Spatial Evaluation of Energy Performance at Neighborhood Scale Case Study: Sanandaj City

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Abstract

Climate change has become a challenge with adverse impacts on Earth. Reducing the use of fossil fuel is a primary step to solve environmental problems. As the population continues to rise, to meet the growing demand for construction with a large share in energy Consumption, Efforts to make the built environment more energy efficient is crucial. The main objective of this research is to evaluate the relationship between urban form and the energy performance of neighborhoods, focusing on their energy demand, through case studies of Ghatarchyan and Mobarakabad neighborhoods in Sanandaj city. The forms of these neighborhoods were measured using spatial metrics (physical and climatic criteria). For analysis and evaluation, ECOTECT, GIS software, and ANP method have been used. The results of the research indicate a negative correlation between spatial metrics and building energy performance. Therefore, if the spatial metrics amount of each neighborhood increases, neighborhood energy demand will decrease. Moreover, the result can form a basis for urban design recommendations to achieve energy-efficient urban development through spatial design.

Keywords: Energy performance, Energy Efficiency, Urban form, Neighborhood, Sanandaj

1. Introduction

Global warming is attributed to being the main cause of climate change. The agglomeration of greenhouse gases at an excessive rate in the atmosphere is the main cause of the current rapid increase in global warming (IPCC, 2007; NASA, 2016). As the population of cities continues to rise, the impact of cities on climate change also rises (UN, 2015). Changes in urbanization can affect economic growth, energy use, and co_2 emissions (Sadorsky, 2014). Currently, buildings are estimated to be responsible for over 40% of the overall energy use globally, counting for an aggregated of 30% of global greenhouse gas emissions. These figures have grown over the past decades and are expected to continue rising in the future (UN Habitat, 2016). By 2040, three-quarters of the world population will be living in cities, compared to one-half today and billions of people will require new homes (UN Habitat, 2016). The challenge for Civil engineers, architects, and urban planners is to design buildings that can respond to these global housing needs while reducing greenhouse gas (GHG) emissions (Mohammadi et al., 2017). Yet this is no easy task (jones, 2015). The world's energy intensity index in 2015 is 0.149 (Koe / \$ 2005p[i]), down from 2.61% in 2014. Iran's energy intensity index in 2015 was 1.5 times the world's average energy intensity. The energy intensity index is declining in different parts of the world, but the Middle East is rising (NIPO[ii], 2016). It increased from 0.157 (Koe / \$ 2005p) in 2001 to 0.162 (Koe / \$ 2005p) in 2015 (NIPO, 2016).Therefore, integration of energy efficiency considerations into all planning aspects including urban planning and design is essential. Urban design can provide strategies through the creation of efficient urban forms (Mirmoghtadaee and Seelig, 2015). This urban form affects transport, land use and buildings and offers opportunities to reduce energy consumption. However, there are many challenges like lack of knowledge about the relationship between urban form and energy consumption, lack of interest from investors and poor implementation of urban design regulations, for the ability to create such a city. This paper studies urban form in the Iranian urban context. Sanandaj has been chosen as a case study. Sanandaj is the capital of Kurdistan province and is located in western Iran .According to Kurdistan's electrical power distribution data, the maximum energy consumption in this city is close to 500 MW per year (Kurdistan electrical power distribution, 2017). The main reason for this increase is a significant number of non-native residents. Therefore, with increasing population growth and the need for people for housing, construction is rising and the city spatially expands. The purpose of this research is to investigate the relationship between urban form and energy performance in the context of two different neighborhoods. So first, the key factors of the urban form will be identified and then the selected criteria in the research case study are examined. After analyzing and evaluating, urban design recommendations with an energy-efficient approach base on results.

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2. The Theoretical Background of the Research

As the focus of this study is energy performance and urban form relation, in this section, a brief outline of the theoretical background will be presented.

