković, 2019). The physical form of cities has a huge impact on the way that people live. Factors such as density are crucial for understanding how a city function. It is also an important factor in determining the efficiency of a city and its sustainability goals.

2.2.2 Urban morphology

From the 1950s, the study of urban forms led to urban morphology, sometimes considered a discipline in its own right. Urban morphology is the study of urban forms whether at the most local level (plot) or at the most global level (agglomeration, metropolis) (Bourgeois, 2015). Urban morphology describes the physical form of a city in terms of its building layout, road patterns, land uses, and green space (Lai et al., 2018b). Urban morphology combines the technological factor with the formal and several aspects of cities. Urban morphology is “the study of the physical urban form” and the many factors (e.g. the people and the process) that govern and influence form” (Kropf, 2011). Urban morphology is an important skill for designers and architects to have better understanding of the physical environment and urban quality to deal with the many facets of urbanism.

2.2.3 Urban pattern

Urban form is a result of the combination of several elements-concepts: The urban patterns. Urban patterns consist broadly of a limited number of nearly regular types of elements that are repeated and combined. Hence, these patterns have strong similarities and can be grouped conceptually into what are called concepts (Lozano, 1990). Particularly, concepts might be street patterns, block size and form, street design, typical lot configuration, the layout of parks and public spaces, and so on (Y. Jabareen, 2006). and Kevin Lynch defines urban form as “the spatial pattern of the large, inert, permanent physical objects in a city.”

The Urban pattern is the result of a dynamic transformation process, which can follow two different paths: the planned transformation process generally creates clear geometrical patterns, and the unplanned transformation process requires time but generates complex urban patterns (Bölen and Kaya, 2017). It is not easy to define urban pattern though they are familiar as it is used differently in several contexts(Chowdhury, 2015). According to Lynch, pattern is starting with the region and then neighborhoods, clusters of buildings, rooms, and finally construction details (Lynch, 1981). The city pattern shows how functions and elements are distributed and mixed together spatially.

Urban patterns can be divided into two types: land use and building patterns. Land use refers to how buildings are used in space, whether they are residential, commercial or industrial. Building patterns refer to the arrangement and configuration of buildings and include such aspects as heights, spacing, densities and alignment with other buildings or streets (Dempsey et al., 2009).

2.3 The structure of urban form and its morphological component

This section will discuss the structure of urban form to explain why some cities are structured as they are. It is important to understand the city and its structures in order to understand how it will change over time(Fleischmann, 2017). A city is a heterogeneous and complex system. The urban form, as it is known, can be seen as a multi-scale object which is the outcome of the interactions and dynamics between people and their environment, as well as with other cities .This system has the potential to support inclusive and sustainable growth in the future.

The urban structure represents the spatial arrangement and configuration of components of streets network, blocks and buildings. It is usually related to the street scale (street pattern), like a grid or tree. It affects other urban form aspects such as density or land use (Dempsey et al., 2009). the generic types of form are linked together in a hierarchy of scale levels, which in the simple form includes: street patterns, plot patterns and building patterns(Kropf, 2011). The structure of urban form is the product of social/cultural processes and there are different kinds of structures with different characteristics at different geographic scales.

2.4 Spatial relation of morphological component

Physical and spatial urban form and its relation to the efficiency of the city is the most acknowledged issue in the world's environmental agenda(Aditjandra, 2013). many spatial logics and regulation principles are founded in planned, unplanned, formal, informal, gridded, and organic urban patterns (Boeing, 2021). The use of spatial measures has been instrumental in understanding the complexities of urban form. It allows us to analyze and compare communities or regions without relying solely on human observation. The following is a brief introduction to these measures.

Some spatial measurement types exist, but the most frequently used ones are land use, density, and connectivity. These three measurements are very closely related to one another and can be measured in many different ways (Boeing, 2018). The spatial analytical work represented by Michael Batty uses various techniques such as cellular automata or fractal analysis, based on the premise that 'global structure develops from local process (Whitehand, 2001).

The physical and spatial classifications of the pattern of the urban elements : the street is defined in terms of Centrality, Connectivity, Composition, Structure and Interaction, the Block in terms of Geometry, Composition, Usage, Structure and Density, the Plot in terms of Geometry, Composition, Structure and Density, and the Building in terms of Composition and Type(Iovene, 2018) .

2.5 Quantities approaches for describing and measuring urban form

The quantitative methods in this approach are mostly based on available data and therefore less subjective. As a result, they can be applied to areas at different scales with only a main constraint of computational power, and can also be used for different locations (Li and Quan, 2020). Understanding quantitative relationships between urban elements is crucial for a wide range of applications(Dong et al., 2020). that has been used in the design and planning of cities for a long time. It is considered one of the most important and useful tools that urban planners have at their disposal, and is often used to describe or measure urban form. In spite of the morphology complexity in such cities, but it is possible to explore homogeneity in these patterns.

There are two critical issues that obstruct a quantitative approach to the analysis of urban form: first, the availability, quality and compatibility of data across geographical areas; second, the difficulties to give a consistent definition of urban form, its fundamental components and the relationships between them (Fleischmann et al., 2020). Among many existing tools and approaches towards quantifying urban form performance; the Gaussian Mixture Model (GMM) is a great method to solve those challenges. The GMM can be considered a simple version of k-means and assumes Gaussian distributions for characteristics in each group. the GMM method differs from the k-means method, as it can identify clusters that vary in their size, density, and diversity using the expectation-maximization approach(Li and Quan, 2020). the toolbox will bring together those identified as relevant to this area of research. these tools are directly conducted from the urban form.

2.6 Indicators of Urban Form

The development of a city is largely determined by the form of its urbanization. There are many indicators that we can look at to make our predictions of what the future of a city will look like. Some indicators are population, density, economic activity, transportation systems, and land use(Y. Jabareen, 2006).

Anas et al (1998), in their studies of an understanding of the urban spatial structure, pointed to the dynamics and diverse nature of urban form (Anas et al., 1998). it is a representation of the way that space is developed, occupied and used. It usually includes such features as population density, land use, and transportation. So far, the most common indicators of urban form are population density, urban sprawl, and socioeconomic status. The higher the population density is in an area, the more congested it will be. This can also be a reflection of a place’s socioeconomic status. A typical indicator of urban form is density; and there are three types of density: low-density residential areas, medium-density residential areas, and high-density residential areas. The residential population would be an indicator of how densely populated a city (Cities in the World,” 2020).

Colaninno (2011), identified nine indices, useful to quantify the city morphology. The nine indices were selected on the basis of a statistical and also qualitative analysis of the original 15 variables. that is Building Area, Core Area Index, Buildings Proximity, Area to Perimeter Ratio, Shape Index I, Shape Index II, Corners of the building, Buildings to Convex Hull Area , and Buildings to Buffer Area (Colaninno et al., 2011).

2.7 Urban density Indicators

Building density has an intricate relationship with urban morphology.it plays an important role in the shaping of urban form(Ng, 2009). Density could be considered as uniform building coverage on a specific plot, that reflect the spatial contrast between form and terrain(Li et al., 2016). HENG and ZHANG Defined it as an indicator of urban development intensity that has its limitations when used as the individual criterion for urban quality(HENG and ZHANG, 2017). it concerns the urban form because it is a first approximation commonly used to explain the relation between urban form elements and for the planning process as a simple prescription(Aiazzi, 2017). so, it is considered a tool to read an urban form; in this sense, urban density is an element that contributes a lot to understanding a city and several studies address the question of what is the relation between density and urban form.

physical density is a spatial indicator, a quantitative and mathematical measure of the people or physical structures' concentration in the geographical unit (Ng, 2009). The most commonly used urban density indicators are population density. Population density is defined as the number of people per square mile. This is the most commonly used indicator, and it refers to how people are distributed within a city, with more dense cities having more people living in a smaller area than less dense cities.

Berghauser Pont & Haupt (2009) in their book "Space, density and urban form" compare the different methods to measure density and analyze how they perform in describing the urban form. They found that population or dwelling density are a poor performer and FSI is a better indicator, so they propose the use of a multi-variable density concept to measure the physical density of the built environment to be able to classify different urban typologies(Berghauser Pont and Haupt, 2009). For example, density is expressed as Population and dwelling density , Land Use Intensity , Coverage, Height and open space ratio(Aiazzi, 2017) .

For the quantitative description of density, it can be measured by the floor space index (FSI) and ground space index (GSI), FSI is used to represent the total value of built floor space in a specific area; GSI describes the separation between built and non-built area (Berghauser Pont et al., 2019).

2.7.1 Building Intensity (FSI)

Building intensity is the ratio of a building’s total floor area to the land it occupies. It can be measured in square meters per square meter (Berghauser Pont and Haupt, 2009). the built intensity (FSI) is calculated by dividing the area of each building by the plot area.

2.7.2 Compactness (coverage)(GSI)

Compactness describes the allocation and spatial distribution of buildings within urban blocks, and it is compatible with density (Li et al., 2016). Compactness measures the spatially spread of the sources of a city (people, buildings, jobs etc.); the closer they are located to each other, the more compact the city is. A clear understanding of how compactness can impact environmental performance cannot be achieved without the quantifiable measure tool of compactness in a city(Kamin, 2020). It is a necessary criterion to understand and analyze the city as a process that constantly shapes urban form.

2.7.3 Open space Ratio (OSR)

OSR is defined as the relationship between open space and total floor area, to measure the quality of an urban plan. it was used as a way to provide a certain amount of open space in specified districts to achieve development. It can be considered as an expression of the trade-offs between the desire to maximize the building bulk and the public and private demand for adequate open space (Berghauser Pont and Haupt, 2009). Adding a new building (spatial object) within an open space ratio changes the configurational characteristics of the urban environment. It impacts several configurational parameters and physical phenomena like visibility, lighting, air circulation, movement, etc. (Hamaina et al., 2012).

2.7.4 Average building height (L)

The average number of stories (or layers) (Berghauser Pont and Haupt, 2009) (Aiazzi, 2017). By evaluating the average building height, practitioners may examine the current built density and decide if any future developments fit within the character of the built form. This indicator will help practitioners comprehend the character of a region (Place, 2023).

2.8 Impact of urban form and density on energy demand of residential building

This section reviews the current literature related to energy demand. Firstly, it begins with an overview of the impact of urban form and density on the energy demand of residential buildings, and it focuses on energy as a determinant of urban form.

In today's world, energy is essential, where the energy demand in the present and the future is significantly influenced by how metropolitan areas are constructed (Oliveira, 2016), which only occupy 2% of the surface of the world (Girardet, 1999). Even though they only cover about 2% of the planet's surface, metropolitan areas consume most of the world's energy (Salat, 2009). According to Madlener and Sunak,(2011) Fonseca and Schlueter (2015), urban areas are expanding as a result of economic growth and industrialization. Consequently, there is a rising demand for energy in urban areas, and this demand will only expand as urbanization is predicted to continue growing (Osorio et al., 2017) (Reinhart and Cerezo Davila, 2016) (UN, 2014). with concentrations of social and economic activities that lead to (GHG) emissions in cities, which represents 40 to 70 percent of all anthropogenic (GHG) emissions worldwide (Changalvaiee et al., 2017). Accordingly, cities in developing nations will account for more than 80% of the growth in worldwide annual energy demand over 2006 levels by 2030 (Pérez-Lombard et al., 2008). Improved planning, urban design, and management should be capable of both mitigating and adapting to the direct and indirect effects of climate change on urban areas.

As cities have grown in size, initiatives to reduce residential energy consumption have gained prominence. According to the literature, the primary influences on how much energy a building uses are its geometry(Chen and Hong, 2018) (Ourghi et al., 2007), envelope (Sadineni et al., 2011) (Smith et al., 2010), and operating system, these criteria have the advantage of having effective laws, benchmarks, and standards created for them since they can be quantitatively characterized and quantified well (Loeffler et al., 2021). Aside from these variables, recent research has shown that spatial interactions between buildings and local urban morphology influence how much energy is used in buildings (Ko and Radke, 2014) (M. Silva et al., 2017). (4), but research on how urban form attributes affect building energy consumption in practice is limited(Ma and Cheng, 2016) (Zhao and Magoulès, 2012). With the increasing availability of significant data sources on urban building energy consumption, it has been founded that reshaping the urban form based on its impact on overall building energy usage can improve urban energy management (Ahn and Sohn, 2019).

2.9 Urban Density and energy demand

The urban form has several characteristics, including density(Güneralp et al., 2017) (3)(Li et al., 2018) (Salvati et al., 2019)(Cheng et al., 2006)(Steemers, 2003) compactness(Asfour and Alshawaf, 2015) (van Esch et al., 2012), diversity, green spaces, connection, orientation, shading, passivity (Y. R. Jabareen, 2006) (M. Silva et al., 2017) and variation in building heights (Deng et al., 2016)(Chen et al., 2017) that affect energy consumption (building's energy demand), where density is the most frequently utilized measure to determine the link between energy use and urban shape(Ahn and Sohn, 2019). It appears to be crucial to the energy demand of buildings(Boukarta and Berezowska, 2017). The scientific literature contrasts and continues to debate the result that admits density as a significant factor in reducing energy use(Ko, 2013). Compared to urban sprawl, a compact built form with increased urban density uses less energy, according to several studies (Steadman et al., 2014) (Salat et al., 2011) (Holden and Norland, 2005). claim that the energy consumption of buildings falls in denser cities like Paris, Hong-Kong, and Oslo. However, other research that contradicts the compact city theory suggests that a distributed urban shape might offer higher energy efficiency (Hachem et al., 2011) (Mohajeri et al., 2016). This is because urban areas are increasingly producing their own energy from renewable sources, such as ground-source heat pumps and roof-mounted photovoltaics (PVs), which require big space and cannot be accommodated by small buildings(Byrd et al., 2013). and (Steadman, 1977) showed that while energy demand for buildings increases with increasing density, energy demand for transportation decreases (Steadman, 1977).

Several indicators, including, plot ratio (Rode et al., 2014), volume-area ratio (Javanroodi et al., 2018), building density, open space ratio, site coverage(Berghauser Pont and Haupt, 2009) (Cheng, 2009), compactness index(Peponis, 2015), surface to volume ratio(Ratti et al., 2005), urban entropy, form factor(Coccolo et al., 2016), and habitable rooms per hectare (Gordon et al., 2016), have been used to define urban density, where comparing and contrasting the findings of several studies makes this difficult (Resch et al., 2016). Furthermore, a single metric cannot accurately and completely define urban density (Ahmadian et al., 2019). Although many studies have found a connection between energy production and demand, their analyses are either limited to the "building" scale(Cao et al., 2016) (Ferrara et al., 2019) or, when addressing the "urban" scale (Kazas et al., 2017) (Murray et al., 2020), they do not pay attention to the effects of urban design and density on building energy demand. Because of this, there isn't a framework in the literature that can link all the characteristics stated with building energy and handle their concurrent intercorrelations. measures by Ahmadian et al.(Ahmadian et al., 2019). They created a collection of graphs known as the Form Signature to show the relationship between density indicators, energy demand and geometrical characteristics of various constructed forms.

Research has also shown that a building's solar potential and the airflow around it are affected by the height of the building (Cheng et al., 2006) (Gu et al., 2011). In situations when the heating and cooling loads of buildings may vary(Steemers., 2003), random vertical layouts provide greater overshadowing than uniform building heights, which can reduce a building's solar potential (Chatzipoulka et al., 2016). The residential building's energy use is balanced between the benefits of heat losses and the drawbacks of reduced solar gain and daylighting (Ahn and Sohn., 2019).

2.10 The impact of local climate and greenery on urban form and energy demand (Heating and cooling demand)

Previous studies have demonstrated that the local climate significantly influences how urban geometry affects a building's energy demand (Dawodu and Cheshmehzangi, 2017). Due to this, numerous researchers offered data analysis while taking into account local weather factors, such as seasonal temperature, solar radiation, and wind speed (Zhao and Magoulès, 2012).

Activities such as heating, and cooling consume dwelling operational energy, where the amount of heating or cooling varies with the climate (Olgyay 1963). In hot climates, density is generally associated with increased cooling loads due to reduced wind exposure and an intensified thermal island effect(Ahn and Sohn, 2019). According to Asfour and Alshawaf (2015) energy use is proportional to the increase in housing density in areas with high cooling demands, where the overall operational energy needed decreases with increasing climate warmth since heating consumes more energy than cooling and refrigeration combined. In warm climate zones, however, there may be a rise in the use of air conditioning due to growing temperatures and wealth(Asfour and Alshawaf, 2015). Northern European nations have put a lot of effort into reducing the operational energy needed for heating, but mid-latitude nations must endeavor to strike a balance in the design of heating and cooling energy (Bank, 2008) (Boukarta and Berezowska, 2017).

Vegetation has direct and indirect effects on the reduction of energy demand and consequently greenhouse gas and atmospheric carbon dioxide CO_2(Balogun et al., 2014). Literature shows that urban greening provides a means of adaptation and mitigation to urban heat island and climate change. These happen through temperature modification. Some studies have quantified the effect of vegetation on temperature modification. For example, trees or a nearby park affects ambient temperature from 0.5 ◦C to 1.0 ◦C averaged over night and day (Eumorfopoulou and Kontoleon, 2009) or up to 2 ◦C for outside air temperature (Tan et al., 2014). Tree-shading and ground materials' modification offer up to 2.7 ◦C temperature reduction (Jim, 2015) and up to 3.0 ◦C temperature difference in comparison with un-shaded spaces(Yin et al., 2017). Greened open spaces change the surface roughness of the landscape, which in turn affect air movements and local temperatures (Boccalatte et al., 2020) (Peng et al., 2020).

2.11 Incorporating characteristics related to urban form into planning policies

There is little evidences of practical strategies, rules, or clearly defined techniques for incorporating features of energy efficiency into concrete planning during the earliest planning phase, in which the pertinent urban planning parameters are established and cannot be changed later(Asarpota and Nadin, 2020) (Cajot et al., 2017) (Yeo et al., 2013). Because of this, issues of energy efficiency frequently take a backseat to other considerations, such as aesthetic design, and stakeholders, such as legislators, planners, or people who are less aware of the impact of urban planning (Lenzholzer et al., 2020). The terms of competition in urban design cannot be clearly defined, nor can energy efficiency-related factors be taken into consideration when evaluating inputs, due to the lack of opportunities for quantitative evaluation of urban design characteristics in terms of energy efficiency (Eicker et al., 2015) (Djukic et al., 2016).

2.12 Conclusion

Quantitative approaches of urban morphology are critical to identify the physical structure of the urban form. To progress further, it is essential to understand what the limits and potentials of the existing measuring methods are, and where the gaps of knowledge are. The terminology used is often unclear, and methods and urban form characters vary in ways that are at times difficult to understand. This limits the development of comparative studies, which however are essential to research, in fact, the multivariable density seems to be highly suited to account for structural differences in urban form. The concept is not too statistical and general, or too detailed and specific.

No sector of the economy can escape the urgent need to minimize energy consumption, but the building industry is particularly vulnerable because about half of the world's energy resources are used to regulate internal environments (Ratti et al., 2005). According to the PCBS data, Hebron's residential building required more energy of electricity than the city's transportation and industrial processes combined (“PCBS,” 2016). Therefore, serious energy strategies must be applied at the residential building sector in Hebron in order to lower the city's overall energy consumption, and implementing energy-saving methods may be one of the most crucial options to reduce reliance on foreign energy sources.

The development of new methods, ideas, concepts, and techniques should lead to a greater understanding of the relationships between urban form and the energy demand to maintain contemporary urban systems (M. Silva et al., 2017). The discussion of current urban development policies should be informed by it, with a focus on the promotion of resource, land, and energy sustainability as essential components of long-term prosperity. Energy is undoubtedly one of the most significant problems being discussed in the current debate on cities. Urban energy is a significant challenge for the current decade due to rising energy prices, the urgent need to cut emissions and prevent climate change, and the significant costs that will be required to make buildings appropriate for the future, taking into consideration the quality of the energy sources. Recent studies relate to more energy optimization of buildings and relate to several urban indicators. It served as the basis for the study of some of the indicators; parametric of urban forms such as building intensity, compactness, open space ratio, and building height. Therefore, these four variables were chosen in the research methodology, as they were mentioned as the most important indicators.

Chapter 3
Research Methodology

3.1 Preface

Chapter four explains the methodology used in this research to achieve the objectives. This chapter first presents an overview of the research method employed and the analytical framework developed. Secondly, it discusses the methodology used in this thesis and the tools used during the study process to collect data and select case studies. Finally, the research framework and the simulation process are proposed for this research.

3.2 Research design

This work presents a methodology to characterize the urban taxonomy of Hebron city in order to identify the typical urban form patterns of residential building stocks, building energy demand is included to show a relationship between urban architectural form, density, and building energy. This method can be adopted as a baseline for future urban assessments, specifically for investigating relationships of energy with density and built form in order to advise policymakers on, for example, energy-oriented urban planning for sustainable cities. ‘Planning decisions, we make today determine the scope of choices we will have tomorrow.

The current study relies on the collection of empirical and numeric data to objectively assess the city and allow quantitative comparison, and at the same time providing relevant data for the statistical analysis of the city. As a result, the research design consists of a number of quantitative data and modes of analysis, which are combined to create a holistic methodology. From this, the design of the methodology emerges in Figure (3.1).

This research is based on linking four selected methods to reach the objectives of this study. The research methods used are a review of literature, Data collection, urban analysis of case study and simulation of different configurations. This research assumes that there is a strong relationship between urban form and energy demand.

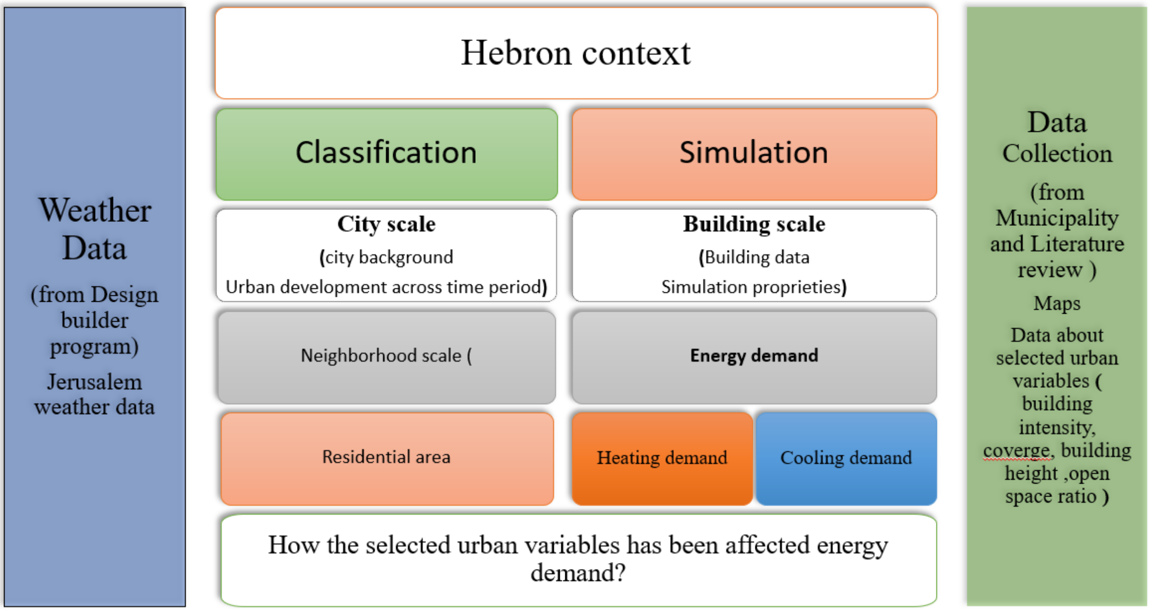


Figure 3.1: The scheme of the research design

3.3 Site study

A case study approach is selected for this research to conduct an analysis of the current urban form of the city of Hebron. It was chosen for this research which requires collecting information related to urbanization in Hebron focusing on the neighborhood level. The case study methodology allows for a comprehensive examination of a specific setting or situation and a variety of information-gathering where investigation procedures can be utilized.

The housing sector in the city of Hebron was chosen because of its significant impact on energy use, as the percentage of residential buildings in the city is approximately 50% as shown in table (3.1) below. Three neighborhoods within the city were chosen for a more in-depth study. A comparative study examines and analyses in detail the contexts and characteristics of three neighborhoods in relation to a specific subject. It is believed that there are variables between each neighborhood unit in Hebron, in relation to, its location, internal functions, and relationship to the city.

Hebron is considered to have a diverse urban form throughout history due to its random planning and increasing population pressure in a small area. It is an Israeli-occupied city surrounded by settlements on all sides, with the Kiryat Arbaa and Kharsina settlements to the east, the Hagai settlements to the south, and the Telems settlements to the west. As a result, the city will see an increase in the density of buildings, particularly residential ones, within this captured area. In addition, it is considered the most energy-consuming governorate in the

West Bank in the residential sector, according to a Hebron Municipality report. So, it is worth to focus research efforts on the case study of this city.