2.1. Energy Efficiency

Energy efficiency is the convert of each unit of energy consumed to more service and product without any compromise on quality and comfort requirements. The most important element in energy efficiency is energy-saving, and one of the most significant indicators is energy Intensity (Bayraç, 2010). The most important factor triggering energy efficiency policies in the world was the energy and petroleum crisis encountered in the 1970s. Also, environmental protection coming into prominence in the 1980s, the concept of energy efficiency became an extremely important part of energy and development policies. Energy efficiency is one of the parameters affecting sustainable growth, which allows relaying present-day necessities to future generations without eliminating natural resources. Pursuant to Brundtland report in 1987, that defined sustainable development as that: "… which meets the needs of the present without compromising the ability of future generations to meet their own needs…" (WCED 1987: 3) and it has become necessary to take urgent, unyielding and on time actions for more efficient energy utilization (Aksoy,2013). As the Pioneer country recognizing the importance of energy efficiency, the United States of America (USA) has conducted studies on this issue since the 1970s. Finding the gains of such studies is not enough, the USA prepared a national action plan on energy efficiency in 2008, named vision 2025, for reasons such as increasing security of energy supply and mitigating potential risks in carbon policies. Likewise, since the early 1970s when the petroleum crisis was faced, EU countries started studies and set certain targets in order to minimize dependency on petroleum to, Increasing supply security, reducing energy costs, encouraging competition, reducing unemployment, protecting the environment and reducing greenhouse gases (EMO Publications,2012). Having experienced adverse impacts from the 1970s petroleum crisis, japan renewed the law on energy saving in 1999. In Japan, the studies on energy efficiency are supported by the state by various financial models, such as tax incentives, long-term loans, and industrial organizations. Besides, people support such studies voluntarily, and urban managements apply for various efficiency programs occasionally within their boundaries (Kavak, 2005).

2.2. Urban form

Urban form can be defined as the spatial configuration of human activities, which reflects economic, environmental, technological and social processes at a certain time (Tsai, 2005). This consists of the spatial pattern and density of land uses as well as the spatial design of transport and communication infrastructure (Anderson, 1996). The urban form has a direct impact on habitat, ecosystems, water quality through land consumption, urban fragmentation, and the conversion from natural cover to urban land use (Camagni, 2002), moreover, a growing body of literature supports the notion that urban form strongly influence the energy consumption and the related co_2 emission. It can be explained by a variety of factors, such as topography, planning efforts, and environmental development. The analysis of urban form can reveal the problems and challenges during urban development (Conzen, 2001). The current rapid urban growth brought about a series of environmental as well as socioeconomic problems which form a great challenge for sustainable development. The relationship between urban form and building energy performance draws more and more attention nowadays as building energy use has a considerable share in the total energy use (Perez, 2008). Many scholars have tried to identify this relationship using different definitions of urban form. Some scholars have focused on the spatial metrics of urban form. for example, Pisello, Wong, Giridharan, Ratti and rode examined how different geometries of urban form influence building energy performance through the building typology, urban heat island effect, daylight and mutual shading (Pisello,2012, Wong, 2011, Giridharan, 2007, Ratti, 2004, Rode,2013). Ko, assessing the sustainability of urban forms using energy as an indicator. Urban form, the spatial pattern and density of urban physical objects, such as: buildings, streets, vegetation and open space, has a significant impact due to its long-term influence on macro-scale environments (Ko ,2012) Pan, evaluating the effects of residential morphology (e.g. building distance, density, etc.) and microclimate (e.g. wind speed, temperature, etc.) on building energy use are quantitatively assessed using EnergyPlus. Analyze the effects of different morphology indexes on the energy balance in the same floor-area ratio (Pan.2015). Mirmoghtadaee related the urban form with the optimal use of resources and adaptation to climate conditions to four factors: movement, density and orientation, energy supply, green and open spaces (Mirmoghtadaee,2018). Mahdy Youssef draws out twelve main design principles that outline energy-efficient urban configurations in residential projects such as: compactness and density, transportation and circulation network, streets orientation, greening and urban trees, cool surfaces and albedo, district central cooling and heating, buildings heights and s/v ratio, site selection, external shading, building forms, housing types (Mahdy Youssef,2013).

Another group, including Wang and ye, and Salat (Wang, 2012, Ye,2011, Salat,2013), began to test the idea of urban form as a complex system including spatial metrics and non-spatial metrics such as material types, characteristics of residents, housing units and neighborhoods, and construction years(Ratti,2005). Yang, see urban form as much more than simply geometry since it develops with many engineering constraints such as structure, HVAC system, material, users' behavior, etc.