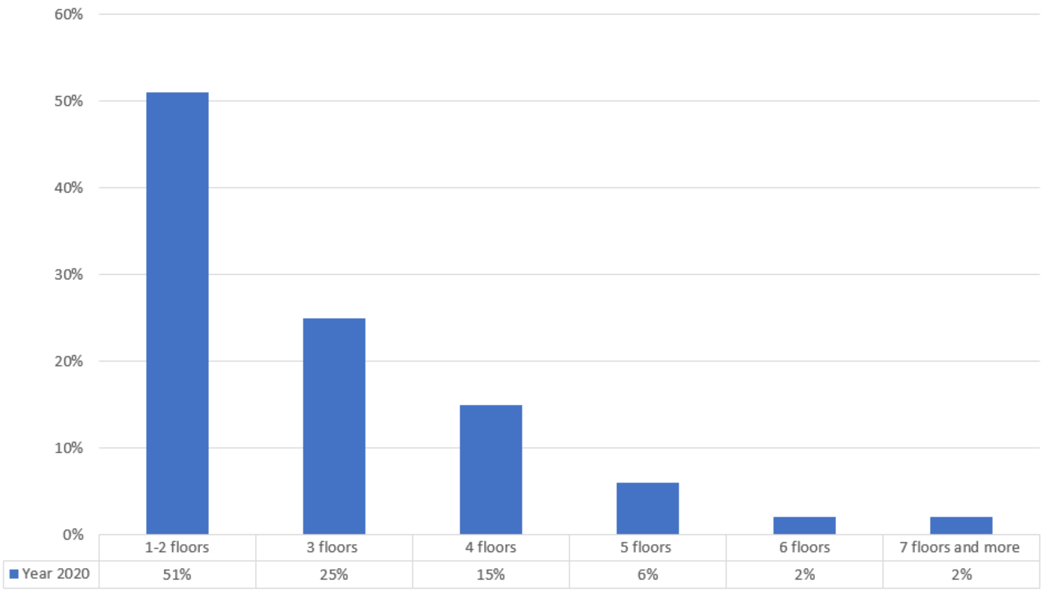


Fig 3.2: Number of Buildings in Hebron city by number of building floors, 2010-2020- source: GIS department in the Hebron municipality.

Table 3.1: Number of Buildings in Hebron city by Type of Building, March 2020- Source: GIS department in the Hebron municipality

Type of Building	Number of building	Percentage
Residential buildings	10,948	50.0%
Multifunctional buildings "shops with apartment building"	7,238	33.0%
Public buildings "Educational, Commercial, Industrial, Mosques"	3,561	16.0%

3.4 Data collection and preprocessing

Statistical data, maps, planning and building regulations for the neighborhood design were collected from Hebron Municipality.

3.4.1 Data type

The information can be gathered through geographic information system (GIS) to facilitate the management, analysis and visualization of large amounts of data(Gil et al., 2012) . This information is within the GIS system. It deals with basic physical data referring to spatial information that measures the urban form properties of an urbanized area such as its area, perimeter, building intensity, building height and regular analysis grid to relate these different spatial units to one another, etc.

1. Existing land use, buildings, building under construction, boundaries, building height.
2. Natural constraints, valleys, mountains ,spring.
3. Man-made constraints: Street network, landmark, artificial water reserves.

3.4.2 Data source:

1. The main source for the required spatial data is Hebron municipality and Geo-molg.
2. The coordinate system: Palestine -grid -1923.

3.4.3 Data Processing:

The literature review showed an extensive variety of different ways to study the quantitative analysis of urban form. Hence, it is expected that there have been many different metrics developed. The K-means clustering technique was chosen to perform a statistical analysis in the GIS program.

K-means cluster analysis was developed initially for multivariate analysis (Hartigan, 1975). According to Brus et al., K-means is a centroid-based clustering algorithm in which we calculate the distance between each data point and a centroid before assigning it to a cluster. The objective is to find the group in the dataset. The objects in this method's spatial implementation are fine grid cells, and the classification variables are the geographic coordinates of these cells' midpoints. The process output is a grid division and its corresponding cluster centers. Clusters can be used as strata in stratified random sampling, or cluster centers can be used directly as sample locations in a model-based sampling technique(Bigdeli et al., 2022).

A classic k-means clustering technique (Witten and Frank, 2005) is then applied to identify urban form types within the given area. Clustering allows the classification of instances in multi-dimensional space where there are no classes defined beforehand. The k-means algorithm, as found in most standard statistical analysis packages, is a partitioning process that subdivides a large data set into a k number of clusters seeking to minimize the mean distance between all members of each cluster.(Gil et al., 2012) To determine the best number of clusters (k) one can use a scree plot. As the number of clusters increases, this distance will naturally decrease.

3.5 Selection of urban variable to be investigated

As described in section 2.7, a mono-dimensional index such as density is not enough to distinguish different urban typologies from each other, as the same density value can be associated with very different spatial layouts. The definition of the principal measures used for the classification and the assumptions made in the present study:

3.5.1 Built environment factor (physical density factor)

1. FSI = The FSI (Floor Space Index) expresses the built intensity of an area; this is similar to FAR (Floor aspect ratio). This is given by equation's= F/A /F= gross floor area /A= area of the plot. This index uses the unit square meter per square meters (m^2/m^2) (Berghauser Pont and Haupt, 2009).
2. GSI = The GSI (Ground Space Index) expresses the compactness of an area; this is similar to SC (Site coverage), which demonstrates the relationship between built and non-built space, it is calculated as follows for all levels of scale as described earlier: GSI=B/A/ B= footprint of the building / A= Area of Plot.(Berghauser Pont and Haupt, 2009).

3. L= The L (Layers) expresses the average number of floors of an area, and it expresses building height, and it can calculate by the equation L= FSI/GSI(Berghauser Pont and Haupt, 2009).

4. OSR = The OSR (Open Space Ratio) expresses the pressure on the non-built space This is given by Eqns OSR=(1-GSI)/FSI (Berghauser Pont and Haupt, 2009).

These four geometric variables are enough to fully govern the geometry of urban areas. The geometric parameters significantly affect the energy demand for heating and cooling (Tsirigoti and Tsikaloudaki, 2018), particularly by altering urban microclimate as they affect Urban Heat Island UHI (Boccalatte et al., 2020).In order to validate the presupposition and test the assumptions, data for all indicators are calculated by the equation for each variable.

Table 3.2: urban variable (built environment)

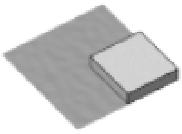
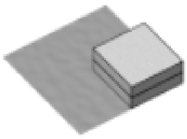
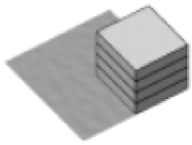
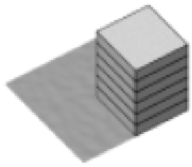
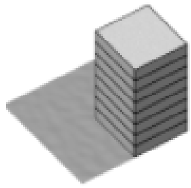
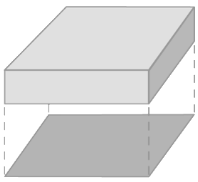
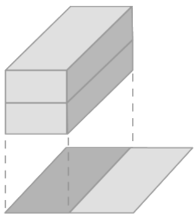
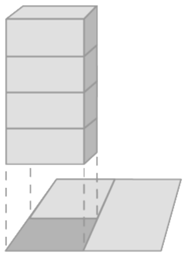
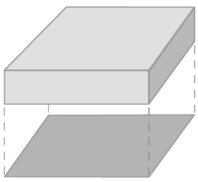
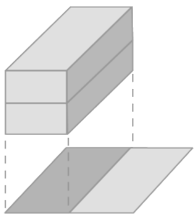
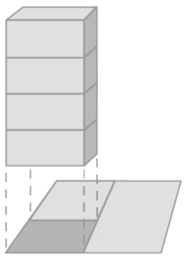
<table>
<tr><td colspan="15">FSI (Building Intensity)</td></tr>
<tr><td colspan="3">FSI=0.25</td><td colspan="3">FSI=0.5</td><td colspan="3">FSI=1</td><td colspan="3">FSI=1.5</td><td colspan="3">FSI=2</td></tr>
<tr><td colspan="3"></td><td colspan="3"></td><td colspan="3"></td><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td colspan="15">GSI (coverge)</td></tr>
<tr><td colspan="5">100 % lot covered</td><td colspan="5">50 % lot covered</td><td colspan="5">25% lot covered</td></tr>
<tr><td colspan="5"></td><td colspan="5"></td><td colspan="5"></td></tr>
<tr><td colspan="15">OSR(Open space ratio) related to each floor</td></tr>
<tr><td colspan="5">0% OSR</td><td colspan="5">25% OSR</td><td colspan="5">18.75 % OSR</td></tr>
<tr><td colspan="5"></td><td colspan="5"></td><td colspan="5"></td></tr>
</table>

Table 3.3: coverage (GSI) and building height (L) index -(Aiazzi, 2017)

<table>
<tr><td colspan="4">0 < GSI < 0.18</td><td colspan="4">0.18<GSI<0.28</td><td colspan="4">0.28<GSI<1</td></tr>
<tr><td colspan="4">Low coverage</td><td colspan="4">Mid coverage</td><td colspan="4">High coverage</td></tr>
<tr><td colspan="3">1-2 storeys</td><td colspan="3">3-6 storeys</td><td colspan="3">7-12 storeys</td><td colspan="3">Above 12</td></tr>
<tr><td colspan="3">Low Rise</td><td colspan="3">Mid Low Rise</td><td colspan="3">Mid High rise</td><td colspan="3">High rise</td></tr>
</table>

To evaluate the neighborhoods, the adopted urban variables are chosen, which are associated with the research framework and methodology. These variables were generated from a well-established theoretical background.

3.5.2 Natural factor (Topography)

The wind vector (speed) across a large region, measured at a height of 10 meters. The topography of the area and other factors have significant effects on the wind that blows (weather spark). the topography has a large effects at energy demand of the prototype building

3.5.3 Constant Parameter (urban block)

As shown in literature review other constant parameter is considered to be evaluated which is (Area plot ratio: Form factor: (Habitable room:) (Dweik, 2008).

3.6 Simulation by Design builder software

Many building energy simulation packages exist , making it challenging to select the most appropriate package for this research, the packages receiving the highest percentage of agreement of suitability from both architects and engineers were Design Builder and IES-VE.(Ahmadian, 2021) Through literature review and communication with experts, their relevance to this study is also checked.

The effects of various parameters are excluded (such as building type, occupancy profile, glazing ratio and building materials) from the analysis, it can all be considered as constant in Design Builder software, except urban built form and density, to facilitate an accurate comparison of site plans with different forms and densities, and to building plans with different forms and densities.

Simulations specifications were determined, as follows

1. Heating and cooling period: The heating period begins in November and lasts until the end of March. The cooling period begins in April and last until the end of October.
2. Activity template: TM 59-2 Bed- living – kitchen is used as a source of activity data (building usage) for building models, the data covers occupancy equipment usage and set point temperature.
3. Internal temperature: Typical minimum (Tmin) and maximum (Tmax) setpoint temperature for heating and cooling periods are considered as 21ºC and25ºC, respectively.
4. HVAC system: split no fresh air.

5. Orientation: East-west axis (south) Depending on a study of Thessaloniki city which is located in the Mediterranean climate, indicated that directing the building to the south at the east-west axis will reduce energy consumption and increase solar gains (Vartholomaios. A.,2016, p.16).
6. Number of occupants: To make accurate comparisons between different models, the density of occupants in all the models was kept constant, the value of 0.045 (m^2 /person).

3.7 **Criteria and Proprieties the prototype of residential building**

Residential apartments in Hebron constitute approximately 46.40% of the total occupied housing units,("PCBS," 2022.) . Most of these buildings are designed in regular shapes square or rectangular. Each floor consists of one or four apartments in most cases of multi-story buildings, and one or more vertical circulation units (staircase) in addition to the elevator. The floors are usually distributed as parking in the basement or ground floors, and residential apartments on the upper floors (Manassra, 2022).

According to Estaji (2017), changing house design (arrangement spaces) is a result of developing social and cultural settings, economic situations, and technological developments. (Estaji, 2017). Palestinian house layouts increasingly began to shift toward separating the bedrooms into a private zone with doors leading to a small lobby. Residents also attempted to get privacy by providing an outdoor door to enter the guest room and entrance hall and living room. The location of the living room in the centre of the house, this form of structure spread quickly and became known to the new generation(Ammar, 2021). This design was also seen in Hebron, and the number of spaces was determined, with three bedrooms for family members and at least two bathrooms for each residence. In terms of the kitchen, there were two options: closed kitchen or open kitchen. the house's orientation was also typically with the street in most residential buildings.

Considering the tendency to build multiple floors- buildings in Hebron, a 5-floor building was selected as the prototype building is residential, the ground floor is about stores and the other Typical floor is residential. The prototype building 18x16.70x19m(h), having 24 windows 1.50m×1.50m on each residential Typical floor and 14 windows 1.50m×0.85m on the ground floor (96 windows overall) and one 2.6m×3m entrance glass door on the north of the building. A 6.40m×2.40m staircase, 1.80 m×1.80m elevator and a two entrance door with dimension (1.20×2.50)m^2 entrance for two apartments are also considered and modelled as shown in Fig (3.4). the area of the apartment is 18*15.5m^2, and it consists of an entrance, a guest room, a kitchen, three bedrooms, three bathrooms, and a balcony.

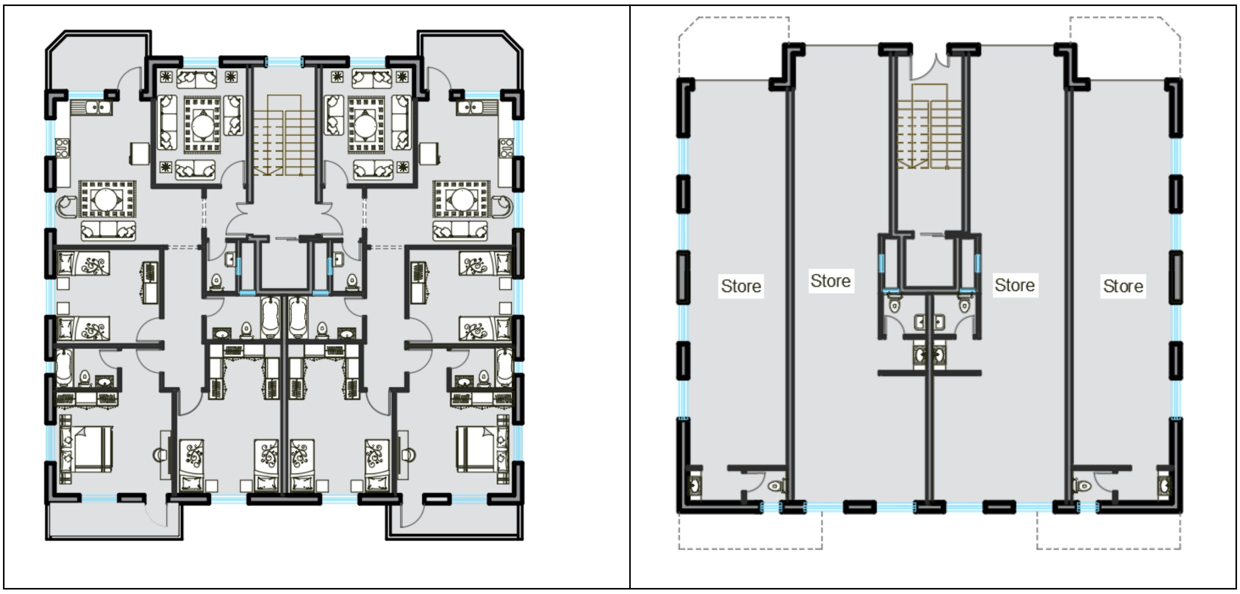
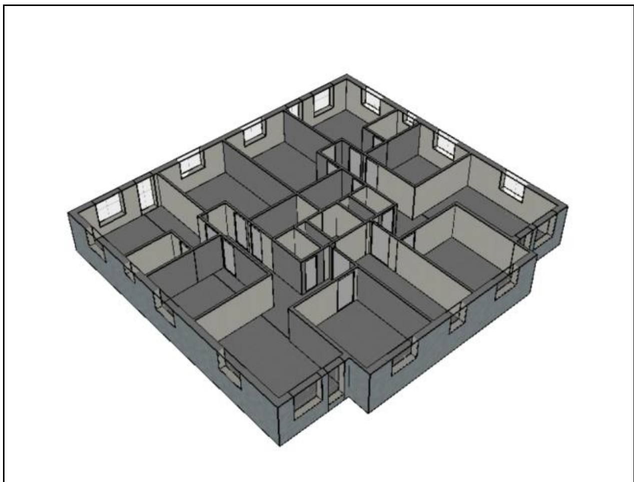
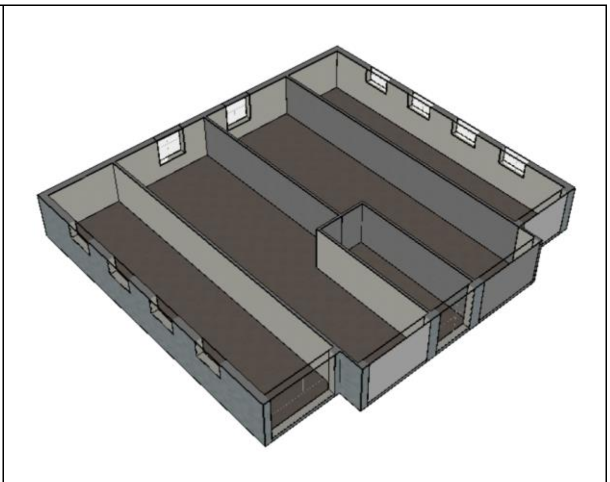


Fig 3.3: Typical Floor plan of Prototype building.



First floor (residential)



Ground floor (store)

Fig 3.4: 3D view of Prototype building in Design builder.

Moreover, the physical characteristics of the building such as materials, structure, ceiling, walls, insulations, glazing ratio and some other influencing variables designed based on the construction sector in Palestine, see Table (3.4).

The physical characteristics of a building envelope are influenced by the climatic conditions. Parameters such as building material, glazing ratio and walls/windows U-values may differ in different climates. However, in this study, in order to be consistent in all case studies and to focus the study on the impact of the built form, and density on the building energy demand, these parameters are kept constant for all case studies.

The model is used with a design-builder and all characteristics are defined through either the software interface or changing the underlying code. The required data has been obtained from reliable sources; & They are as follows:

1. Infiltration rate: The infiltration rate of all buildings is chosen to be 10 m3/h/m^2 (GBGP,2010).
2. Envelope U-values: Following the Ministry of local government (the Ministry of local government,2004), the current standard of U-values of walls, roofs and floors are 3.2, 2.8 and 1.17 W/ (m^2. K), respectively.
3. Windows U-value: Considered to be 2.1 W/ (m^2.K) according to International Energy Conservation Code (GBGP,2010).
4. Glazing ratios: The percentage of glazing for residential buildings is a design parameter. Hence, a range of glazing ratios can be found in buildings. The minimum value of the glazing ratio is limited by the view and the maximum value is limited by energy demand. The glazing ratio used in the prototype is 30 %.

Table 3.4: Most common envelope components and their material arrangement in Palestine (Muallem, 2020)

Layers	Density Kg/m^3	Specific heat J/kg .K	Thermal conductivity W/m. K	Thickness m	U value
Walls					
Stone	2250	1000	1.70	0.05	3.2
Concrete	2300	1000	1.75	0.20	
Roofs					
Plaster	2000	1000	1.20	0.03	2.8
Reinforced Concrete Layer	2500	1000	1.75	0.26	
Inclined concrete layer	2300	1000	1.75	0.07	
Rain water insulation	2300	1000	1.10	0.03	
Floors					
Porcelain Tiles	1900	1000	1.05	0.02	1.17
Sand	1750	1000	0.42	0.15	
Reinforced concrete	2500	1000	1.75	0.26	
Plaster	2000	1000	1.20	0.02	

A selection of materials and composites are already defined in the design-builder. However, to achieve the exact U-value indicated in table (3.5), new composite materials have been defined in the design-builder code that impart the required U-values. Then, by selecting each wall, roof or floor, the desirable values were specified through the software interface.

Table 3.5: construction materials of prototype building envelop used in the design-builder

Exterior Wall		
Layer	Material	Thickness (mm)
Finish out	Stone	50
Structure Out	Light Concrete	200
Insulation / Air	Polyethylene	5
Structure In	Cement block	100
Finish In	Plaster	10
		335
Interior Wall (Partition)		
Finish out	Plaster	10
Structure	Cement block	100
Finish in	Plaster	10
		120
Roof		
Structure	Local Slab	70
Structure In	Light Concrete	250
Finish In	Plaster	10
		330
Door		
Flat Entrance Finish Frame	Metal	100
Flat Partition	Wooden	80
Building Entrance	Glass	50
Window		
	Double Glazing layer	50

To reach the energy use for each urban fabric, the heating and cooling load will be calculated for the prototype building within the urban fabric, where the location of the building was determined by the mean centre in the GIS program based on the horizontal-vertical built density. Also, the location of the prototype building was determined based on the presence or absence of an existing building in the plot of land that was determined by the mean centre, if it exists, the nearest land was chosen for the mean centre.

3.8 Conclusion

The proposed methodology was applied to the city of Hebron, stage by stage and as described in the previous sections. The result of the implementation is to identify the urban form patterns in the city, which link urban layout with blocks and building types; Besides, an urban GIS database of the city that allow urban information to be processed and urban maps to be generated and created.

In order to investigate a specific field. In energy efficiency terms, this enables urban patterns to be standardized and these small urban systems to be energy-assessed in order to extrapolate conclusions on the neighborhood and city scales. Since the energy demand of buildings has a great deal to do with the intrinsic design aspects of the built environment (e.g. urban morphology and the physical context of the surrounding built environment), the multi-staged urban taxonomy methodology stated herein enabled significant building and urban aspects for the energy demand of buildings to be identified. Thus, urban morphologies were linked to different energy demands, allowing an energy characterization of different urban patterns.

Chapter 4
A study site of Hebron city

4.1 preface

This chapter will explain the study context and the case study of Hebron, to get the most significant indexes for determining the urban form of the city. It focuses on the quantitative analysis conducted on Hebron neighborhoods using GIS. The study conducted a spatial and statistical analysis of the urban form for each of the neighborhoods. In addition, the statistical analysis compared the results among different neighborhoods. Based on the kind of available data, the proposed method is to utilize different analysis tools in the GIS environment, which can combine multiple layers and contain geo-referenced features and their attributes. This combination of layers and features allows the analysis of a set of variables situated within a certain geographical environment. It describes these neighborhoods in some detail, providing information about their urban form.

The study site is described first, followed by the profiles of the selected neighborhoods. It also debated the results of the neighborhood analysis, which are represented by the existing patterns, and characterization of the urban form of Hebron city. Finally, a discussion and a conclusion of the results.

4.2 A study site of Hebron city

This section gives information about the study site: firstly, it begins with a brief background, Urban development, constraints that limit the urban form, energy demand of residential building, and the climatic features of Hebron city.

4.2.1 City background

The history of Hebron city dates back to 3500 BC, and it is likely that it was built shortly after the pyramids, i.e. about 5500 years.(“History of Hebron | PDF | Hebron | Mosque,” n.d.) Hebron was subjected to Islamic rule, and architecture thrived in Hebron during the Mamluk period (1250-1516) and the Ottoman period (1517-1917) due to the existence of the Ibrahimi Mosque (ARIJ,2009). It was an important postal centre, especially with Egypt, Gaza and Karak (Abdul Rahman Muhammad, 1990: 7-14). and it was controlled by many colonial powers, since in 1917 it was subject to British colonialism, and fell under Israeli occupation in 1967, They worked to establish many settlements inside and outside the city.

4.2.2 Urban development in the city

In 1967, the Israeli occupation entered the city of Hebron, and they used force, establishing a number of colonial belts by the Israeli government in 1968. Accordingly, the city was surrounded by settlements, where Kiryat Arba and Kharsina are from the East, and the colonies of Haggai and Har Manoah from the south, and had a significant and clear impact on the construction and expansion process, as construction stopped in the eastern side where the two settlements of Kiryat Arba and Kharsina are located, in addition to the Israeli settlements in the southern side, where the two settlements of Kiryat Arba and Kharsina stationed, as well as Israeli settlements on the southern side, which limited the expansion. Thus, an outlet border for the city's urban expansion remained in the west and partly in the north (Al-Sawalha, 2016), and the population is obliged to grow vertically as a result of Israel's seizure of a sizable portion of the city's territory for the construction of settlements and the natural increase, as building "residential structures" is one of the answers to the current housing shortage.

Following the creation of the Palestinian Authority, the city experienced a tremendous urban form, and the Authority's existence helped to stimulate investment in the area (Harb, 2017). Hebron's area was estimated to be 42,552 dunums in 2006 AD, and due to a scarcity of land appropriate for construction and the high cost of land, the vertical building pattern predominated in the city at the expense of horizontal construction. In a significant way, this encouraged people to utilize technology to make the best use of the land possible. The second census of population, housing, and establishments was carried out by the PCBS (2011), Hebron's total area was about (17,593 structures), and there were approximately 17,593 buildings in the city (53,098 dunums) (PCBS,2011).

In Hebron’s development, two types of urban patterns have emerged: the traditional urban pattern; and the random pattern. Of these patterns, the random is the most predominant, and it is important to highlight that this pattern has been repeated throughout the city master plan, whereas the traditional urban pattern is found only in the center of city according to the Hebron municipality, as shown in Fig (4.1).

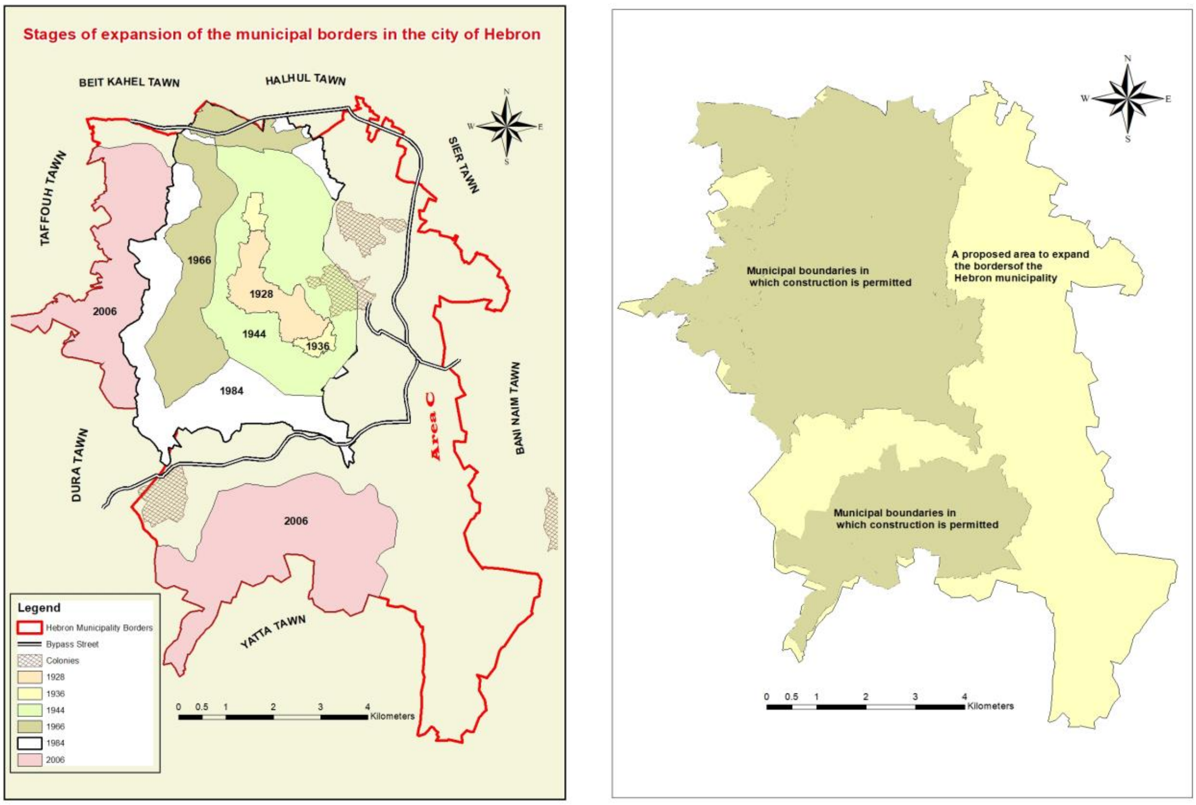


Fig 4.1: Stages of expanding the municipal boundaries in the Hebron city–source: Hebron Municipality and a proposed area to expand.

4.2.3 Constraints that limit the urban form in the city of Hebron

Urban form is significantly affected by the environmental, economic, social, and political aspects that are present in cities. (Charehjoo, 2013) Six factors were regarded as the constraint and generator of the urban form and the urban fabric diversity; that are, the topography, the Perimeter, the plot structure, the built fabric, the courtyard and the building.(Leite and Justo, 2017)

The natural factors are the first limitations to the set-up and organization of the distinct elements of urban form.(Dempsey et al., 2009) The land topography, the quality and suitability of soil and subsoil, the climate, the solar and wind exposure, the type of natural landscape from the first paths, streets, plots, the different buildings that are built in plots, and to the material's surface of all these forms(Oliveira, 2016). The mountainous nature of the city of Hebron affected the street network and greatly shaped the expansion patterns of the city (Zahda, 2009) The most significant constraint on the urban form is climate. For example, cities in hot and humid tropics usually have a high density of buildings to help with ventilation and reduce heat absorption.

The structure of the urban form is a complex thing that is determined by many factors such as topography, land use and land ownership, but the most important factor is the geopolitical factors which are the main powers in configuring the urban spaces of cities located in regions under conflict(Avtar et al., 2019). the colonization power will redraw the physical landscape to provide security, geographical mobility, and territorial sovereignty for one group at the expense of the other(Zahda, 2009). In Hebron city, Israel has prevented the natural growth of urban areas by trying to separate areas and residential communities. (Shaheen, 2021) This proves that governments have a lot of power in determining how urban morphology evolves and changes over time.

The structure of the urban form is also determined by economic factors such as the type of industry located in an area(He et al., 2020); the city of Hebron includes public services like schools, universities, hospitals, internal and external transport networks, but it is not enough for the city's population, so there is a need to enhance the living situations of the people, as the residential buildings were randomly distributed along with the commercial and industrial buildings. (Shaheen, 2021) The population in the city increased from 163 thousand in the period (1997-2007) to 21٥ in the period (2007-2017), with a population growth rate of 2.3 (Shalaldeh,2020), and the population growth was accompanied by a significant increase in the demand for housing. The level of development is another determinant that influences how the environment is configured. For example, housing density affects how large or compact a city will be, Human constraints are more difficult to define but they may include population growth or a desire for protection from environmental disasters. Saleh and Al-Hagla (2012) consider density as a primary factor to generate urban form (Saleh and Al-Hagla, 2012).

Land use and transportation networks play a role in creating the constraints that limit the urban form. Land use is determined by zoning regulations(Lai et al., 2018b). The land use of Palestinian cities is greatly affected by Historical stages , especially the history of last century. These stages are the Ottoman Empire , the British Mandate, the annexation of the West Bank to Jordan, the stage of the Israeli occupation and finally the stage of the Palestinian Authority until now(Shaheen, 2021). These phases had a great influence on Hebron for its planning and management as these forces set laws for managing areas, that led to a weakened urban planning system in Hebron. Besides, transportation networks especially ring roads that Israel establish around the city.

The current master plan for the city of Hebron does not exist; jurisdiction boundaries only apply with constraints on housing development in the Industrial Zone. The only existing plan for Hebron is the Mandate plan accepted in 1944 for an area less than a tenth of the present municipal area and a population of 20,000. and no plan was made under the Jordanian rule and the Israeli occupation(Zahda, 2009). However, a new master plan has recently been developed by the municipality.

4.2.4 Energy demand of residential building in Hebron city.

In order to comprehend the effects of urban form on the energy demand required for heating and cooling, this section examines the energy demand in Hebron to reduce the increasing demand for energy, particularly in residential structures. This was highlighted since Hebron has a significant and rising demand for energy, where the majority of the energy used by households in the city is used by heating and cooling systems.

Buildings sector in Palestine is the largest energy consumer when compared to other sectors since it accounts for 46.90% of the country’s total energy consumption(Manassra, 2022). In particular, thermal systems are one of the largest energy consumers in residential buildings. Therefore, a reduction of heating, and cooling energy is expected in order to reduce the overall energy consumption of residential buildings to improve building energy demand (Environment, 2019).

As a result of population growth and urbanization in Palestine (PCBC), the need for energy increased. Indeed, energy provision in the Palestinian territories is highly dependent on electricity imports from Israel (PCBC). This is especially true in Hebron, where the Israeli Electric Corporation currently meets all of the city's electricity needs (IEC)(Lazzeroni et al., 2017) ,and People purchase inexpensive equipment without considering the increased level of energy use, which over time leads to a larger "global cost" (Municipality of Hebron et al., 2016).

The electricity used in residential buildings is distributed by Hebron’s distribution company HEPCo, which purchases electricity from the IEC in Israel. HEPCo serves nearly 68,000 electricity consumption units (residential places, shops, factories, and service buildings). It is worth noting that, due to the political situation in Hebron (Israeli settlement in the heart of the city and Israeli rules dividing the city into two parts, H1 and H2, meaning that some houses, shops and SME’s are completely isolated from the rest of the city)(Municipality of Hebron et al., 2016). energy demand for heating and cooling is difficult to estimate.

Residential buildings in Hebron is the largest energy consumer when compared to other sectors (tertiary building, public lighting, industry ,etc.) since it accounts for 25% of the city’s total energy consumption (Municipality of Hebron et al., 2016), as shown in Figure (4.2) below.

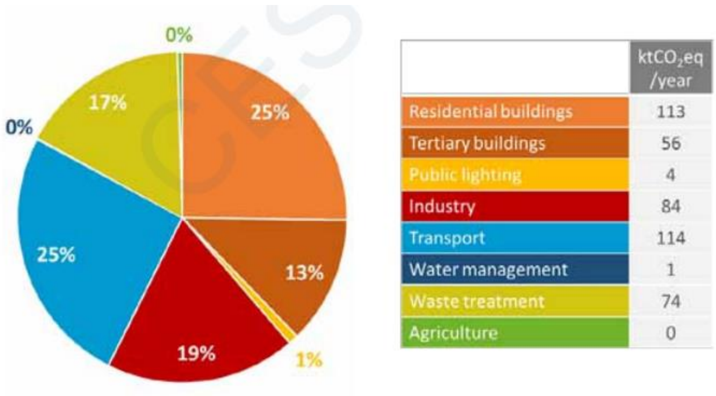


Fig 4.2: Energy consumption in Hebron city (2014)-(Municipality of Hebron et al., 2016)

Since space heating and cooling requirements in Hebron buildings are met by air-conditioners/heaters (i.e., reversible heat pumps with split units), electricity currently accounts for 35% of the total energy demand. Residential structures, in particular, account for 40% of the city's total annual electricity demand (Lazzeroni et al., 2017). Hebron's global GHG emissions were estimated to be 448 ktCO2eq/year in 2014, or 2.22 tCO2eq/person/year (equivalent to 11000 km driven by car). Due to the BEI scope not exactly matching the national inventory and the fact that metropolitan regions consume more energy, this is much greater than the average emissions per person in Palestine (1.0 ktCO2eq/person/year) (in which electricity production is assigned to Israel). (Municipality of Hebron et al., 2016)As shown in Figure (4.2), the residential sector is responsible for a large amount of global GHG emissions, and if we take a closer look and analyze consumption by energy and sectors, we can find that the primary energy demand sources are fuels for transportation and electricity for buildings, notably residential buildings sector ranks first .It also can be found that LPG (Liquefied Petroleum Gas) as a second-rank consumer of residential building, as shown in Fig(4.3).

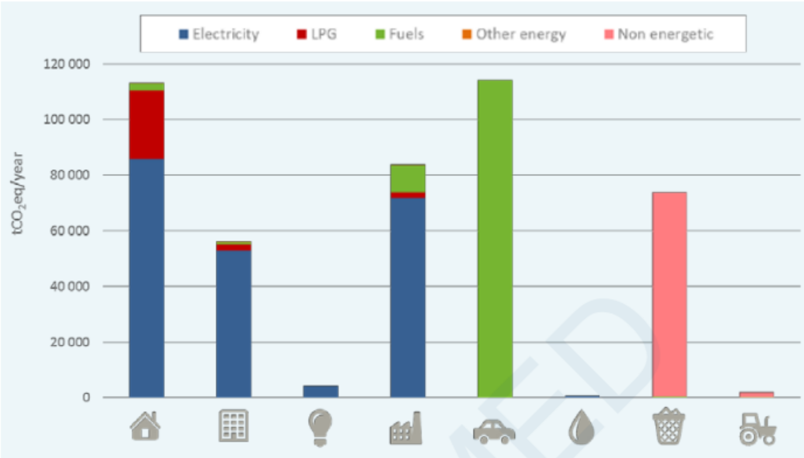


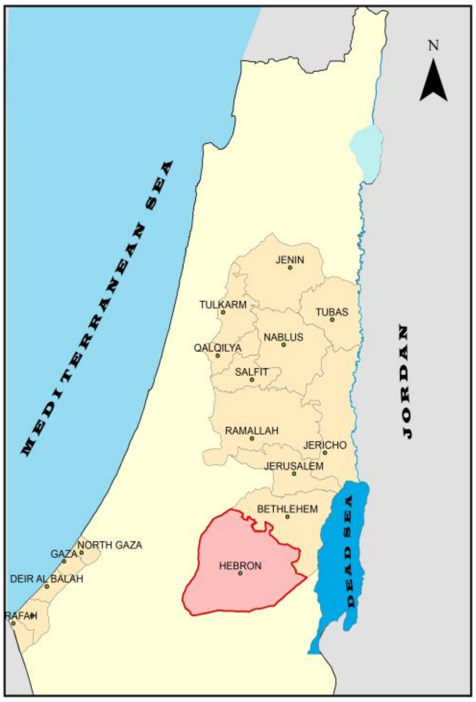
Figure 4.3 : GHG emissions per sector and per energy in Hebron (2014) -(Municipality of Hebron et al., 2016).

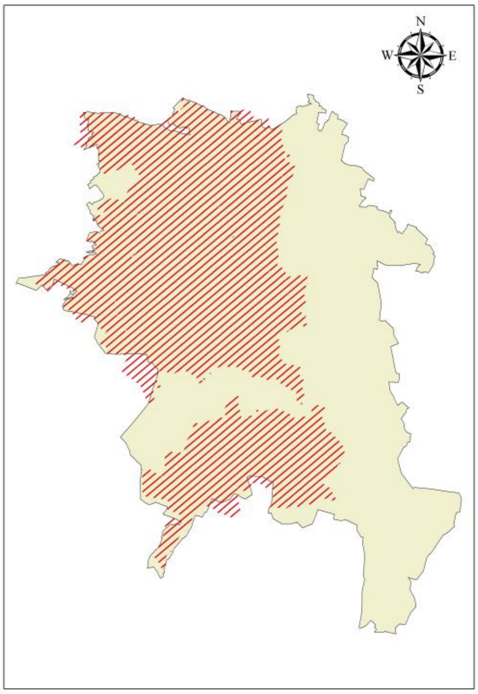
According to the Palestinian Central Bureau of Statistics (PCBS), the average home power usage in Palestine for households that utilized electricity was 306 kWh in 2015. (PCBS,2015), Al-Qadi found that the specific heating energy (energy/sqm) in apartments in residential buildings is the highest compared to the other typology (single house, apartment in an extended family, apartment in residential building), and the average heating energy calculated in Hebron Governorate was 3555.9 kWh (Al Qadi et al., 2018).

4.2.5 Climate settings

Hebron city is located within Hebron Governorate in the southwestern part of the West Bank and is bordered by Jerusalem city to the north, Ber Sheva to the southwest, and the Jordan Valley to the east. It is also characterized as a moderately elevated area, with its highest elevation reaching up to 930 m above Sea level (“Hebron,” 2023). The city experiences long, hot, dry, and clear summers and chilly, mainly clear winters. The average annual temperature ranges from 3°C to 29°C, seldom falling below -0°C or rising above 32°C. The amount of rain that falls each month in Hebron varies seasonally. Hebron experiences 37 millimeters of rain on average in January, which is also the wettest month, and the length of the day changes greatly throughout the year. The longest day in 2023 is June 21, with 14 hours and 12 minutes of daylight, while the shortest day is December 22, with 10 hours and 6 minutes of sunshine (“Climate in Hebron,” 2023).

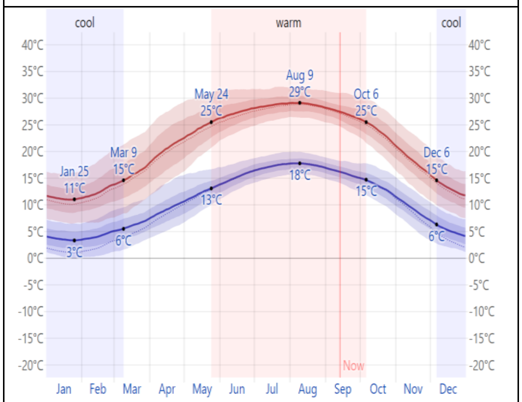
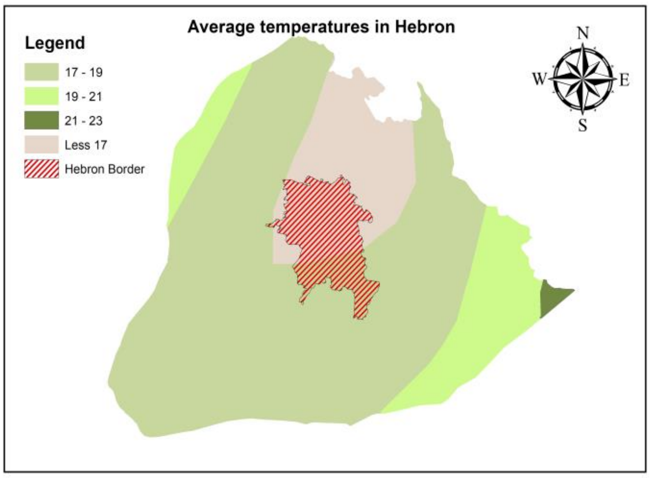
Table (4.1): Hebron Governorate and city map and Weather Data Source :(Hebron municipality, (“Climate in Hebron,” 2023)).





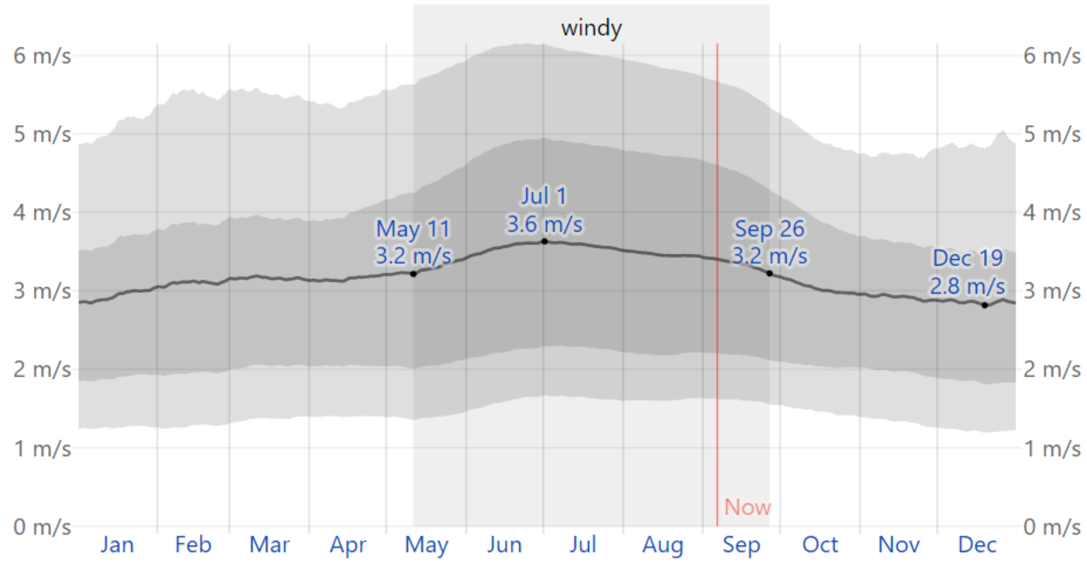
Warm seasons	Cool seasons
From May 24 to October 6, which is 4.4 months, there is a warm season with average daily high temperatures of above 25°C. August is the warmest month of the year in Hebron, with average high temperatures of 29°C and low temperatures of 18°C. (“Climate in Hebron,” 2023)	Between December 6 and March 9, which is the length of the cool season, the daily maximum temperature often falls below 15°C. In Hebron, January is the coldest month of the year, with an average low of 4°C and high of 11°C.((“Climate in Hebron,” 2023)

Table (4.2): Study area annual temperature ranges in Hebron (source: municipality of Hebron).

The daily average high (red line) and low (blue line) temperature	
	

The geographic and climatic conditions of Hebron are used for energy simulation in this case. It is situated at a latitude of 31.87° N and a longitude of 35.22° W, representing a Hot-summer Mediterranean climate in the Koppen climate classification (“Mindat.org,” 2023) , with a population of 215,452(“PCBS,” 2016), it contributes significantly to overall urban energy demand, indicating the importance of energy optimization in it. As a result, providing guidelines for energy optimization in terms of built form and density is extremely beneficial for future developments in this city, which can save significant amounts of energy and prevent high levels of carbon emissions. Meanwhile, the availability of additional studies on Hebron in the literature allows for a comparison of the findings of this study with those of others. The influence of each geometrical variable on the building energy demand can be critically observed, which shows the impact of building physics on building energy system design and consequently total energy demand.

Over the course of the year, Hebron's average hourly wind speed shows some seasonal fluctuation. From May 11 to September 26, which is 4.5 months, is when the winds are the strongest, with an average speed of more than 3.2 meters per second. In Hebron, July is the windiest month of the year, with an hourly average wind speed of 3.6 meters per second. From September 26 to May 11, the more tranquil period of the year lasts 7.5 months. With an hourly wind speed of 2.9 meters per second, December is the calmest month of the year in Hebron (“Climate in Hebron,” 2023).



Fig(4.4):The average of mean hourly wind speeds (dark gray line), with 25th to 75th and 10th to 90th percentile bands (“Climate in Hebron,” 2023).

4.3 Selection Criteria of neighborhoods

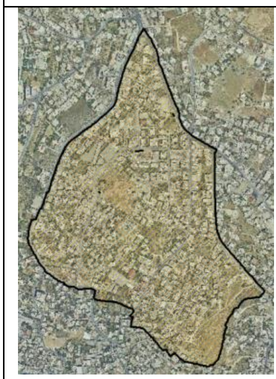
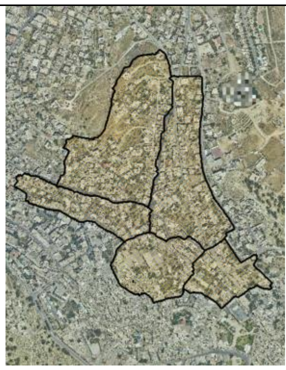
This section will explore the criteria that should be taken into consideration when selecting different neighborhoods of interest for research, where have been selected to represent a wide number of morphological patterns. They have been influenced by a variety of constraints considered in the last sections, to narrow the number of zone and constraints that will be focused fundamentally on zones dominated by housing.

Many studies have taken into account a wide range of features, such as land use, architectural period, geographical location, sociological criterion, building regulations and architectural layout(Iovene, 2018) (Berghauser Pont and Haupt, 2009). The first phase of pattern investigation (Pattern Detection); includes visual observation of the recursive spatial patterns of urban elements(Iovene, 2018). So this phase relies on visual detection to limit the number of case studies.

Each case study area is selected by:

1. Case studies that have a particular geographical spread, allowing an examination of structural similarities and possible differences.
2. Case studies that represent different horizontal and vertical densities.
3. Case studies that represent different morphological patterns by visual detections.

Table 4.3: Case studies selections – Source: Hebron municipality.

	Contemporary development	Traditional	pre-planned
SHAPE			
Name	Al-Sheikh neighborhoods	Old Town	Al-Zaytoon neighborhood
Height of Building (m)	0 - 8	0-10	0-30
Contour Level (m)	935-970	935-970	920-960
Horizontal Density of residential area	Medium	High	Low

Three areas of Hebron – Al-Sheikh neighbourhood, Old Town ((Khilat Hadoor, Ain Qurna, Al-Sawakneh, and Al-Zahid)), and Al-Zaytoon neighbourhood were selected as case studies. They are diverse in terms of urban form, which is traditional development, preplanned neighbourhood and contemporary development of (2-3) height. Al-Sheikh neighbourhood is an example of contemporary development that was developed as an extension of the old town, which had become overcrowded due to economic growth. The old town is a traditional development, these were developed individually. The third area, Al-Zaytoon neighbourhood is a preplanned neighbourhood, its fabric generally consists of a number of individual plots, where individual houses or villas were constructed for the owners of those plots.

4.3.1 Al-Sheikh neighborhood (Contemporary development):

Al-Sheikh neighbourhood is located in the southeastern part of the city and to the north of the Ibrahimi- Mosque in the old city. The study area is around 433,183 square meters, and it was established in 1944. Although it is known to locals as the Al-Sheikh neighborhood, the basin's division in the Hebron municipality calls it Khallet-Qashqala. This area contains the "Ain Qashqala" spring, as well as caves and rock burials. From this Ain, a road goes to the Bab Al-Zawiya and Habayel Reyah neighbourhood. Figure (4.5) is illustrated the study area (Al-Sheikh neighbourhood) boundaries, the building's heights, the street network and the landmarks (schools, water reserves and mosques) in the area. In addition to the fact that the Israeli checkpoint is located in the south of the neighbourhood.

This type of urban form is considered an individual building, which reflects the independence and openness to the outside, with more freedom and more development on the building architectural plan, as the percentage of this type of building reached 75% of the total of city buildings. It consists of (1-8) floors approximately, which is considered medium horizontal density of residential areas in the city, and contour level ranges between (935-970) m, see table (4.3) above.

4.3.2 Old town (Traditional)

The case study of the old city is located in the centre of the city. It was established from the time of Ottoman rule until the start of the British Mandate,(UNESCO, 1972) and the selected case study is located to the north of the Ibrahimi- Mosque. It consists of five blocks, which are Ain al-Qurna, al zahed, al-Sawakna, al-Muhtasibiyyah, and Khallet Hadour. The area that will be studied is about 212,635 square meters. Figure (4.6) illustrates the study area's (the old city) boundaries, the heights of the buildings, the street network and the landmarks (schools, diwan and mosques).

The buildings in Hebron's old city contain several patterns of urban form. Furthermore, the general building appearance, as well as architectural elements and details, reveal the urban development of its buildings. Each pattern reflects a different historical period in the old city. The overlapping urban fabric, connected buildings, and individual buildings that are less connected express more independence. (Shalad, 2020) individual buildings represent the selected neighborhood in old town.

This type of urban form (individual building) reflects the independence and openness to the outside, and it is in itself an extension of the strip buildings with more freedom and more development on the architectural plan of the building, as the percentage of this type of buildings reached 15% of the total buildings of the old city, which are concentrated in the outskirts of the old town . It consists of one or two floors, which prevailed in most homes in Palestinian towns and villages. These buildings are often old, that is, what is known as the courtyards that date back to the Ottoman era.(Dweik, 2008) It consists of (1-5) floors approximately, which is considered high horizontal density of residential areas in the city, and contour level ranges between (935-970) m .

4.3.3 Al -Zaytoon neighborhood(pre-planned):

Al -Zaytoon neighbourhood was developed at the beginning of 1984's. it is located in the southeastern part of the city on the outskirts, as it borders the city of Dura from the north. The dwelling density of this low-rise development, with 328 buildings is bordered to the east by the Hagai settlement and Sindas mountain. In the north of the neighborhood, there is the Tahrir Square. The area that will be studied is about 417,495 square meters. Figure (4.7) illustrated the study area's (Al-Zaytoon neighbourhood) boundaries, the building's heights, the street network and the landmarks (Diwan, Garden and mosque).

This type of urban form is also considered an individual building as al sheikh buildings, It consists of (1-3) floors approximately, which is considered low horizontal density of residential areas in the city, and contour level ranges between (920-960) m. These areas in Hebron have been analyzed in this research to investigate whether formal differences within certain densities can be found in the real urban context.

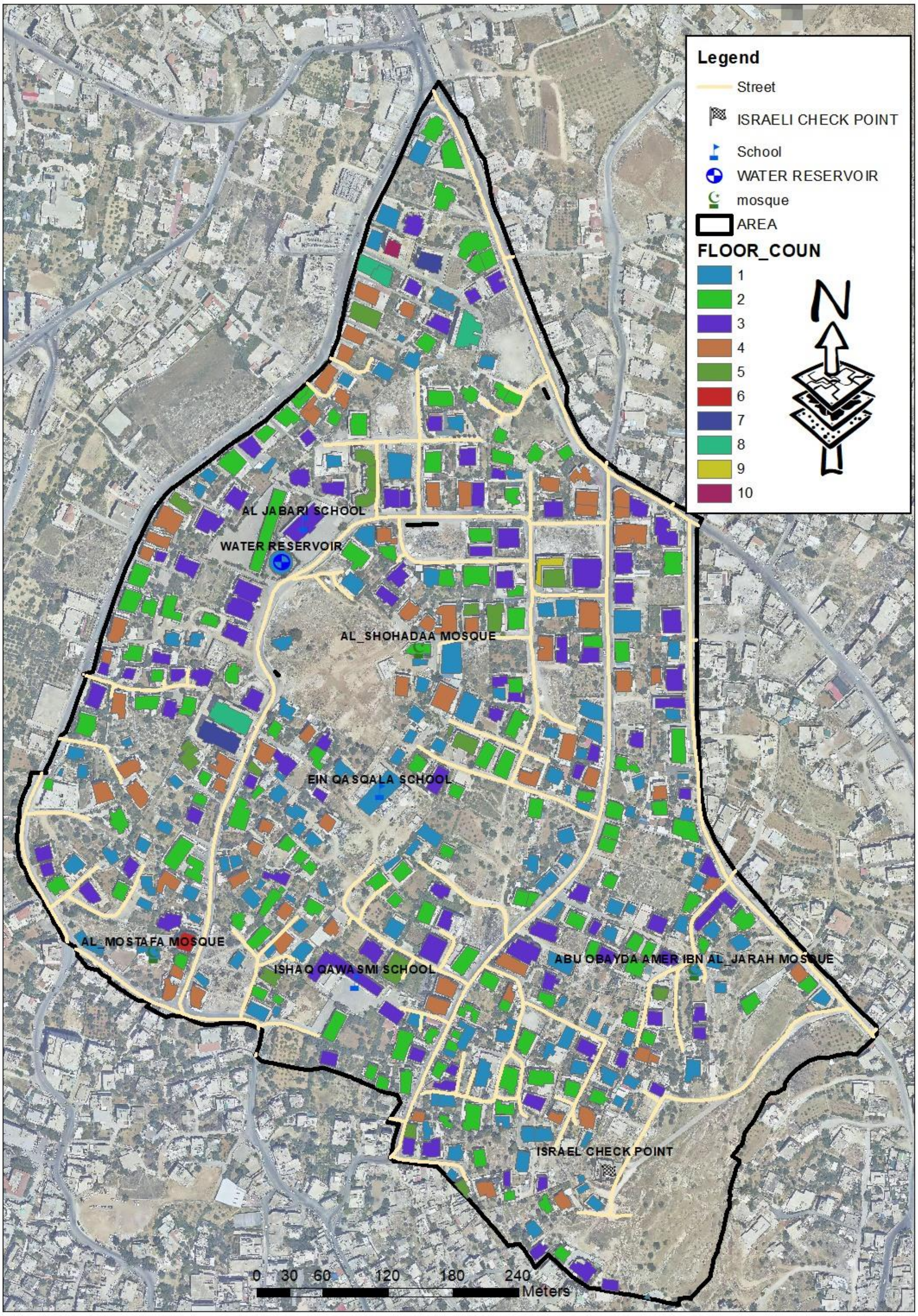


Figure 4.5: Map of the number of the floor of buildings for Sheikh Neighborhoods and remarkable buildings – information’s source: Hebron Municipality.

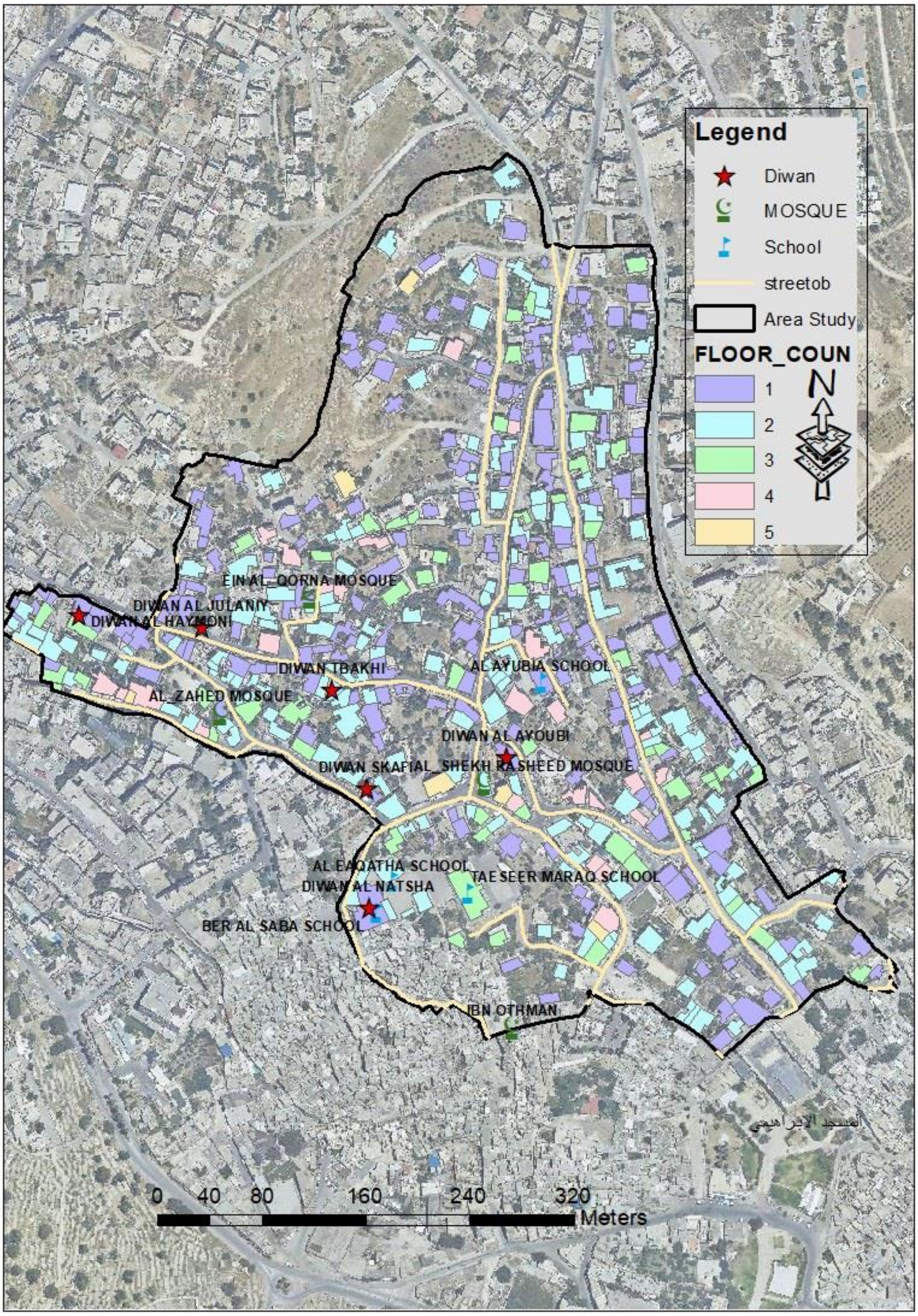


Figure 4.6: Map of the number of the floor of the buildings for Old town and remarkable buildings – information's source: Hebron Municipality- Drawn by the researcher.

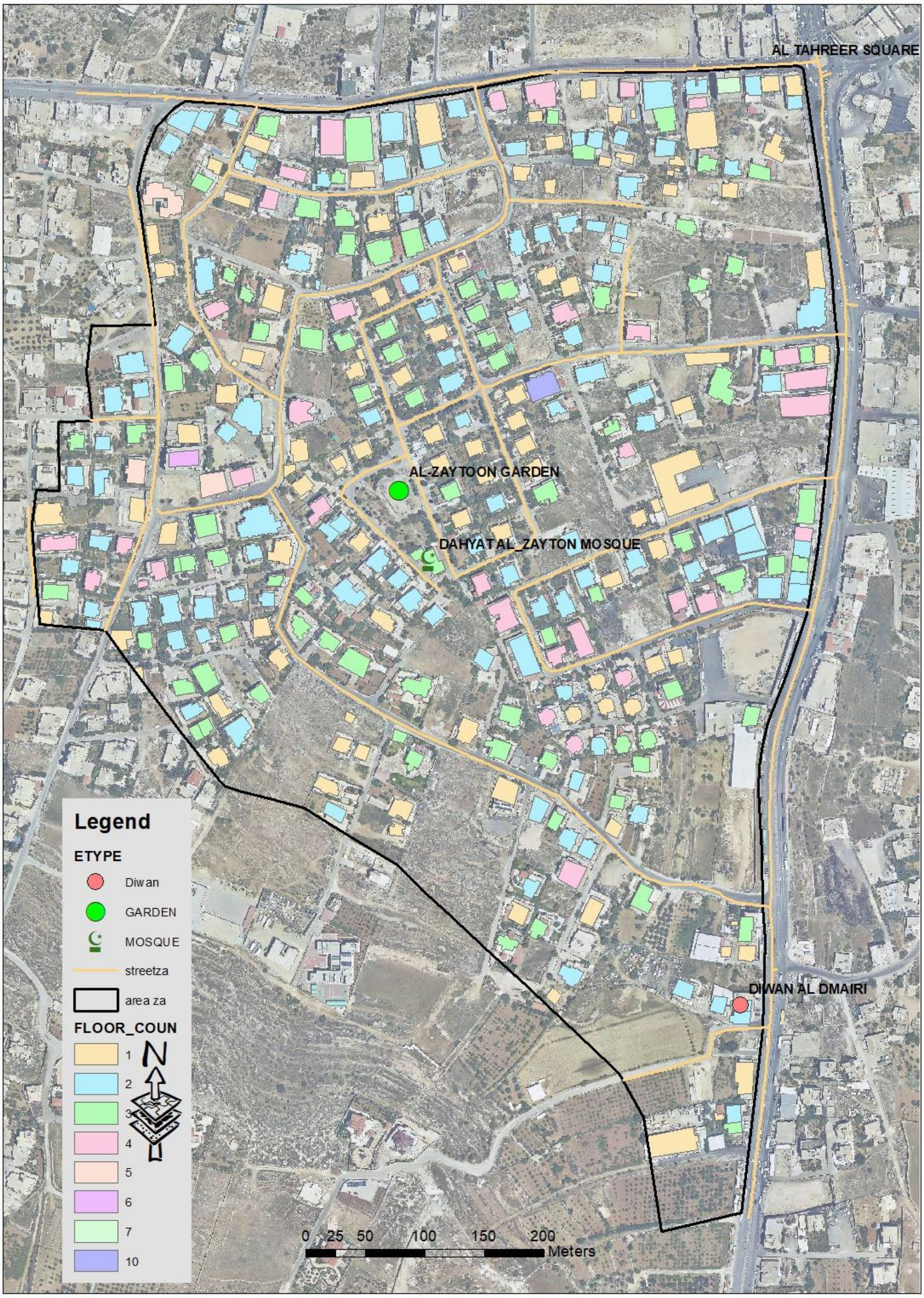


Figure 4.7: Map for the number of the floor of buildings for - Al -Zaytoon neighbourhood and remarkable buildings – information's source: Hebron Municipality- Drawn by the researcher.

4.4 The result of study site analysis:

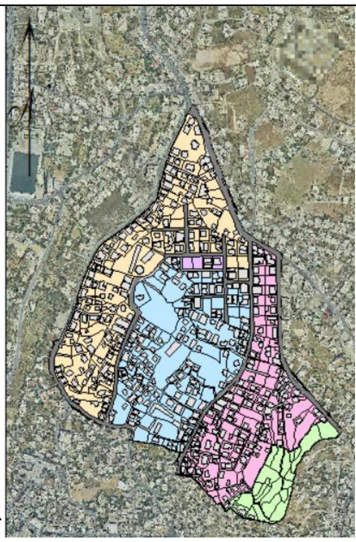
Each area is subdivided into several subcategories that are classified by four urban parameters (Built Intensity, Compactness, building Height and Open Space Ratio), where each of them indicate a specific criterion. The contribution of the four urban variables (geometrical properties) will be discussed in the classification process. The basic spatial properties of an area can be conveyed using all the indicators by which the urban fabric type is characterized.

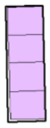
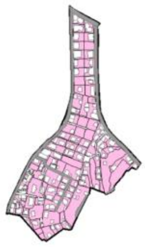
4.4.1 Al-Sheikh neighborhood (contemporary development):

Table (4.4) presents the results of a clustering process using all morphological indicators in al sheikh neighborhood. This is a determination of urban sub-areas (clustering) after inputting all the data using GIS. The analysis shows that the neighborhood is characterized by (FSI), (GSI) and (OSR), that at the same time notify us about the average amount of floors (L). Built intensity (FSI) variable varies between (0 – 0.80), coverage values between (0 – 0.40), the value of the average amount of floors between (0-3) and open space Ratio between (0-2.7).

(FSI) describes the level of exploitation of the land in terms of quantity of floor space by a unit of land, there are no urban areas in the two zones (1,5), and Three zones are found (2,3,4), where (FSI) values are 1,0.80,0.70 while the GSI value is the high coverage of these three zone types are 0.30-0.40-0.30 ,respectively . The basic definition of (OSR) describes the relationship between gross floor area and all non-built space of the fabric; when we look at (OSR), high OSR values are found in zone 1, and it is 2.4. This is due to the presence of empty and semi-empty plots on the outskirts and in the center of this zone. building height (L) values are stable and near to each other, see table below.

Table 4.4: Pattern zones of Al-Sheikh neighborhood by GIS.



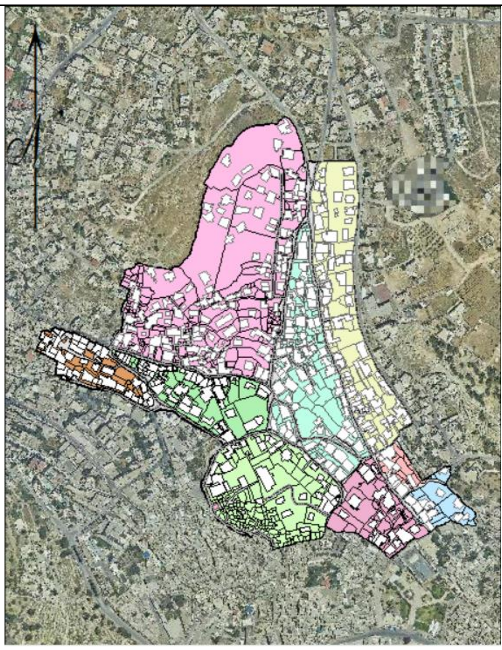
block					
zone	1	2	3	4	5
FSI	0	1	0.8	0.7	0
GSI	0	0.3	0.4	0.3	0
L	0	3	2.3	2	0
OSR	0	1.62	0.65	2.4	0
FSI	Floor Space Index this is given by equation's= F/A /F= gross floor area /A= area of plot				
GSI	Ground Space Index this is given by equation's =B/A/ B= footprint of building. / A= Area of Plot.				
L	expresses the average number of floors of an area this is given by equation's = FSI/GSI.				
OSR	Open Space Ratio this is given by equation's = (1-GSI)/FSI.				

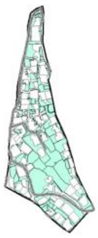
The studied variables in Regulation law applicable in Hebron city-Hebron municipality				
Type (A, B,C and D) regulations	FSI	GSI	L	OSR
D	252%-882%	42%	6-21	23%

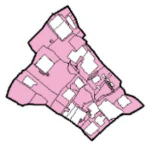
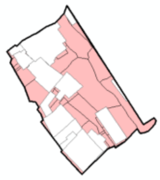
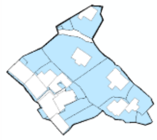
4.4.2 Old Town (Traditional)

Table (4.5) presents the results of a clustering process using all morphological indicators in Old city with a very complex urban fabric within limited boundaries. it is split into nine zones that can be characterized by their mean (FSI), (GSI), (OSR) and (L). Differentiation among these zones starts to emerge when we take (FSI) into account, where the (FSI) and coverage (GSI) values vary between (0.36-1.30) (0.36-0.70), respectively, while building height (L) values are stable and near to each other, where (L) values average between (1.3-3) That is, an average of one to three floors. Finally, Open space ratio (OSR) values range between (0.20-0.60), and most of their variable values are also smoothly distributed, presenting no significant difference from the zone values.

Table 4.5: Pattern zones of Old building by GIS.



block					
zone	١	٢	٣	٤	٥
FSI	1	1.30	0.7	1	1
GSI	0.60	0.70	0.60	0.50	0.60
L	1.7	2	2	3	1.7
OSR	0.30	0.20	0.30	0.50	0.60

					
zone	6	7	8	9	
FSI	1.20	0.36	0.90	1.30	
GSI	0.60	0.36	0.50	0.60	
L	1.7	3	1.7	1.7	
OSR	0.30	0.60	0.40	0.50	
FSI	Floor Space Index this is given by equation's= F/A /F= gross floor area /A= area of plot				
GSI	Ground Space Index this is given by equation's =B/A/ B= footprint of building. / A= Area of Plot.				
L	expresses the average number of floors of an area this is given by equation's = FSI/GSI.				
OSR	Open Space Ratio this is given by equation's = (1-GSI)/FSI.				

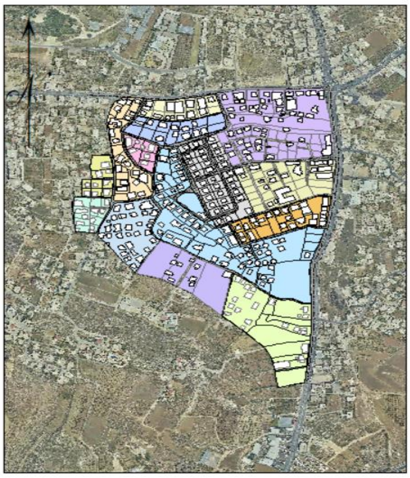
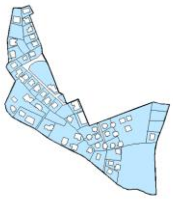
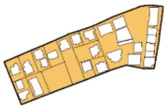
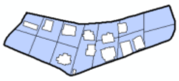
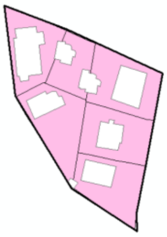
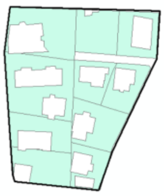
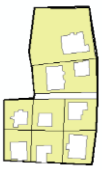
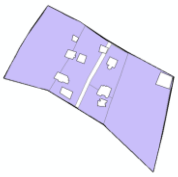
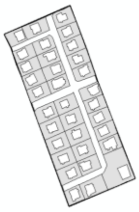
The studied variables in Regulation law applicable in Hebron city				
Type (A, B ,C and D) regulations	FSI	GSI	L	OSR
Old city (heritage)	-	-	-	-

All clustering zones represent high coverage values because the buildings of the old town are close to each other ,cluster with lower coverage (GSI) is zone 7, with a value of 0.36, The coverage values of other blocks stabilize, especially when we compare zone 1, 3,5,6 and 9. The highest coverage value is zone 2,which is 0.70, and zone 4,8 is 0.50.When we look at (FSI) values (1-1.30-1-1-1.20-1.30) zones (1,2,4,5,6,9) are denser than the values (0.70-0.36-0.90) of (3,7,8) zones, indicating that denser zones are obtained by low-rise buildings in a compact configuration. Privately built one-story or two-story buildings account for a majority of this block.

4.4.3 Al-Zaytoon neighborhood (preplanned neighborhood)

As can be seen in table (4.6) presents the results of a clustering process using all morphological indicators in Al zaytoon neighborhoods. The urban fabric is more diverse in this Case study, as the total zones reached 14. The classification identifies the area as low rise - medium coverage (GSI), and its value ranges between (0.18-0.28), it reveals high and low coverge, high zone (1,3,5) ,which is (0.35-0.31-0.35), and two zones has low coverage (4,12) zones, which is (0.15-0.1) , respectively, , and L values average between (1.3-3), an average of one to three floors. However, it considered high values of built intensity (FSI) ranges between (0.17-0.84), with the peak value at zone (3) which is (0.84) at east of the neighborhoods. Finally, the Open space ratio (OSR) the less value can be found at 0.70 and a higher value is 12.1, which presents a significant difference from the zone values.

Table 4.6: Pattern zones of Al-Zaytoon neighborhood by GIS.

					
block					
zone	1	2	3	4	5
FSI	0.60	0.50	0.84	0.30	0.82
GSI	0.35	0.21	0.31	0.15	0.35
L	2	2.4	2.7	2	2.4
OSR	5.13	2.30	1.20	2.80	0.70
block					
zone	6	7	8	9	10
FSI	0.47	0.57	0.69	0.62	0.62
GSI	0.23	0.25	0.26	0.26	0.29
L	2.4	2.5	2.4	2.4	2.15
OSR	1.04	1.76	1.1	1.47	1.13
block					

zone	11	12	13	14	
FSI	0.80	0.17	0.52	0.48	
GSI	0.27	0.1	0.20	0.25	
L	2.5	1	2.7	2.15	
OSR	1.32	1.21	0.92	2.1	

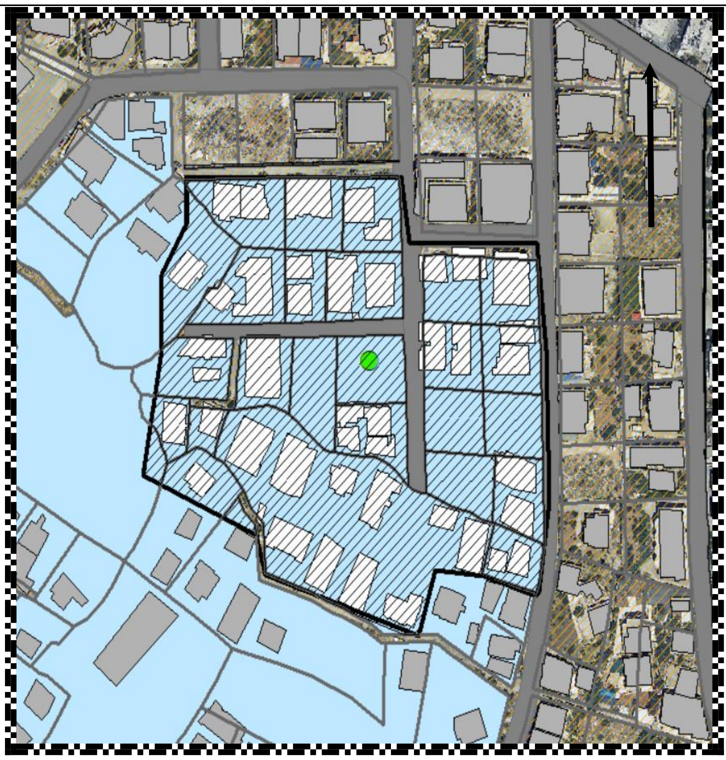
FSI	Floor Space Index this is given by equation's= F/A /F= gross floor area /A= area of plot
GSI	Ground Space Index this is given by equation's =B/A/ B= footprint of building. / A= Area of Plot.
L	expresses the average number of floors of an area this is given by equation's = FSI/GSI.
OSR	Open Space Ratio this is given by equation's = (1-GSI)/FSI.

The studied variables in Regulation law applicable in Hebron city				
Type (A, B, C and D) regulations	FSI	GSI	L	OSR
A	180%	36%	5	35%

4.5 The basic definition of urban pattern of Hebron city:

This section proposes a framework for urban pattern of the case study classification, which is the building urban pattern of the city. For example, building heights (as the average number of floors) are attributed to urban building blocks. (done for the samples in Hebron City), It has employed a spatial characteristic in GIS and analyzed georeferenced photos, if available, Street View information (where the number of floors is counted for each individual building).

Table (4.7): Definition of urban pattern of Hebron city: Example of zone (3) (pattern-1) in al sheikh neighborhood.



Urban form factor	
Confounding parameter (density Factor of urban)	
Building intensity	0.80
Site coverage	0.40
Building height	2.3
Open space ratio	0.65

						Local Topography (LT)	40
zone (3) (pattern-1) in al sheikh neighborhood – source Hebron municipality							
Constant parameter of (urban block)							
Area plot ratio	Compactness	Built intensity	Building height	Open space ratio	Form factor	Habitable room	greenery
31%	0.33	0.73	1.90	1.65	13	4	20%

4.6 Discussion:

When discussing urban form, the multivariable approach is useful. Accordingly, we demonstrate that this multivariable approach can be used to define urban types in terms of density using empirical research and mathematical analysis (exploratory research). All the variables in these case studies (neighborhood) have different values, indicating that the urban fabric has changed and become more diverse.

It is interesting to note that the (FSI) values of Al-Sheikh, Al Zaytoon neighborhoods and Old City have similar values of blocks, indicating that the built-intensity (FSI) of the urban form is similar in the three cases. These cases are similar in terms of FSI, but there are significant differences in terms of GSI and OSR the zone type's building height (L) is also similar, ranging between 1 and 3. The difference in built density can thus be explained by the compactness (GSI) and open space ratio (OSR).

When comparing all zones of Al-Sheikh, the Old City Al, and Zaytoon, the coverage (GSI) in Al- Sheikh neighborhood is (0.30-0.40), the old city is (0.36-0.70), and in Al Zaytoon neighborhood it is only (0.1-0.35). Due Al-Sheikh neighborhood has streets that are relatively narrow, and a high floor average (L), but the old town has narrow streets and close proximity buildings, whereas in Al Zaytoon neighborhood has been leaving large amounts of undeveloped space.

In Al-Sheikh neighborhood (contemporary development) is considered an extension of Hebron's old town, its streets have remained somewhat narrow, as they did not expand as much as those in the Al-Zaytoon neighborhood. According to, the building regulations (setbacks of buildings), which is classified as a residential area C, it led to an increase in the open space ratio (OSR) and decreased the percentage of coverage (GSI). With regard to the average number of floors (L), recent building techniques allowed vertical development, as buildings with a height of 27 m were found in those areas.

While in the Old City (traditional), the built intensity (FSI) and the coverage (GSI) values were higher and the open space ratio (OSR) is lower , because its streets are narrower, its buildings are closer together, and there is a vertical orientation in some buildings, as the building codes were based on what was known to the people. In addition to the fact that building technology was less developed, this led to the limitation in the number of floors (L), which reached a maximum of 4 floors.

When looking at the Al-Zaytoon neighbourhood (pre- planned), a series of FSI and OSR variables are described. The distinctions are based on the type of housing and are related to development types commonly found in the case study, where the urban fabrics are dominated by single villa houses and detached family houses, with increased public space (garden) and stricter building regulations resulting in a decrease in GSI, while the number of areas, which reached 14, makes it evident that there have been certain misuses in this neighbourhood that seem disorganized, as can be seen in the Table (4.7). Furthermore, the analysis method over time can provide a more accurate interpretation and analysis of the development and, as a result, the processes' orientation to a new way of urban planning and intervention. However, in order to conduct more detailed research on urban interventions, other elements that help in measuring complexity and extracting valuable data must be included. In other words, only when a multivariable density concept is used can zone types be distinguished from one another in terms of density.

4.7 Conclusion

The findings demonstrate that this analytical method is more powerful and comprehensive than traditional descriptive classifications. The classification generates a large number of spatial structures in very heterogeneous environments, such as Hebron city. However, when the typology can be used (as in some urban modelling and simulation studies), this approach can be extremely beneficial. The characterization developed here is easily extensible by incorporating more urban variables data in the morphological properties, particularly those associated with urban open space geometry.

Based on these findings, it is possible to conclude that the built intensity (FSI) and coverage (GSI) values were high prior to 1928, as seen in the old city (traditional) with low values of open space ratio (OSR). Between 1928 and 1984 it is obvious that the extension was horizontal since at that time people had started to emigrate from the city center and construct buildings outside the old city, and the need to increase the number of houses and apartments resulted in a significant increase in density due to a lack of planning, as in Al sheikh neighborhood (contemporary development). Therefore, the built intensity (FSI) and coverage (GSI) values decreased, because the buildings began to gradually move away from each other, thus open space ratio (OSR) increased.

Due to economic growth and the establishment of relevant housing buildings, the density increased immediately beginning in 1984 and has continued to this day. In Al Zaytoon neighbourhood (pre-planned) also the extension was horizontal. However, compared to cases, in traditional and contemporary development, the built intensity (FSI) and coverage (GSI) values were lower and the open space ratio (OSR) was higher. In this case, it is clear that density is directly related to planning policies. Furthermore, based on the analyses conducted in these areas over various time periods, the values of these urban form (FSI, GSI, OSR, L) didn't not change significantly during these periods.

Indeed, multivariable density appears to be well-suited to account for structural differences in urban form. So far, real urban form has been studied, as has the relationship between density and urban form. Since there is a lot of diversity in these areas, density variables become very statistical.

Chapter 5
Analysis

5.1 Preface

In this chapter, building energy demand is included to show a relationship between urban morphology (density factor). By creating the prototype building in Chapter 4, the relationship between urban form and density for the seven configurations (urban built forms) was established. Site plans are created for the energy analysis of residential buildings using Design-builder simulations software, and building energy analysis is performed on the geometrical model (prototype) of urban forms. Design-builder can calculate a building's heating and cooling energy requirements based on the climate. It also can calculate CFD analysis for Site and building.

Building heating/cooling demand is significantly affected by urban planning decisions (Hukkalainen et al., 2017) Strategies and policies for urban and spatial planning must link urban energy efficiency actions (Zanon and Verones, 2013). The energy demand of several configurations (built forms) with various densities is examined to determine the best and worst building forms for this environment. Planners can identify the worst/best form and density combinations in urban areas using diagrams. This allows future urban policies to be more precise and appropriate in terms of increasing urban energy efficiency.

5.2 Criteria of Selection Simulation patterns

To investigate the impact of density on building energy demand, the urban patterns were selected from three neighborhoods, the selection criteria of the patterns characteristics are as follows (Foell and International Institute for Applied Systems Analysis, 1979):

- The area of each pattern is 33,000 m^2, zones. areas that are less than this are excluded.
- Different density conditions (form morphology): the seven patterns in these three neighborhoods can also serve to describe the differences in building densities as shown in Figure (5.1) to recognize differences and define these patterns.
- Urban area: there are no urban areas in these parts of patterns to be investigated.

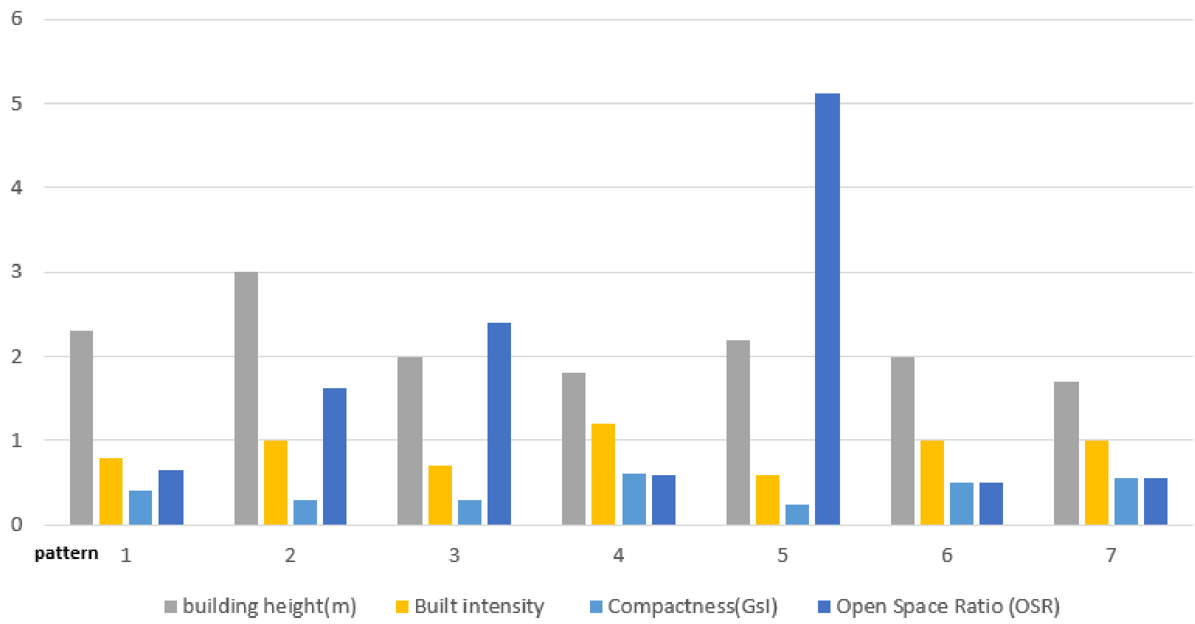
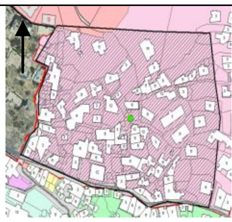


Figure 5.1: Density variables of different studies areas.

Each pattern is selected to represent one of the main zones, as shown it table (5.1) below

Table 5.1: Different selected study areas with urban variables.

SHAPE				
pattern	1	2	3	4
Name	Al-Sheikh	Al-Sheikh	Al-Sheikh	Old town
FSI	0.80	1	0.70	1.2
GSI	0.40	0.30	0.30	0.62
L	2.3	3	2	1.7
OSR	0.65	1.62	2.4	0.60

SHAPE			
pattern	5	6	7
Name	Al-Zaytoon	Old town	Old town
FSI	0.60	1	1
GSI	0.25	0.50	0.55
L	2	2	1.8
OSR	5.13	0.50	0.55

5.3 Energy simulation of the selected urban pattern.

This section summarizes the results of the simulation energy demand. Energy simulation was carried out for all seven urban patterns in their current situation, and the results of this simulation are displayed in table (5.1) above, which shows the urban variables. Additionally, the simulated energy demand (ED). It also displays the outcomes of the study areas with and without the area topography.

5.3.1 Heating and cooling calculations by Design builder.

The findings for each urban pattern are summarized here. The results for the heating and cooling -energy demand presented below in Figure (5.2) are measured in kWh per m^2 per year (kWh/m^2/a). The distribution of heat demand for the whole building in all 7 patterns in the city followed a standard normal distribution with an average of 35 kWh/m^2/a. The highest heat-energy demand was calculated for the pattern (4) at 40.3 kWh/m^2/a, while the lowest value, at about 18.6 kWh/m^2/a, was identified for the pattern (3), while the amount of energy required for the whole building cooling varies between 6.1 kWh/m^2a and 10.2 kWh/m^2a annually, so the highest cooling demand is 10.2 kWh /m^2 at pattern (3), with average of 7.8 kWh/m^2/a . Different patterns have different energy demands, with the results being influenced by urban form-related factors. It can be noticed, that the cooling load of the prototype building is the lowest compared with the heating load demand.

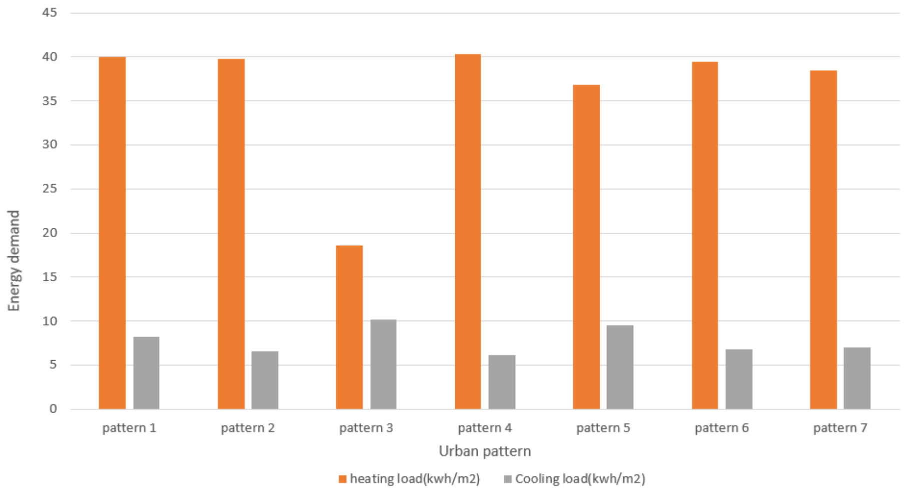


Figure 5.2: Heating and Cooling demand per year for seven patterns.

Javanroodi K and Mahdavinejad M (2018) employed the “highest cooling demand” (HCD) in each month to facilitate the comparison between parameters and objectives, (Javanroodi et al., 2018) so the highest cooling and heating demand (HCD, HHD) per year will be used as the baseline for comparison in this thesis to examine various patterns. The number four and three urban patterns were identified as the highest heating and cooling demand, where each value was 40.3 kWh/m^2, and 10.2 kWh/m^2 respectively. As shown in Figure (5.2) above.

5.3.2 Heating and cooling simulation result of urban patterns (with the topographical and non-topographical factor)

This section displays the simulation results for the urban seven patterns, with the topographical and non-topographical factor, since it was anticipated that this factor affected the values of the heating and cooling demand. These patterns are based on the urban building forms parameters, the most efficient pattern is selected.

Tables (5.3.1) - (5.3.7) show the energy simulation of patterns made with Design-builder for a prototype building located in selected neighborhoods. The results refer to the system loads for the whole building. In particular, the monthly heating and cooling demand for patterns distinguishing monthly energy demand and annual demand has been indicated; shows the 3D view of pattern at the design-builder program.

For most patterns, the largest reduction in heating demand occurs in March, with the exception of pattern (3) (the lowest heating demand) has an 11.7% reduction compared to HHD in January. The difference in the other months is 41.9%. patterns (3) with a high open space ratio (OSR) and built intensity (FSI) demonstrated a significant monthly heating demand reduction compared to the HHD. The largest cooling load reduction occurs in July and august for all patterns; for example, pattern 4 (the lowest cooling demand) has an 11.6 % reduction against HCD in July, and 9.2% in august. In the other months, the difference is 18.7%. Patterns with high built intensity (FSI) showed a remarkable cooling load reduction compared to the HCD in each month.

According to Tables (5.3.1)-(5.3.7) below, also the effects of surrounding building forms on heating demand are evaluated by examining the four urban variables (FSI, GSI, L, OSR) for the seven introduced urban forms (P (1), P (2), P (3), P (4), P (5), P (6), P (7)). Where pattern (4) have the HHD, with (FSI:1,20, GSI:0.62, L:1.7, OSR: 0.62). The relative reduction for pattern (1), with (FSI:0.80, GSI:0.40, L:2.3, OSR: 0.65). (compared to the HHD pattern 4) are 0.7%. The prototype building is the lowest heating demand in pattern (3) with (FSI:0.70, GSI:0.30, L:2, OSR: 2.4), where the relative reduction is 53.7 %. pattern (7) with (FSI:1, GSI:0.55, L:1, OSR: 0.55) has the relative reduction is 2.6 %. Finally, the relative reduction of pattern (2) pattern (5) with (FSI:0.60, GSI:0.25, L:2, OSR:5.13) and pattern 6 with (FSI:1, GSI:0.30, L:3, OSR: 1.62) (FSI:1, GSI:0.50, L:2, OSR: 0.50) are (1.2-1.8 %), respectively, where there is the lowest reduction.

By examining the effects of four urban variables, the cooling demand for each of the seven patterns shown is also evaluated. According to Tables (5.3.1) -(5.3.7), pattern (3) form has the HCD, with (FSI:0.70, GSI:0.30, L:2, OSR: 2.4). The relative reduction for patterns 1 with (FSI:0.80, GSI:0.40, L:2.3, OSR: 0.65) (compared to the HCD pattern) is 18.5%. The cooling load of the prototype building is the lowest in patterns (4) with (FSI:1,20, GSI:0.62, L:1.7, OSR: 0.62), where the relative reduction is 39.75 %. Pattern (2) and pattern (6) with (FSI:1, GSI:0.30, L:3, OSR: 1.62) (FSI:1, GSI:0.50, L:2, OSR: 0.50) respectively, also show a notable cooling load reduction against the HCD, where the relative reduction is 33.2 %,and the relative reduction is 30 % for pattern (7) with (FSI:1, GSI:0.55, L:1, OSR: 0.55). Finally, the relative reduction of pattern (5) with (FSI:0.60, GSI:0.25, L:2, OSR:5.13) is 9.36 where there is the lowest reduction.

According to the table (5.3.1) -(5.3.7) also show the result of heating and cooling demand without topography, the majority of the results showed an increase in the energy demand (heating and cooling demand) against the energy loads with the topography, and this is particularly evident in the cooling demand finding. The highest increase in pattern (1) was about 17%, followed by increases of about 12.6% in pattern (2), and 13.8% in pattern (7- Except for example pattern 5, where there was a drop in Cooling of roughly 22%, patterns (4–3–6) all showed a percentage increase of between (0.25%–3.2%). The heating loads show an increase in patterns (4-5-6) by a rate varying between (0.7-1.8) % when we look at the heating loads. The number of patterns (2-3-7) decreased. Correspondingly 0.3%, 0.5%, and 1.8%, while pattern (1) exhibits a considerable reduction of roughly 32%.

Table 5.2: The compression between Topography and None topography heating and cooling demand of pattern (1) in al sheikh neighborhoods.

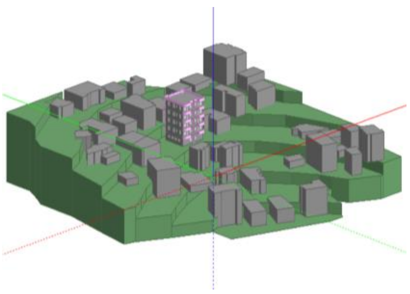
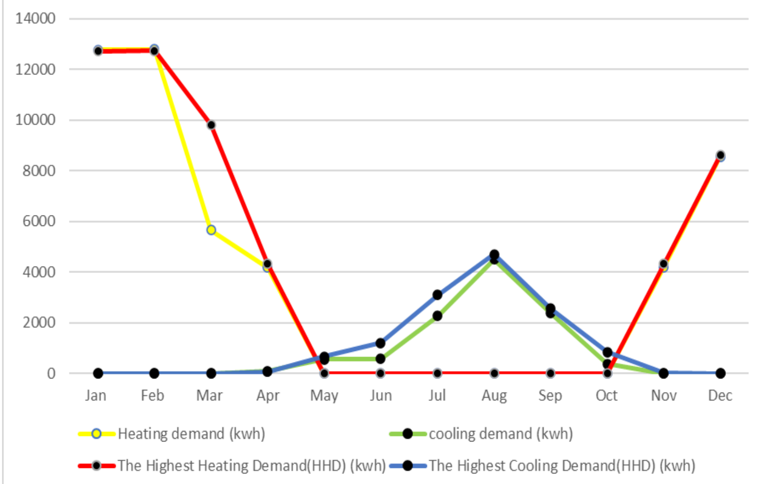
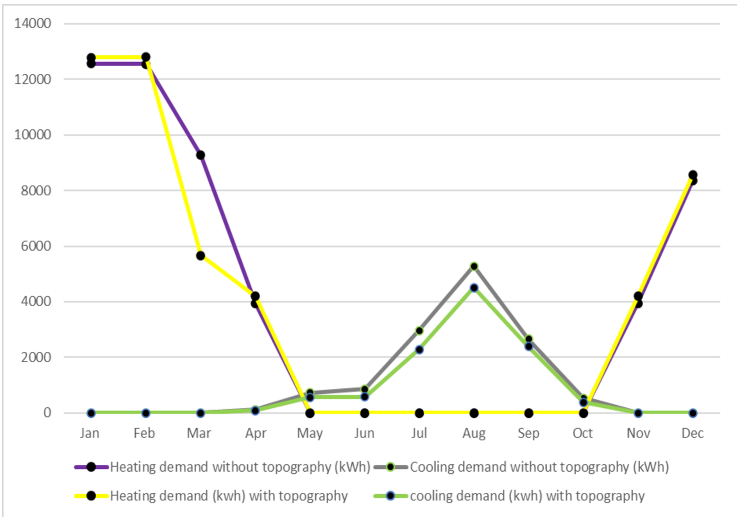
<table>
<tr><td colspan="3">With the topographical factor</td></tr>
<tr><td></td><td colspan="2"></td></tr>
<tr><td>Annual Heating Load(kWh)</td><td>52198</td><td>The relative reduction about the highest heating demand =0.7%</td></tr>
<tr><td>Annual Cooling Load(kWh)</td><td>10782</td><td>The relative reduction about the highest cooling demand =18.5%</td></tr>
<tr><td>Topography slope</td><td>0.16</td><td></td></tr>
<tr><td colspan="3">Without the topographical factor</td></tr>
<tr><td></td><td colspan="2"></td></tr>
<tr><td>Annual Heating Load(kWh)</td><td>50618</td><td>The relative reduction about heating demand with topography = 3 %</td></tr>
<tr><td>Annual Cooling Load(kWh)</td><td>13138</td><td>The relative increment about cooling demand with topography = 17 %</td></tr>
</table>

Table 5.3: The compression between Topography and None topography heating and cooling demand pattern (2) in al sheikh neighborhoods.

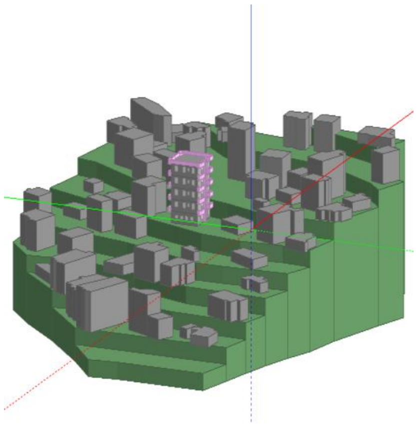
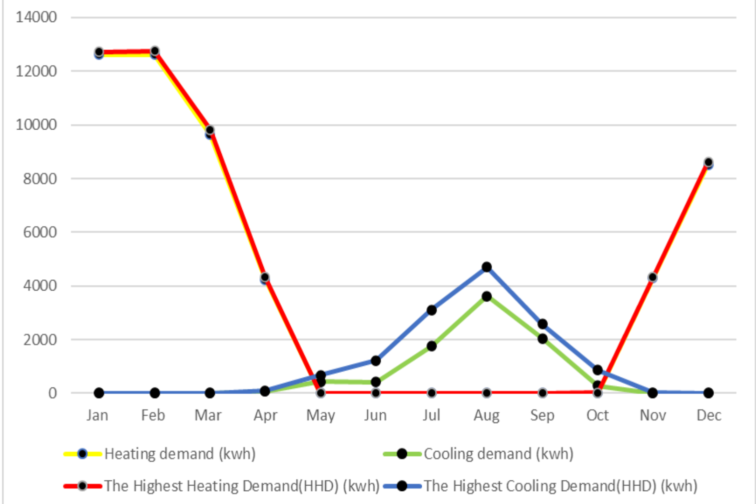
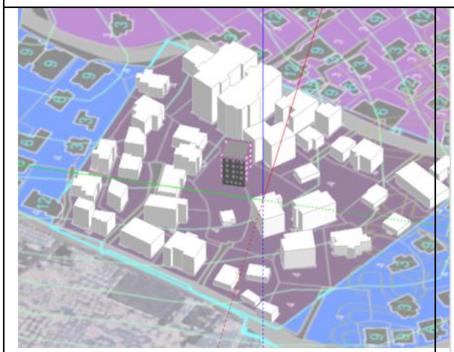
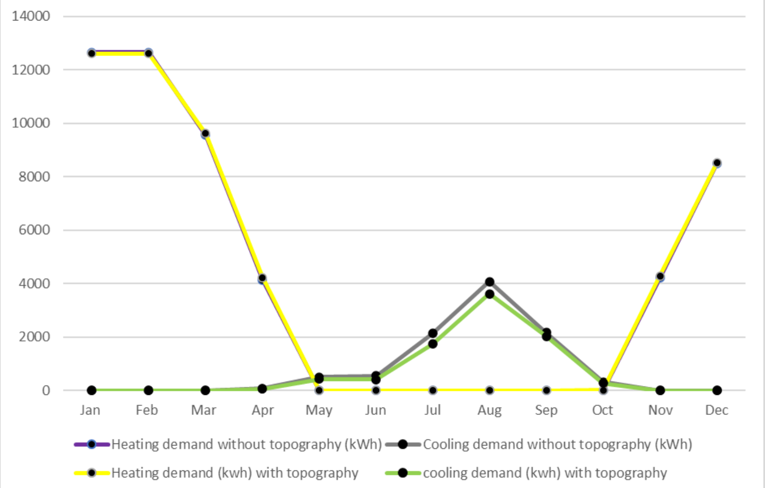
<table>
<tr><td colspan="3">With the topographical factor</td></tr>
<tr><td></td><td colspan="2">
</td></tr>
<tr><td>Annual Heating Load(kWh)</td><td>51900</td><td>The relative reduction about the highest heating demand =1.2%</td></tr>
<tr><td>Annual Cooling Load(kWh)</td><td>8594</td><td>The relative reduction about the highest cooling demand =35%</td></tr>
<tr><td>Topography slope</td><td>0.11</td><td></td></tr>
<tr><td colspan="3">Without the topographical factor</td></tr>
<tr><td></td><td colspan="2">
</td></tr>
<tr><td>Annual Heating Load(kWh)</td><td>51742</td><td>The relative reduction against heating demand with topography = 0.3%</td></tr>
<tr><td>Annual Cooling Load(kWh)</td><td>9841</td><td>The relative increment against cooling demand with topography =12.6%</td></tr>
</table>

Table 5.4: The compression between Topography and None topography heating and cooling demand at pattern (3) in al sheikh neighborhoods.

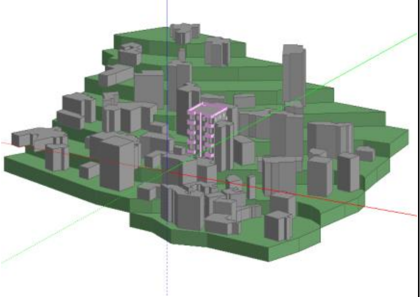
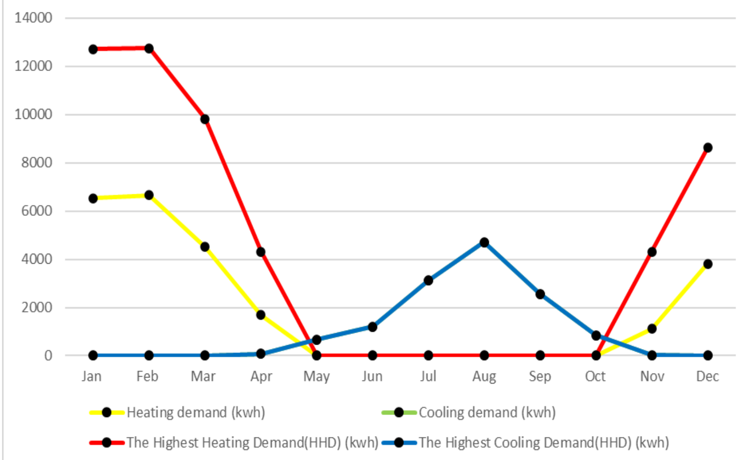
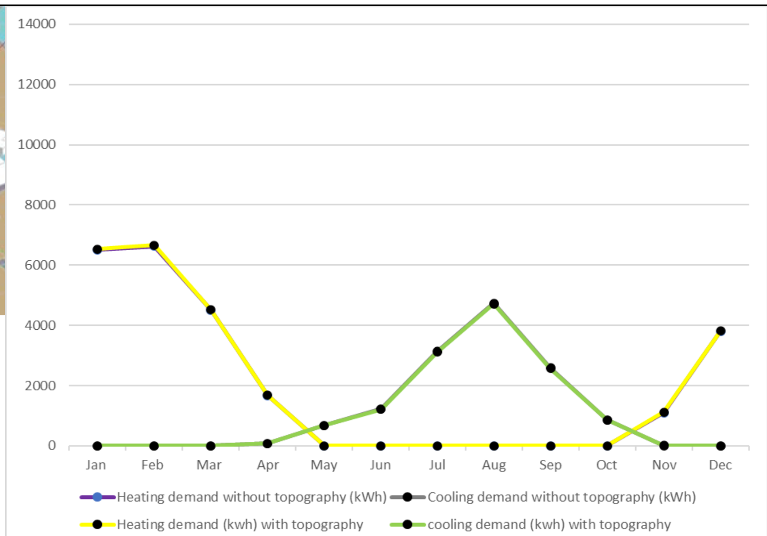
With the topographical factor		
		
Annual Heating Load(kWh)	24325	The relative reduction about the highest heating demand =53%
Annual Cooling Load(kWh)	13237	highest cooling demand
Topography slope	0.2	
Without the topographical factor		
		
Annual Heating Load(kWh)	24208	The relative reduction against heating demand with topography = 0.5%
Annual Cooling Load(kWh)	13299	The relative increment against cooling demand with topography =0.45%

Table 5.5: The compression between Topography and None topography heating and cooling demand at pattern (4) in old town.

<table>
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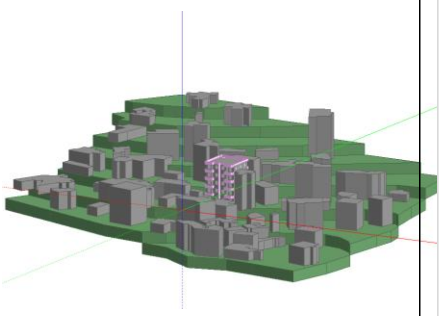
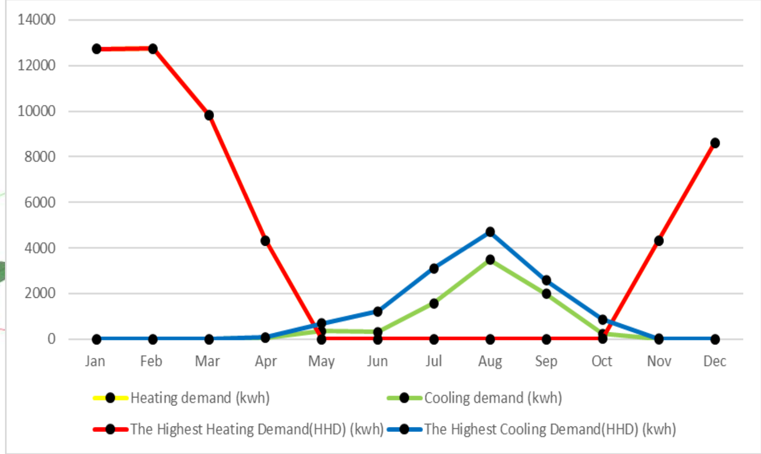
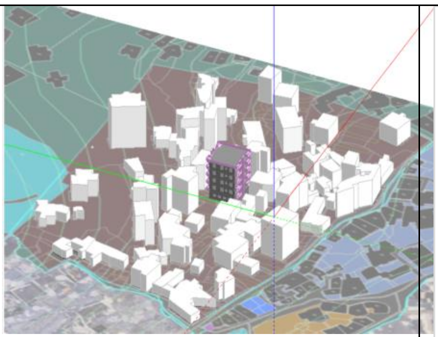
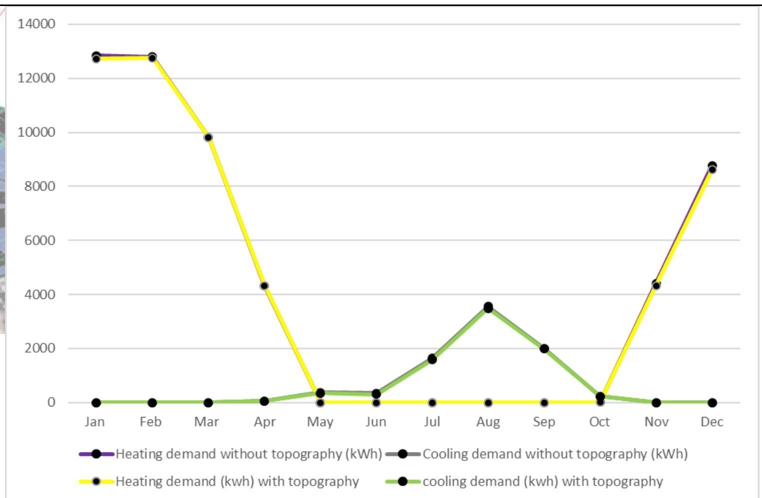
<tr><td></td><td colspan="2">
</td></tr>
<tr><td>Annual Heating Load(kWh)</td><td>52580</td><td>the highest heating demand</td></tr>
<tr><td>Annual Cooling Load(kWh)</td><td>7975</td><td>The relative reduction about the highest cooling demand = 39%</td></tr>
<tr><td>Topography slope</td><td>0.14</td><td></td></tr>
<tr><td colspan="3">Without the topographical factor</td></tr>
<tr><td></td><td colspan="2">
</td></tr>
<tr><td>Annual Heating Load(kWh)</td><td>52959</td><td>The relative increment against heating demand with topography = 0.7%</td></tr>
<tr><td>Annual Cooling Load(kWh)</td><td>8180</td><td>The relative increment against cooling demand with topography =2.5%</td></tr>
</table>

Table 5.6: The compression between Topography and None topography heating and cooling demand pattern (5) Zone 1 in Al Zaytoon.

<table>
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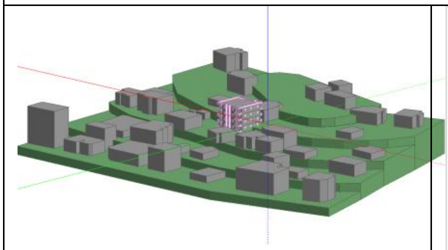
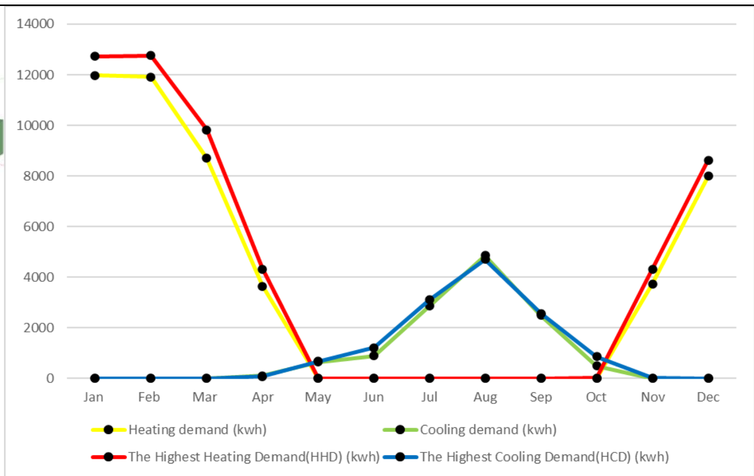
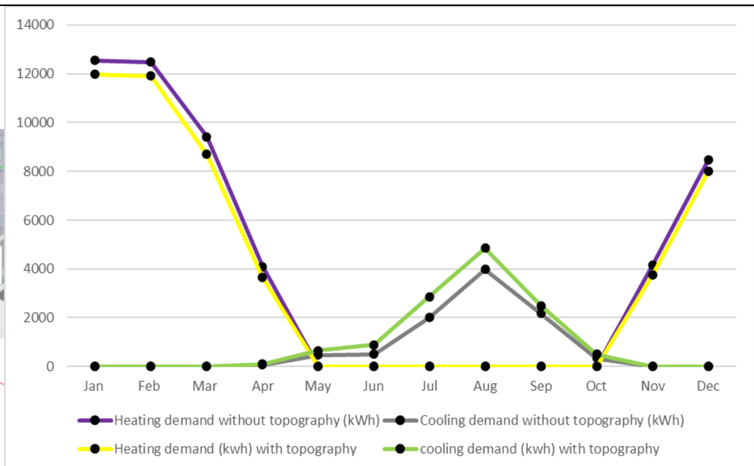
<tr><td></td><td colspan="2">
</td></tr>
<tr><td>Annual Heating Load(kWh)</td><td>48134</td><td>The relative reduction about the highest heating demand =8.7%</td></tr>
<tr><td>Annual Cooling Load(kWh)</td><td>11493</td><td>The relative reduction about the highest cooling demand = 6.7%</td></tr>
<tr><td>Topography slope</td><td>0.11</td><td></td></tr>
<tr><td colspan="3">Without the topographical factor</td></tr>
<tr><td></td><td colspan="2">
</td></tr>
<tr><td>Annual Heating Load(kWh)</td><td>47958</td><td>the relative increment against heating demand with topography = 6%</td></tr>
<tr><td>Annual Cooling Load(kWh)</td><td>12394</td><td>the relative reduction against cooling demand with topography =22%</td></tr>
</table>

Table 5.7: The compression between Topography and None topography heating and cooling demand at pattern (6) in old town.

<table>
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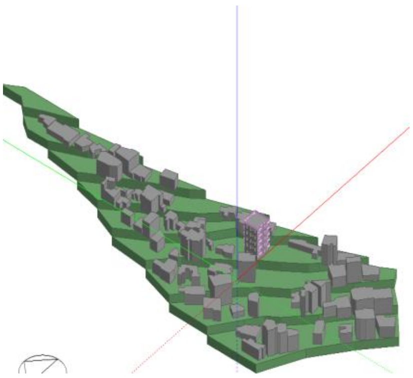
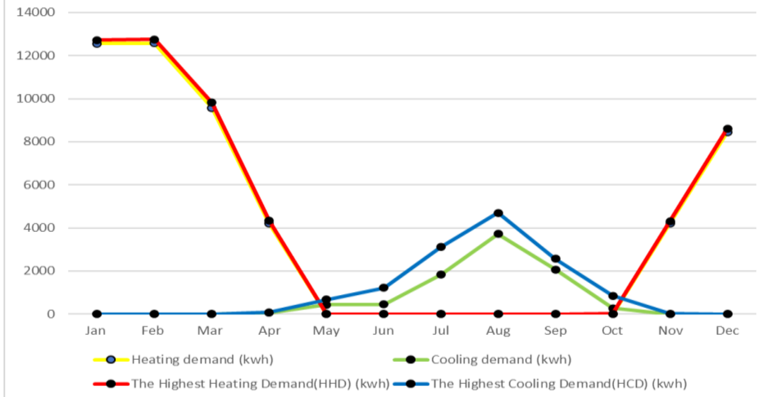
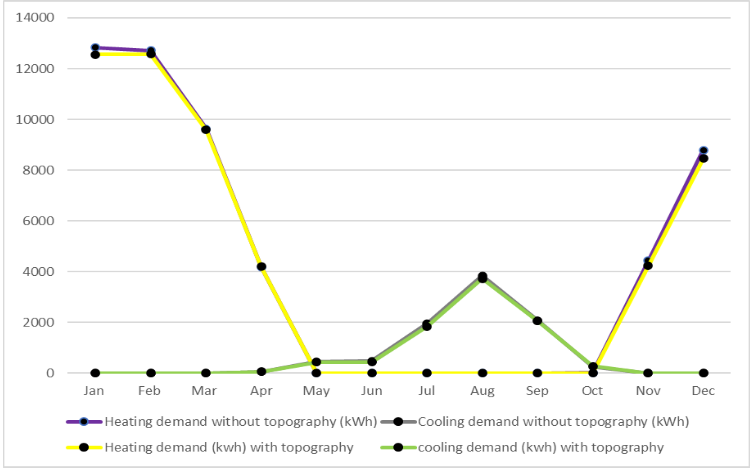
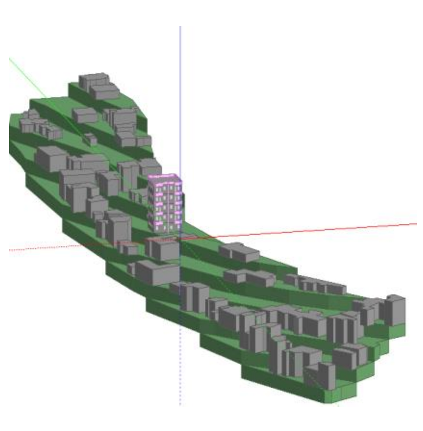
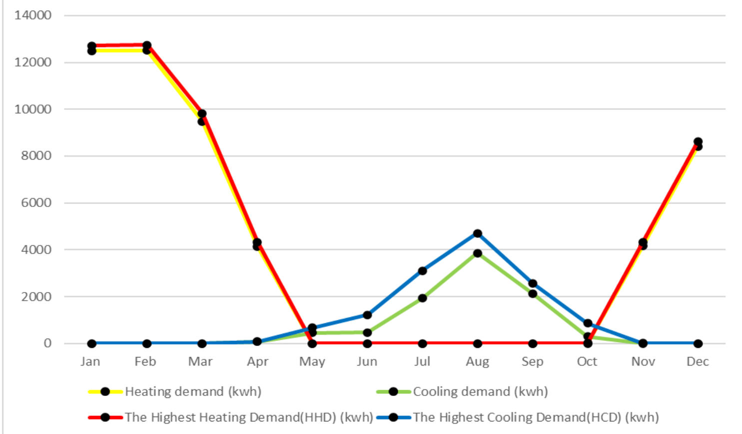
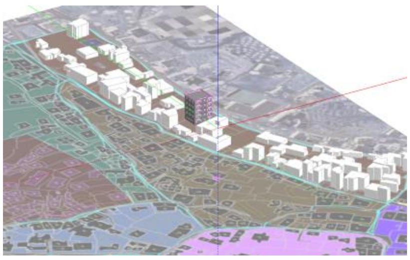
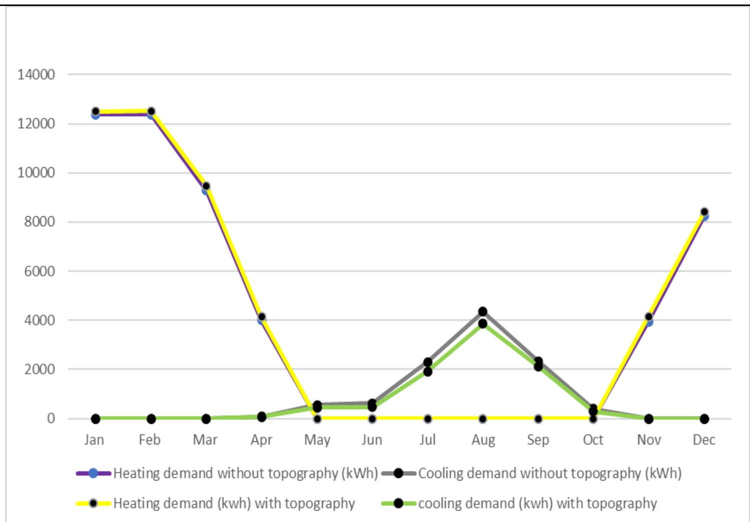
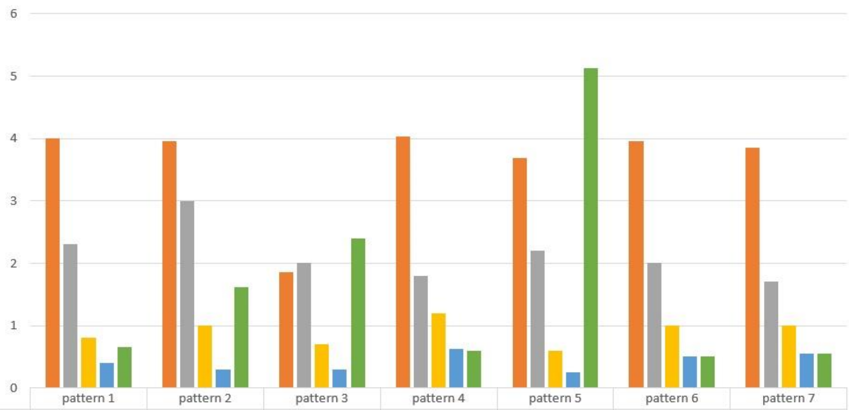
<tr><td></td><td colspan="2">
</td></tr>
<tr><td>Annual Heating Load(kWh)</td><td>51609</td><td>The relative reduction about the highest heating demand =1.8%</td></tr>
<tr><td>Annual Cooling Load(kWh)</td><td>8842</td><td>The relative reduction about the highest cooling demand =33%</td></tr>
<tr><td>Topography slope</td><td>0.1</td><td></td></tr>
<tr><td colspan="3">Without the topographical factor</td></tr>
<tr><td></td><td colspan="2">
</td></tr>
<tr><td>Annual Heating Load(kWh)</td><td>52598</td><td>the relative increment against heating demand with topography = 1.9%</td></tr>
<tr><td>Annual Cooling Load(kWh)</td><td>9136</td><td>The relative increment against cooling demand with topography =3.2%</td></tr>
</table>

Table 5.8: The compression between Topography and None topography heating and cooling demand at pattern (7) in old town.

<table>
<tr><td colspan="3">With the topographical factor</td></tr>
<tr><td></td><td colspan="2">
</td></tr>
<tr><td>Annual Heating Load(kWh)</td><td>49418</td><td>The relative reduction about the highest heating demand = 2.6%</td></tr>
<tr><td>Annual Cooling Load(kWh)</td><td>9207</td><td>The relative increment about the highest cooling demand = 30 %</td></tr>
<tr><td>Topography slope</td><td>0.1</td><td></td></tr>
<tr><td colspan="3">Without the topographical factor</td></tr>
<tr><td></td><td colspan="2">
</td></tr>
<tr><td>Annual Heating Load(kWh)</td><td>51237</td><td>The relative increment against heating demand with topography =0.1%</td></tr>
<tr><td>Annual Cooling Load(kWh)</td><td>9243</td><td>The relative increment against cooling demand with topography =0.4%</td></tr>
</table>

To obtain a comprehensive picture of how urban density affects the need for heating demand, the Highest heating demand HHD, which occurs in pattern 4 with high built intensity, high compactness, low rise building height (FSI:1,20, GSI:0.62, L:1.7, OSR: 0.62) is presented in the old town was compared to other patterns with urban variable see figure (5.3). The annual heating demand reduces by 53.7 % for pattern 3 with a high open space ratio and low coverage (FSI: 0.70, GSI: 0.30, L: 2, OSR: 2.4), where it is considered a mid-low density. However, even though pattern 5 (old town) has the highest percentage of open space, but it did not experience the least amount of reduction. This is because there are other urban form-related factors at play, such as built intensity, building coverage, building height and topography in addition to how the buildings are arranged within this urban form. But, in the other pattern, the values of reduction increased in line with the increase of the ratio of the open space. It is clear that increasing the open space ratio reduces the heating load. While higher coverage and built intensity increase the heating load in a neighborhood, for instance, pattern 4, which experiences the highest heating demand (HHD), has the highest building intensity (FSI) and coverage (GSI) values of other cases. It is difficult to determine the best height because in all urban form, there was a variation in the heights of the buildings, but the highest reduction in the heating demand occurs when the average building's height was two stories in pattern 4. An increase in the height of the surrounding buildings can enhance shading over the target buildings and streets around them. Therefore, it is possible to reduce the solar radiation reaching the target building and thus increase heating demand, and vice versa.

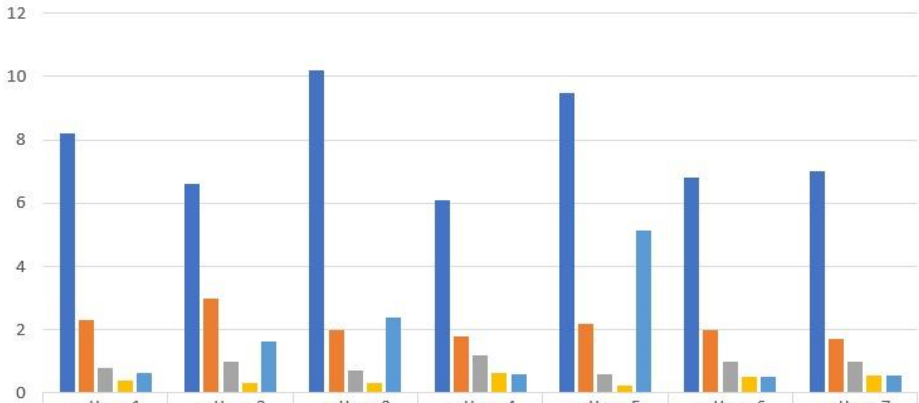


	pattern 1	pattern 2	pattern 3	pattern 4	pattern 5	pattern 6	pattern 7
heating load*10 (kwh/m2)	4	3.96	1.86	4.03	3.68	3.95	3.85
building height(m)	2.3	3	2	1.8	2.2	2	1.7
Built intensity	0.8	1	0.7	1.2	0.6	1	1
Compactness(GsI)	0.4	0.3	0.3	0.62	0.25	0.5	0.55
Open Space Ratio (OSR)	0.65	1.62	2.4	0.6	5.13	0.5	0.55

heating load*10 (kwh/m2) building height(m) Built intensity Compactness(GsI) Open Space Ratio (OSR)

Figure 5.3: The annual average heating load with four urban variables.

To investigate the impacts of urban density on cooling demand, the annual cooling load for the seven introduced urban fabrics is plotted in Figure (5.4) -left for the four warm months(4.4 months). The highest cooling demand (HCD) in all months occurs in pattern 3 with a low built intensity (FSI); a lower surrounding building results in higher cooling demand. The cooling load reduces from max to min (39.7%), where the built intensity is higher in pattern 4 (old town), where "the lowest cooling demand" occurs in patterns (pattern 2: 33.2%, pattern 6: 30%) with high built intensity (FSI). High compactness (GSI) has been found to be a favorable factor to reduce the percentage of energy demand for cooling, where high coverage correlated with low cooling demand as shown in all patterns, except pattern 3. There was no direct correlation between the building height and the cooling demand, which had both lower and higher values, as there were approximately two stories due to the different number of floors across the tissues that were studied. Finally, with regard to the open space Ratio, it can be noted that the higher values had a higher cooling demand value, and the lower values of open space ratio had lower cooling demand, however, pattern No. 3 as shown in Fig (5.4) is an outlier.



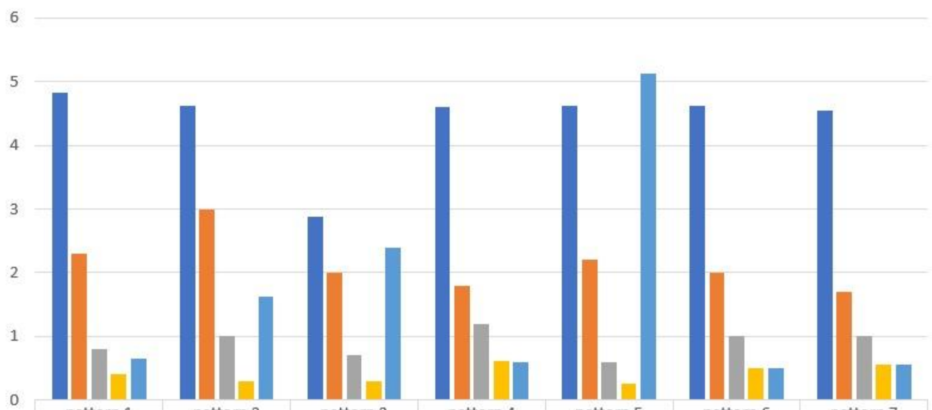
	pattern 1	pattern 2	pattern 3	pattern 4	pattern 5	pattern 6	pattern 7
Cooling load(kwh/m2)	8.2	6.6	10.2	6.1	9.5	6.8	7
building height(m)	2.3	3	2	1.8	2.2	2	1.7
Built intensity	0.8	1	0.7	1.2	0.6	1	1
Compactness(GsI)	0.4	0.3	0.3	0.62	0.25	0.5	0.55
Open Space Ratio (OSR)	0.65	1.62	2.4	0.6	5.13	0.5	0.55

Cooling load(kwh/m2) building height(m) Built intensity Compactness(GsI) Open Space Ratio (OSR)

Figure 5.4: the annual average cooling load with four urban variables

The urban form was the study's most significant influencing factor, resulting in a heating and cooling reduction of up to (53 .7 %-39.7%), respectively, when compared to HCD. It might imply that neighborhoods that are compact and dense with the least amount of open space ratio have the highest chance of lowering cooling demand and increasing heating demand. The opposite is true, where the low compact and dense with a high open space ratio have the highest chance of increasing cooling demand and decreasing heating demand, it can be noted that adjacent buildings around the prototype building have a major impact on heating and cooling load reduction.

Several excellent patterns have been produced by using the introduced framework, where pattern 5 and pattern 3 are considered the best option to reduce the heating and cooling demand of buildings within a neighborhood, as the value of heating and cooling demand is close to the average. as shown in Fig (5.5). For the urban pattern number 3 (al sheikh neighborhood's) is the most efficient pattern with 53% heating load reduction, compared to HHD in pattern 4, and 0.00% reduction in cooling demand, as it is highest heating demand



	pattern 1	pattern 2	pattern 3	pattern 4	pattern 5	pattern 6	pattern 7
annual energy load*10 (kWh/m2)	4.82	4.62	2.88	4.61	4.63	4.63	4.54
building height(m)	2.3	3	2	1.8	2.2	2	1.7
Built intensity	0.8	1	0.7	1.2	0.6	1	1
Compactness(GsI)	0.4	0.3	0.3	0.62	0.25	0.5	0.55
Open Space Ratio (OSR)	0.65	1.62	2.4	0.6	5.13	0.5	0.55

annual energy load*10 (kWh/m2) | building height(m) | Built intensity | Compactness(GsI) | Open Space Ratio (OSR)

Figure 5.5: The annual average load with four urban variables

5.3.3 Validation of simulation result

The simulation results acquired from Design Builder will also be compared with a few benchmarked values taken from previous publications in order to further enhance the level of confidence in the results that are presented. Previous studies used a variety of density indicators, making direct comparison difficult. Furthermore, the impact of urban built form on building energy demand has never been considered in conjunction with urban density. Therefore, studies that examined the energy demand for heating and cooling in the Mediterranean climate, and in a similar urban context of Hebron city were considered, and different values of energy demand for passive homes were considered to be compared with the results obtained to determine how far these values are from sustainability.

In Amman, Jordan, Abu Qadourah et al (2022) discovered that the base area residential building's total annual energy requirements for cooling and heating are 27,545 and 59,247 kWh/y, respectively. Both cooling and heating needs are present, but the heating demand predominates, the simulation results show.(Abu Qadourah et al., 2022) Jaber .S and Ajib.IS calculated heating and cooling demand at different orientations of the facade in the Mediterranean climate, which is 5000 and 9000 kWh, respectively.(Jaber and Ajib, 2011) Also, Manassra (2022) calculated the energy demand for cooling and heating for an apartment in Palestine's urban context scenarios and different orientations. It was found that the energy demand for heating ranges between (7500 to 12500) kWh, while the cooling ranges from (3000 to 8000) kWh in the climate of Jerusalem (Manassra, 2022). Hijab D et al (2017) designed three different residential buildings in the city of Hebron and found that the energy demand for both heating and cooling ranged between (215022 and 15574) kWh and (123499 and 24540) kWh, respectively (Hijab D et al,2017). For two residential buildings types of a five-story, one with four apartments and the other with two apartments on each floor, Monna Sameh et al(2021). computed the energy demand allocated for heating and cooling, which is 61 kWh/m^2 and 38 kWh/m^2, respectively, In Jerusalem's Mediterranean climate.(Monna et al., 2021). Loeffler et al (2021) demonstrate the annual impact on heating and cooling energy demand at new buildings. The simulation result for the HED ranges from 12.3 kWh/m^{2}yr to 42.6 kWh/m^{2}yr, and the amount of energy required for space cooling (CED) ranges from 4.5 kWh/m^{2}a to 10.8 kWh/m^{2}yr (Loeffler et al., 2021).

The maximum space heating and cooling energy demand of a building should be 39 kWh/m^2 /year for apartments and mid-terrace houses and 46 kWh/m^2 /year for end-of-terrace, detached, and semi-detached houses, according to the Zero Carbon Hub report (ZCH, 2010). According to the Passive House Planning Package (PHPP) designer's companion (Feist et al., 2007). The results were compared in Fig (5.4)-(5.5), which shows the heating and cooling loads, as the total heating load is 40 kWh/m^2 /year and the total cooling load range between (10-7) kWh/m^2 /year with the values in Zero Carbon Hub report , as the values for each of the heating and cooling loads are 39 kWh/m^2 /year for apartments and mid-terrace houses. these values are fairly close from the maximum limit for apartments and houses.

5.3.4 The relationship between urban variable and energy demand of several patterns

The results of the simulation patterns showed a correlation with energy demand in terms of building intensity (FSI), coverage (GSI), building height (L), and open space ratio (OSR) .

The comparative process was performed separately for each variable based on the input data obtained from the analysis.

- **Built intensity (FSI):**

The correlation between energy demand and built intensity is shown in Figure (). Although a spread of values is still evident, a clearer relationship is observed between these two variables than in the other urban variable, especially in cooling demand. By looking at the results for heating demand, it can be noticed a slight increase in heat demand with an increasing floor space index (FSI), where the heating demand at 0.6 value was 36.8 kWh/m^2 and at 1.2 was 40.3 kWh/m^2,but there is But at 0.7 value it is noticed that the heating demand decreased to 18.6 kWh/m^2. (with only two exceptions, both al sheikh Neighborhood (p 1, p3)

In the cooling demand, it can be noticed that the distribution is close to being linear, and the relationship is negative, that means, the higher floor space index (FSI), thus the cooling demand is reducing. In Figure (5.6) below, where the cooling demand at 0.6 value was 9.5 kWh/m^2 and at 1.2 value was 6.1 kWh/m^2. The rest of the points follow a linear trend, but here there is a slight change at the value of 0.7, as it is considered the highest value, which is 10.2 kWh/m^2.

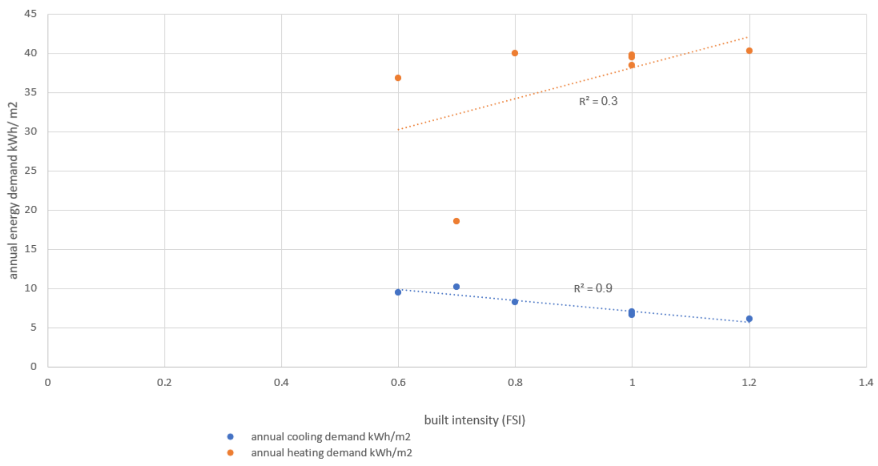


Fig (5.6): The correlation between energy demand and built intensity (FSI)

Coverage (GSI):

By looking at the coverage ratio, the correlation between it and the energy demand is somewhat similar to the correlation between the floor space index (FSI) and the energy demand, but in the floor space index, the relationship is more clearer, especially in the cool demand, as the coverage ratio increases, the heating demand increases, where it is 36.8 kWh/m^2 at 0.25 value of coverage and it is 40.3 kWh/m^2 at 0.62 value , and vice versa for the cooling demand, where it is 9.5 kWh/m^2 at 0.25 value , and it is 6.1 kWh/m^2 at 0.62 value as shown in Figure (5.7) .

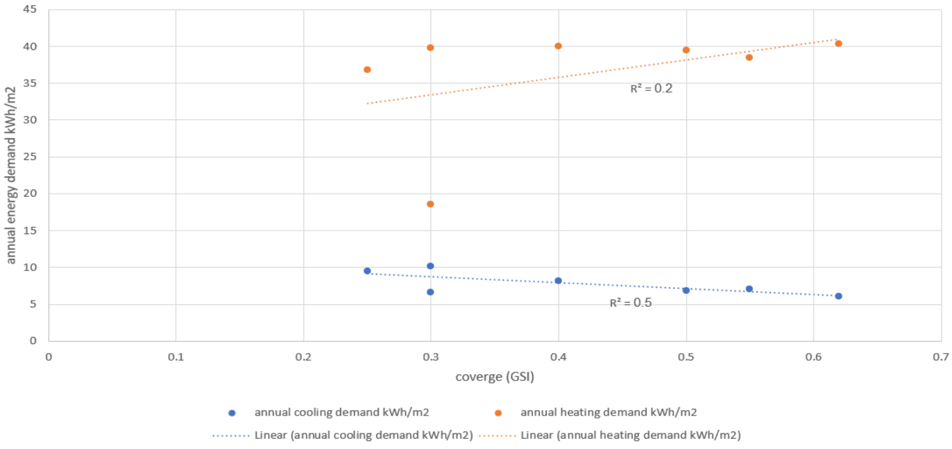


Fig (5.7): The correlation between energy demand and coverage (GSI)

- **Building height (L):**

A comparison between the energy demand and building height is shown in the Figure(5.8) for all patterns. The figure shows no clear relationship is observable, indicating a negligible correlation between the two variables. Consequently,. Further research is needed to investigate if relationships may be distinguished at different scales of analysis. This contradicts some studies that found an important relationship between the average building height and energy demand. This contradicts some studies that found an important relationship between the average building height and energy demand.

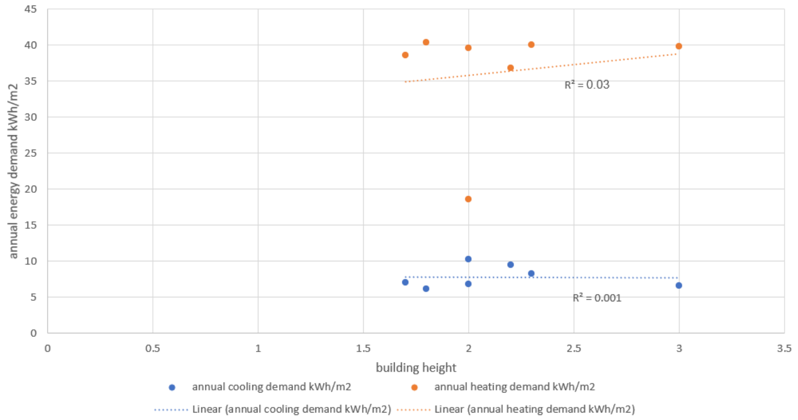


Fig (5.8): The correlation between energy demand and building height

- **Open Space ratio (OSR):**

The Figure (5.9) confirms the significant effect of open space ratio (OSR) on measured seasonal heating demand. A regression line is presented, and it can be observed the very slight negative correlation between heat demand and OSR value, the heat demand reduction is notable with rising OSR then the effect becomes less at a large OSR value. For instance, heat demand varies from 18.5-40.3 kWh/m2 when OSR rises from 0.5 to 5.13. In cooling demand, the correlation between the open space ratio (OSR) variable and the cooling demand is passive, cooling demand increment is notable with rising OSR. For instance, cool demand varies from 6.10-10.2kWh/m2 when OSR rises from 0.5 to 5.13.

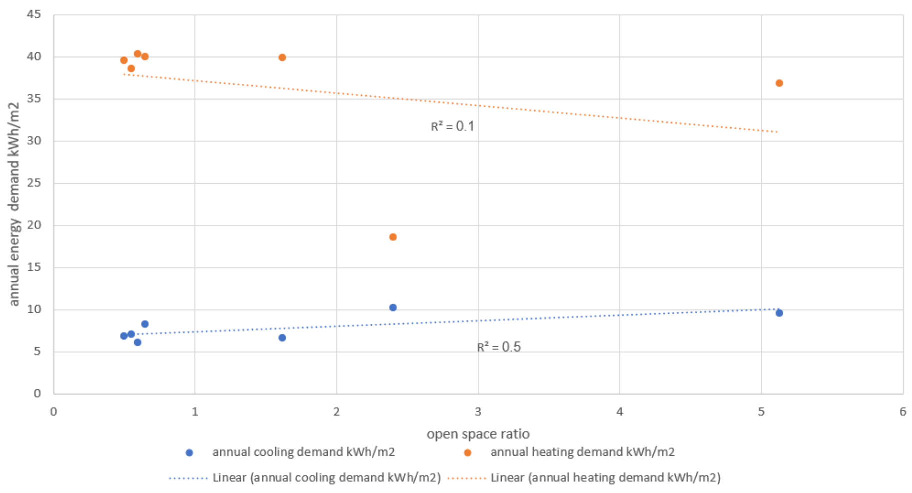


Fig (5.9): The correlation between energy demand and open space ratio

Using actual heating energy consumption values, Uçlar S and Buldurur M investigate the relationship between urban form and heating energy consumption in various Istanbul urban textures. They discovered that while there isn't a single formula that works for all types of settlements, there is a general trend that more compact urban forms result in lower heating energy consumption on a macroscale(Uçlar and Buldurur, 2020). In contrast to what was found in the result that less compact urban morphology will be reducing heating demand, a positive correlation, but not very high, is observed between heating demand and urban variable except for the open space ratio which was negative.

Rode et al (2014) did not find any effects whereby increasing density decreases heat-energy efficiency a finding that is certainly important to verify in future follow-up research ,this was done by studying several cities, including Istanbul(Rode et al., 2014). This is relatively noticeable in the results, as the distribution is not clearly and only a slight increase in energy demand appeared for each of the studied urban variables, as the r^2 values were closer to zero. where the r^2 value for FSI, GSI, L and OSR and heating energy demand is 0.27 -0.18 -0.026-0.10, respectively. This means that the results are far from the correct values to create a relationship, whether positive or negative. Therefore, This led to an ambiguous result, it cannot be adopted to determine whether there is an increase or decrease in energy demand, and therefore it cannot be taken into account in determining guidelines for planners and urban designer ,but it can confirm the hypothesis that different building morphologies feature distinctively different heating demands. This encourages future researchers to study variables at the urban level, but with a different approach that may lead to more accurate results in terms of heating demand where it is the most significant vs cooling demand.

Although the results demonstrate that a reliable trend cannot be found, we can state that a larger floor space index and coverage values lead to an increase in heating demand. This may be because buildings close to each other may hinder the arrival of solar radiation, Mutani et al (2016) confirmed in their study of Turin City in Italy, that there is a linear relationship between energy consumption and the solar factor, S. This is because buildings with good solar exposure get more solar heat gains, which leads to reduced energy consumption for space heating (Mutani et al., 2016). and it may also be due to other factors, such as the orientation and the building shape. In addition to the topography of the site and its exposure to winds , and thus the heat loss increased, as the city of Hebron is considered a mountainous city.

Javanroodi et al(2018), found that the highest value of cooling demand was in configuration with low density(Javanroodi et al., 2018). This is consistent with what was found in this thesis, as the building intensity and coverage increase, the demand for cooling in the building decreases, and vice versa for open space ratio. The floor space index (FSI) variable is considered a significant factor in determining cooling demand , as the r^2 values were close to one, which is 0.88 .As for the coverage (GSI) and the open area ratio (OSR) , the relationship was less clear than in the floor space index, as the values of R2 are close to half, where its value is for each of GSI and OSR is 0.50 - 0.48, respectively, but in average building height r^2 value is 0.001 which is negligible.

The reduction in cooling demand with the increase in building intensity and coverage may be due to surrounding buildings working as shading at the prototype building, thus reducing solar radiation in the summer to the inner. However, the amount of energy required for cool space is not the amount of energy required for heat space, since in heating demand amount is greater.

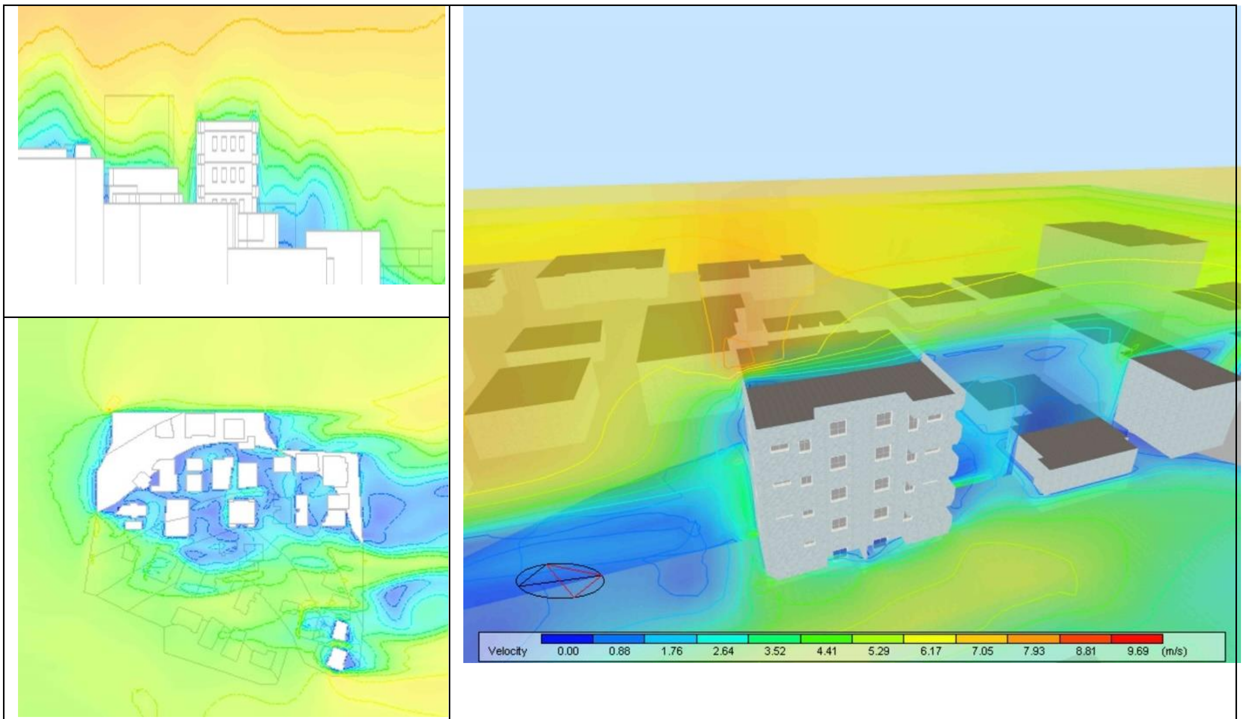
Future energy requirements for cooling are predicted to rise significantly, which would result in a significant rise in the amount of power used in urban regions of cities with relatively warm climates like Hebron City. The high urban air temperatures brought on by climate change and urban heat islands are predicted to exacerbate the peak cooling energy loads, shifting the peak electricity demand upward. This is because, in residential buildings, the cooling demand accounts for the largest portion of the total electricity consumption when compared to lighting and equipment.

As described in previous analysis, for identifying the relationship between energy and urban form, the main parameter analyzed by researchers is density (Bhiwapurkar, 2014, Resch et al., 2016, Steemers, 2003). Comparing results of different case studies using such a diversity of indicators can be challenging (Resch et al., 2016) and indicates the high complexity of cities. The findings of this study demonstrate that urban form has an important role in energy efficiency and sustainability. However, the optimal residential design remains a mystery to academics and researchers since the city is a dynamic and living organism with many major and small aspects that make estimating the heating and energy consumption of various urban forms difficult.

5.3.3 CFD analysis of building patterns

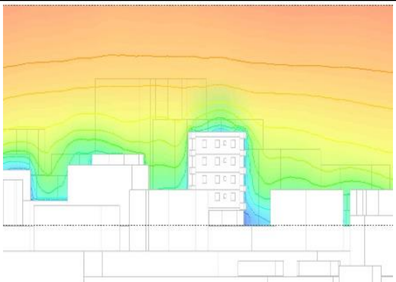
Urban configuration was assessed to check its effect on building's prototype by external CFD analysis to determine the effects of urban morphologies on the wind flow around the prototype building. The wind flow on the prototype building is divided into two types: an upward flow with a significant amount of turbulence that blows toward the building's rooftop and a downward flow toward the building's front. The upstream flow at the prototype building's rooftop creates the highest feasible wind speed in all seven patterns. As a result, a lot of air is carried up to the roof level. The highest wind velocity magnitudes in the pattern vary from 0 to 6m/s for each model. For the values of the velocity magnitudes, these changes are represented by a color scale ranging from blue to red.

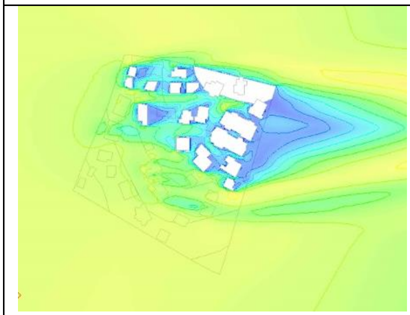
Table (5.9): External and internal CFD analysis of pattern (1) and prototype building.

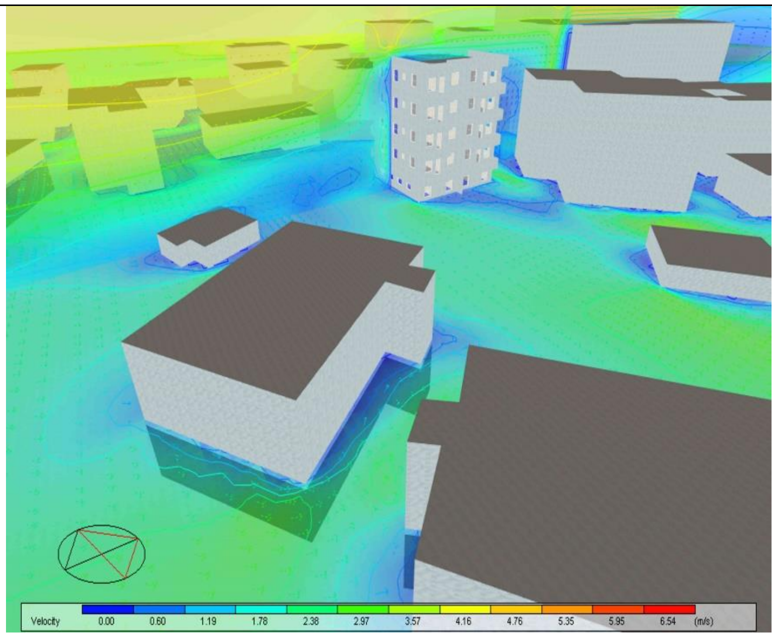


	FSI	GSI	L	OSR
Velocity around the prototype building ranges between (0.88-4.41) (m/s), and it calculated at a height of 10 m for prototype building.	0.80	0.40	2.3	0.65

Table (5.10): External and internal CFD analysis of pattern (2) and prototype building.

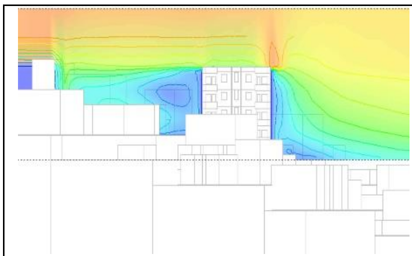


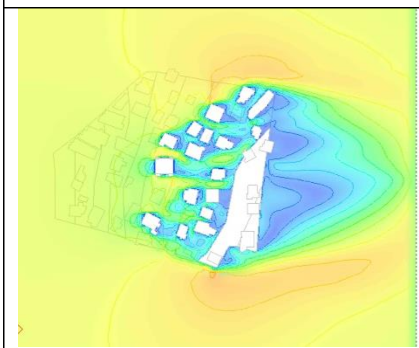


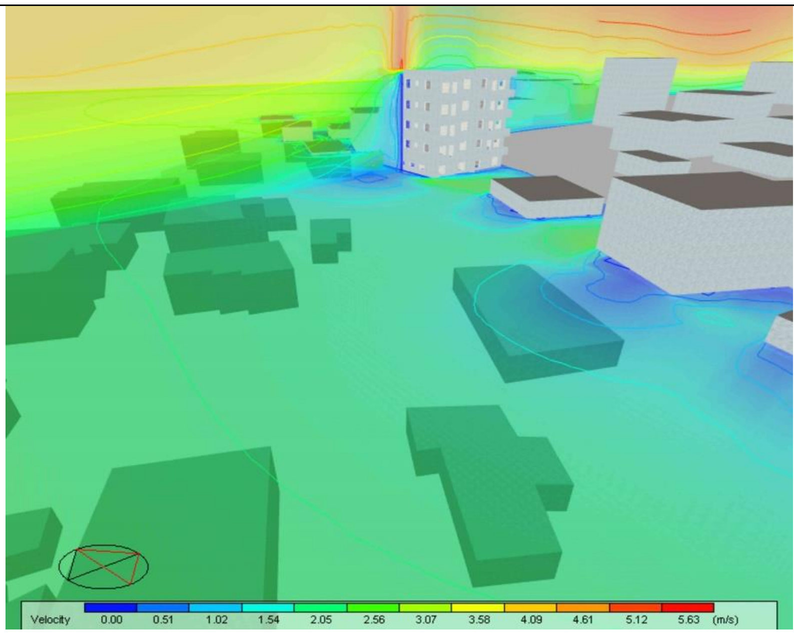


	FSI	GSI	L	OSR
Velocity around the prototype building ranges between (0.60-2.97) (m/s), and it calculated at a height of 10 m for prototype building.	1	0.30	3	1.62

Table (5.11): External and internal CFD analysis of pattern (3) and prototype building.

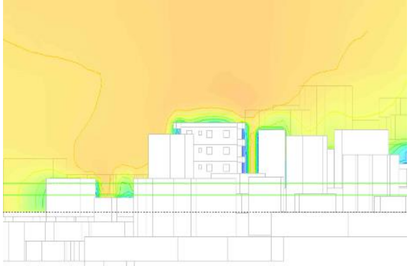


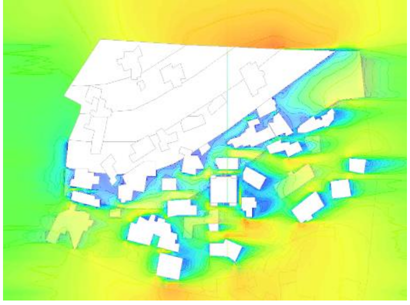


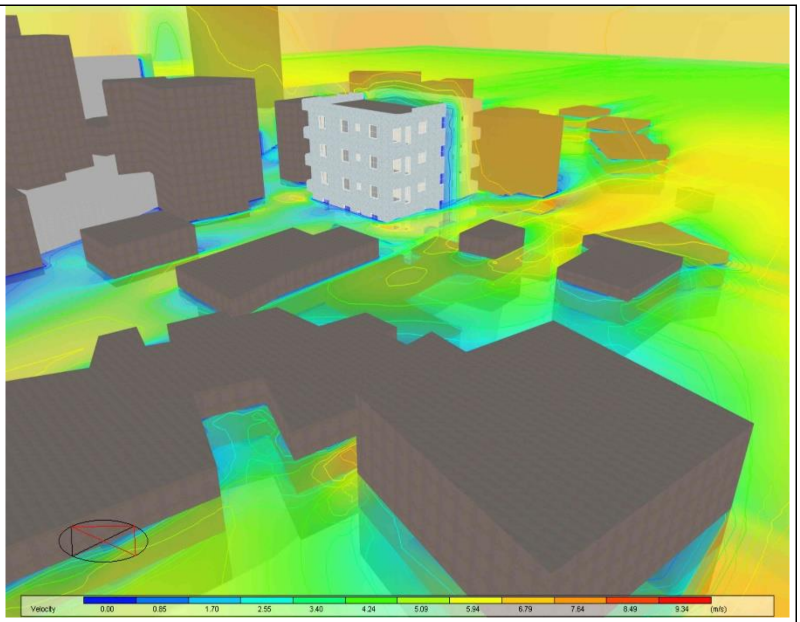


	FSI	GSI	L	OSR
Velocity around the prototype building ranges between (0.00-3.58) (m/s), and it calculated at a height of 10 m for prototype building.	0.70	0.30	2	2.4

Table (5.12): External and internal CFD analysis of pattern (4) and prototype building.

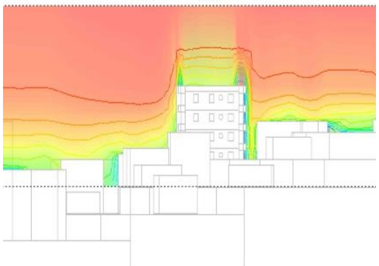


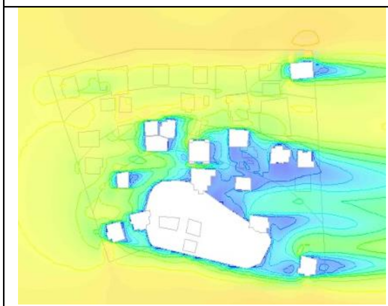


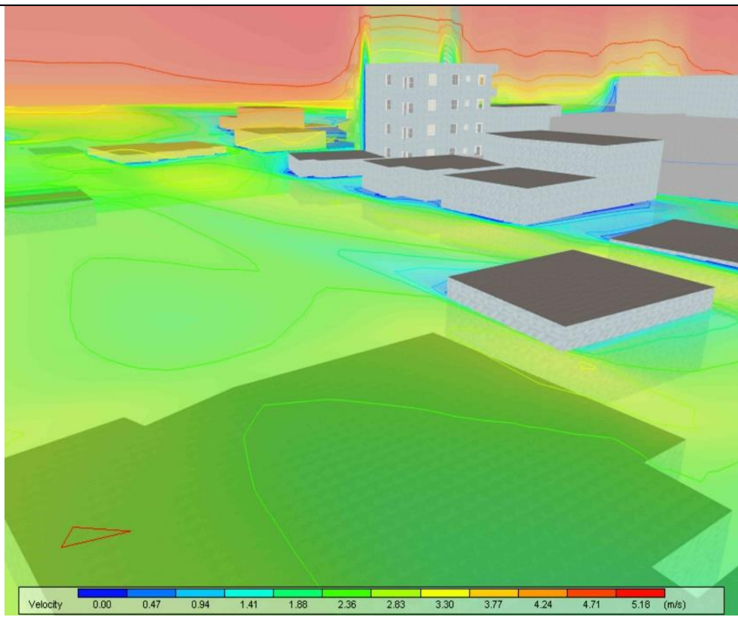


	FSI	GSI	L	OSR
Velocity around the prototype building ranges between (0.00-6) (m/s). and it calculated at a height of 10 m for prototype building.	1.20	0.62	1.7	0.60

Table (5.13): External and internal CFD analysis of pattern (5) and prototype building.

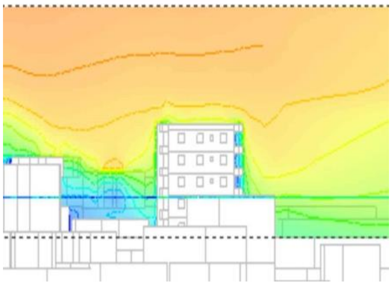


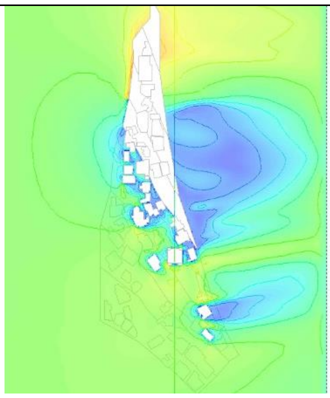


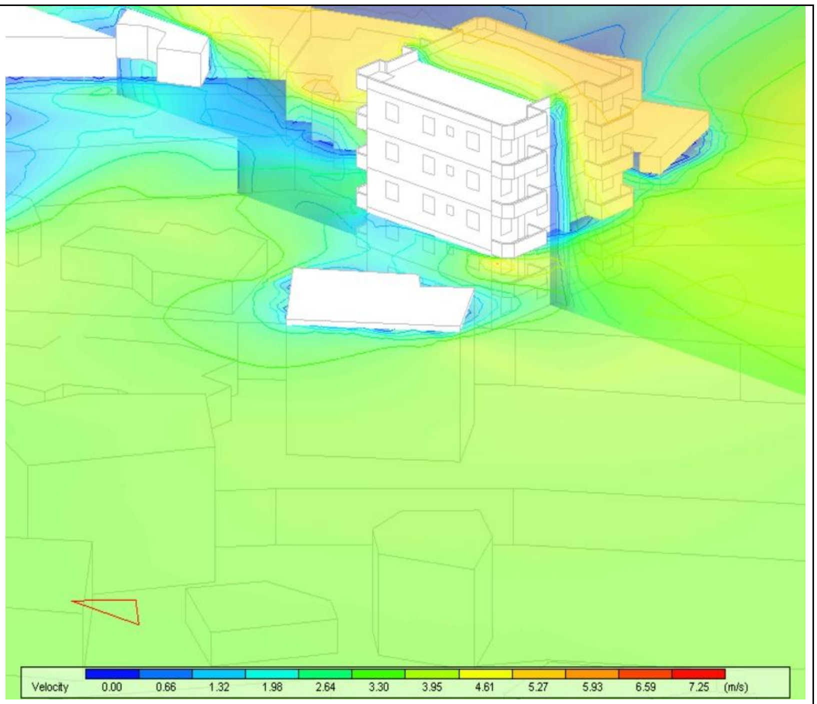


	FSI	GSI	L	OSR
Velocity around the prototype building ranges between (0.00-3.30) (m/s).and it calculated at a height of 10 m for prototype building.	0.60	0.25	2	5.131

Table (5.14): External and internal CFD analysis of pattern (6) and prototype building.

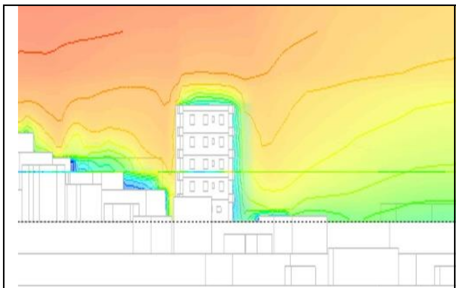


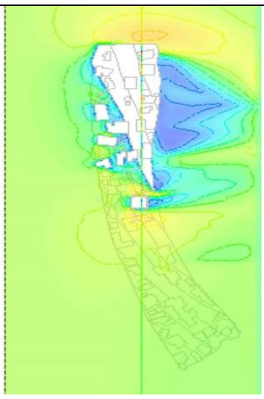


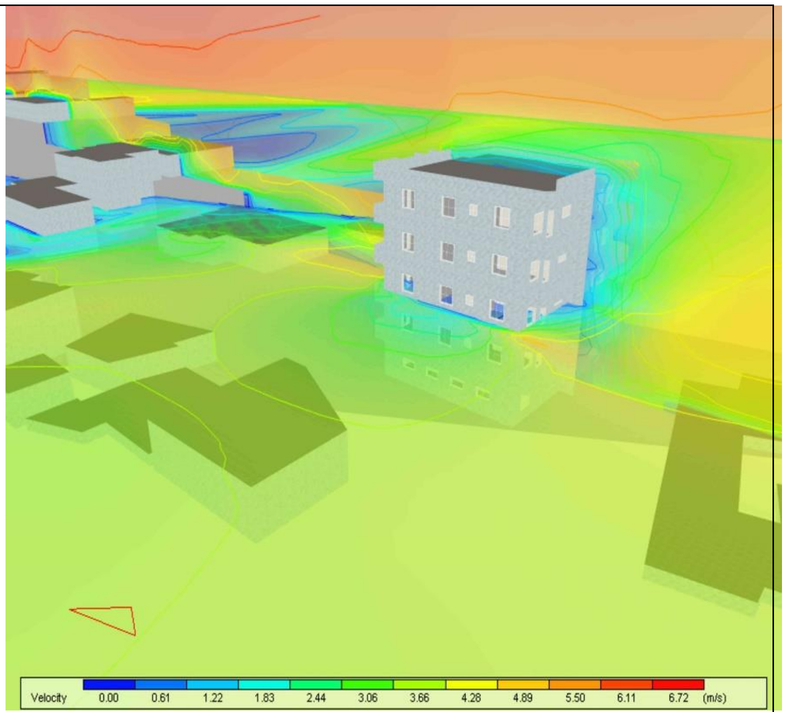


	FSI	GSI	L	OSR
Velocity around the prototype building ranges between (0.00-4.61) (m/s), and it calculated at a height of 10 m for prototype building.	1	0.5	2	0.50

Table (5.15): External and internal CFD analysis of pattern (7) and prototype building.







Velocity around the prototype building ranges between (0.00-4.28) (m/s).and it calculated at a height of 10 m for prototype building.	FSI	GSI	L	OSR
	1	0.55	1.80	0.55

It is clear from table(5.9), that the wind flow of pattern (1) is relatively fast on the western-north side of the building, where it is about 2.6 m/s, while on the opposite side, it decreases to zero, but on the rooftop of the building, the wind speed reaches 4.41m/s . The wind flow velocity for other pattern (P2,P3,P4,P5,P6 and P7) on the western -north side ,eastern-south side and the rooftop , it was as follow P2 (WN:2.38 ,ES:1.19 , RT :3), P3(WN:3 ,ES:1 , RT :3.58) , P4 (WN:4.24 ,ES:4.24 , RT :6) P5 (WN:2.83 ,ES:0.47 , RT :3.30), P6 (WN:3.30 ,ES:1.98 , RT :4.61), P7 (WN:3 ,ES:1.22 , RT :4.28) m/s.

The surrounding buildings in pattern (1) obstructed the wind flow slightly around the prototype building. This is due to the surrounding buildings being located from the northwestern side, in addition to the topography level being consistent with the wind direction, which may reduce wind velocity, as it graduates from northwest to south, and it is also noticeable in the pattern (4). In pattern (2), there are surrounding buildings that obstruct the flow of wind on the northern side of the master plan, and the topography level does not constitute an obstacle to wind flow. It can state pattern (3)(6)and (7) has the same wind flow. In pattern (5), it can be noticed that the highest level is in the south and the lowest is in the north, where it does not constitute an obstacle to wind flow, but there is a group of buildings in the northwestern part that constitute an obstacle.

These assessments highlight the significance of the interactions between the various morphological features as described in the literature by demonstrating that any one of them can have an impact on wind flow. Furthermore, this study demonstrates that varying combinations of these characteristics can yield varied outcomes and that a city's morphology should take into account the direction of the predominant wind as an external factor.

Although the scale of future urbanization is generally established, our knowledge of how urban shapes will change and how this will impact building energy use is still restricted. It was looked into how much energy was utilized to heat and cool residential buildings. Global energy demand for heating and cooling will range between 45 and 59 exajoules annually by the middle of the century (an increase of 7 to 40% since 2010) (Berghauser Pont and Haupt, 2009). This is especially noticeable in the city of Hebron, there are some correlations with the urban variable, but at the same time, there is a variable that did not show any relatively unclear correlation. This is because the number of samples studied is just seven, but more samples in future research may be good for completing the final stage.

5.6 Conclusion

The findings of this chapter demonstrate the simultaneous correlation between the four most used density indicators and urban geometrical qualities. The opportunity to choose the most energy-efficient urban form and density in accordance with planning principles is provided to urban planners. it is possible to select the site layout that uses the least amount of energy for a specific density. The best-built shape (prototype building) can be chosen by altering urban variables in the analyzed configurations, whilst the site plan's density can be controlled by policy.

In general, the findings revealed a strong correlation (relationship) between building morphology (urban variable (density factor) and energy demand. These results concur with some recent studies(Osorio et al., 2017) (Næss, 2012) (Boarnet and Crane, 2001) .By identifying these urban forms, policymakers can target less energy-efficient patterns for actions to reduce energy demand, with a focus on the physical-spatial properties of the built environment. Physical aspects that contribute to the description and comprehension of the urban form include constructed built intensity, coverage, building height, and open space ratio. As density rises, heat-energy efficiency declines and cooling energy efficiency rises. these findings will undoubtedly need to be confirmed in follow-up examinations.

Measuring urban form can be quite useful in supporting design choices. The intricacy of city planning prevents us from ever discovering the secret to creating the ideal city, but quantitative analysis can help us better comprehend its functioning. The necessity for precision and accuracy in dimensioning the physical neighborhoods is the main finding. Additionally, understand how local changes in urban form impact the entire city and vice versa. It can be directed the future city using smart urban rules that specify performances rather than form based on this knowledge.

In addition to the factors that were studied, there are other factors such as topography and greenery, which are considered natural factors, and they are included in this thesis. Nevertheless, there are additional elements that can be applied to the best model in conclusion or other study areas, such as the local weather, soil type, population type in the site study, solar orientation, and plant types (landscape). Furthermore, it is frequently impacted by a number of variables, including an abundance of resources, the growth of infrastructure, commercialization, mining, and education, among others.

Chapter 6
Conclusion and recommendations

6.1 preface.

The main findings of this thesis are now summarized, along with recommendations and suggested future work. Through an analysis of relative building energy demand, this study established the relationships between urban built form and density and energy demand in Hebron. A combination of empirical and quantitative research methods was used to classify the various patterns in the city based on density variables, as well as energy simulation trials. This chapter, as the final chapter, summarizes the overall thesis findings obtained in the preceding chapters. As a result, the first step was to identify the impact of urban density at energy demand, where each factor was analyzed separately to determine its effect on heating and cooling demand. Second, general guidelines and recommendations for urban planners, decision-makers, and local governments were presented.

6.2 Conclusion.

Energy efficiency is one of the most pressing issues confronting building designers in the twenty-first century.(Y. Jabareen, 2006) Buildings in general, and households in particular, consume a significant amount of energy in Hebron (UNESCO, 1972). Some of the most important factors influencing energy demand in buildings are urban form proprieties. An energy demand simulation for 7 patterns in Hebron was performed to determine the relationship between building morphology (built intensity, coverage, building height, open space ratio) and energy demand. The built intensity, coverage, average building height and open space ratio were found to be good indicators for heating and cooling energy efficiency. The following conclusions can be drawn from the results of the experiments and analysis:

- **The Relationship of built intensity (FSI) on energy demand:**

The built intensity (FSI) has a significant effect on building energy demand. Cooling demand is reduced while increasing built intensity, but heating demand has increased. By balancing the values of heating and cooling demand, it is possible to reach energy efficiency at the average values for the built intensity (FSI) which can be notable in patterns (3-5), where the value of FSI is low, when comparing the built forms. This emphasizes the significance of urban policies in recognizing the best built form and density in urban patterns, see Figures (6.1) in appendix.

- **The Relationship of coverage (GSI) on energy demand.**

The findings also revealed a strong positive relationship between coverage (GSI) and energy demand, implying that increasing the coverage of the building (within the same area) can have a significant impact on cooling demand reduction, while heating demand increases, and vice versa. However, in view of the annual energy demand values, the lower coverage also was better than the higher value, especially in areas 5-3.

- **The Relationship of building height (L) on energy demand.**

Since the majority of the patterns had an average height of 1-3 stories and the results of energy demand, it is challenging to compare the results with each other because the urban fabric of Hebron is characterized by the variation in building heights. where the prototype in Fig (6) shows the average building height is (1.9) m, as the maximum value is 3 m and the low value is 1 m, so studying more sample in future may show clearer results.

- **The Relationship of Open Space Ratio (OSR) on energy demand.**

The results revealed a strong positive relationship between the open space ratio (OSR) and energy demand for residential buildings that will be designed in the future. According to this finding, increasing the open space ratio of buildings can have a significant direct positive effect on their energy demand This appears clearly in patterns (3) where it is value is (0.65), because it takes into account three important factors: the floor space index and the building's coverage ratio of the plot in addition to plot land for each person in the prototype.

- **The Relationship of topography (LT) on energy demand.**

The results of the simulation revealed that the topography of the site has a significant role in energy demand reduction (Manassra, 2022). cooling demand decreases by about 0.25% to 17% annually, while heating demand by about 0.7%- 4.7 % annually see tables (5.4.7) to (5.4.9).

- **The Relationship of CFD on energy demand.**

With the use of Computational Fluid Dynamics (CFD), we can greatly improve our comprehension of urban morphology and how it affects human and environmental elements in cities. Urban planners and architects may make better judgments regarding the layout and operation of urban areas by using computational fluid dynamics (CFD) to simulate the movement of air, heat, pollutants, and other factors through urban settings. and it can aid in improving their ventilation, heating, and cooling design, resulting in more energy-efficient and sustainable buildings. Using CFD to analyze and design urban morphology offers a complete method for building safe, pleasant, efficient, and sustainable cities.

This thesis used energy demand data of individual buildings with details on the physical conditions of the buildings to investigate the effects of urban form, in particular the spatial layout of neighborhood-level development on overall building energy demand. A major motivation of this study was to implement a statistical method that integrates available data, which provides detailed information on energy usage and the physical characteristics of a building. The GIS data from the Hebron municipality made it possible to develop variables representing the urban form variable related to density, as well as its neighborhood's urban density pattern.

Given the complexity of the overall effects of diverse urban form components on a building's energy use and the potential for distinct patterns, additional empirical research is necessary to determine which and how much the urban environmental factors influence a building's energy use. To find new ways to lower the energy demand of buildings, further research into the urban form in diverse cities and patterns with various climatic features is needed.

This study adopted a holistic strategy to recognize and measure the influence of urban design on the energy efficiency of buildings as a result of the research gap. In order to compare various aspects of energy usage, the analysis was based on a study pattern in an urban development region of Hebron city. Beyond the significance and scope of the evaluated factors, which are summarized in table (6.1), the issue of how those factors interact is particularly significant. Knowing how density characteristics and energy use relate to one another might aid in identifying strategic choices during the initial planning stages.

6.3 Recommendations:

According to the examination of the propose (prototype building) included in this study, residential buildings in the city of Hebron feature a variety of distinct yet related design patterns. One of the objectives of this study is to make some recommendations for future residential buildings that will be built in light of the findings. The population growth, combined with the lack of building regulations and the difficulties in controlling (illegal) constructions, resulted in the expansion of residential buildings in all uses of the building. This is particularly evident in Hebron.

Here are some tips for developing residential building in the city of Hebron that could save energy use:

6.3.1 Recommendations for Hebron municipality and decision-makers

- The findings of the current work confirm the need to create spatial planning frameworks that are acknowledged by the municipality and decision-makers.
- It is recommended to increase in the built intensity (FSI) value to reduce the cooling demand, as the results showed.
- It is also recommended to increase in the coverage (GSI) value to reduce cooling demand.
- It is recommended to decrease open space ratio (OSR) value to reduce cooling demand.
- the lack of correlation suggests that building height should not be used as an indicator to define urban form when studying relationships between urban form and energy demand in Hebron city. It is recommended to consider the variation in building heights instead of studying the average height.
- • Utilizing topographic lands for residential buildings because the results indicate that impact on energy demand Integrating considerations of topography into urban planning and energy management strategies can contribute to more sustainable and resilient communities.
- Investigating the accessibility to utility data for the residential stock in Hebron city. Perhaps from the Hebron distribution company HEPCo.

6.3.2 Recommendation for future work

In terms of the thesis's theoretical contributions, it advances knowledge of how urban form affects a building's ability to use energy, a topic not previously well explored in the literature in terms of the combined effects of the significant determining factors. As a result, this study's primary theoretical contribution is to encourage the growth of a deeper comprehension of the consequences of urban form. It is critical that future buildings have a low environmental impact. At the urban planning level, there is still a lack of clarity on how to design specific urban morphologies during the early planning stages to keep energy demand low while maximizing its potential for energy production.

- The dissertation’s findings suggest that there is a need for a paradigm shift in how urban forms are planned for future neighborhoods.
- More work can be done to improve the underlying modelling patterns. Consideration of more zones analysis, for example, will result in more precise results.
- The proposal of an urban energy planning tool to assist urban planners and policymakers in determining the most appropriate energy-efficient built form and density is a primary contribution.
- It is especially important to investigate potential trade-offs with other building energy demands, such as lighting, which may have negative density associations.
- The significance of creating a local temperature profile, especially before running a building energy simulation.
- It should set up a platform that planners and researchers may both use. An effective solution is a geographic information system (GIS). Particularly in terms of the 3D modeling input of an urban pattern, some apps that offer alternatives to the parametric method (Rhino and Houdini) also show potential alternatives.
- Currently, the model only considers the physical aspects of cities to determine energy loads. Building materials, dynamic reference weather data, greenery, and anthropogenic heat sources should be the focus of future research.
- Finally, while this study focused on the operational energy of buildings, the effect of embodied energy of buildings must also be considered (using a life cycle assessment) when determining building sustainability, and focus at the greenery in the site.

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