(Yang,2016) and in different historical and cultural contexts (Berghauser,2010). The factors that determine urban energy use can be classified into a few major groups: natural environment (geographic location, climate, and resource endowments), socioeconomic characteristics of a city (household characteristics, economic structure and dynamics, demography), national/international urban function and integration (i.e., the specific roles different cities play in the national and global division of labor, from production and a consumption perspectives), urban energy systems characteristics including governance and access (i.e., the structure and governance of the urban energy supply system and its characteristics) (KhodaBakhsh,2015). It does not adequately investigate the spatial metrics, but also requires an examination of energy and technological systems (Siong, 2017). Since in this research, the focus is mainly on some of the most important spatial key drivers in neighborhood-scale which influence the energy consumption most. Therefore, the following criterions are surveyed to be analyzed within the paper and case studies. The process of the research concludes with two main parts. The first part mainly focuses on a concise literature review aiming to achieve a clear analytical scientific basis, which will be implemented in the case study in the second step. Based on these two steps, a conclusion focusing energy-efficient neighborhood form, for the main key drivers of urban energy within the case studies, will be drawn. Therefore, a wide literature review and subsequent analysis of the key criterions of energy efficiency in urban areas are done. This provides a range of criteria to be analyzed and implemented in the case study (Table.1).

2.3. Urban form components

2.3.1. Spatial metrics

Luck and Wu (2002) proposed that spatial patterns of urban areas can provide a better understanding of the urban form and its effect on the environment. Spatial metrics are already commonly used to quantify the shape and pattern of vegetation in landscape ecology (Gustafson, 1998). They were expanded in the 1980s and incorporated measures from both information theory and fractal geometry based on a categorical, patch-based representation of a landscape (Herold, 2003). Spatial metrics are effective tools for quantifying spatial heterogeneity and providing a better insight on how spatial structures affect the system interaction in a heterogeneous landscape. Planners and policy makers use the spatial metrics to assess and promote policies concerning land use and urban development. Spatial metrics can be grouped into three classes: patch, class, and landscape metrics. Patches are defined as homogenous regions comprising a specific landscape property of interest such as “urban” or “rural” (Dietzel, 2005). Patch metrics are computed for each patch in the landscape. Class metrics are calculated for each class, and landscape metrics are applied for the entire landscape. Variation of spatial patterns can be captured and described by the spatial metrics, which categorize complex landscape into identifiable patterns and reveal some ecosystem properties that are not directly observable (Antrop & Van eetvelde, 2000; Mcgarigal, 2012). Most spatial metrics are scale-dependent and they are determined by the spatial resolution, the extent of spatial domain, and the thematic definition of the map categories (Símová & Gdulová, 2012). Spatial metrics can be used to describe and analyze the change in the degree of spatial heterogeneity when applying to multi-temporal data. With consideration of study objective, the spatial metrics are selected to quantify the urban form because they can (1) bridge the gap between urban land use patterns and urban planning, (2) improve the reflection of heterogeneous urban spatial patterns (Herold, 2005), and (3) promote the analysis of impacts of urban forms on energy consumptions. Fragstats reports over 100 different metrics (MCgarigal, 2012). Many studies used and compared a wide variety of different metrics. Their results showed the role of them in representing spatial patterns. However, there are not the best suitable metrics as the significance of specific metrics varies with the objective of the study and the characteristics of spatial patterns under investigation (Parker & Meretsky, 2004). Furthermore, some studies indicated that only a few of these metrics contain unique information, and thus the use of all spatial metrics is unneeded (Gustafson, 1998), Table 2 shows the research criteria.

2.3.2. Non-Spatial metrics

Non-spatial options for reducing building energy use such as: improving HVAC (heating, ventilation, and air-conditioning) systems, changing people’s behavior and pricing fuels, all undoubtedly have a significant impact. However, even if the impact of urban form on building energy use is smaller than those of other contributors, it can still be considerable due to its long-term impact on numerous buildings in a macro-scale environment (Ko, 2012)

2.3.1 .1. Physical Criteria

The task of urban design is to improve the physical form of the urban area, city and urban neighborhoods. Many parts of the city's physical structure on different scales cause different climatic variations on that scale, while each of these components can have a significant impact on the urban climate as a whole. Since urban structure can be controlled by planners and urban designers, the possibility of changing the urban climate through urban policies and the design of neighboring neighborhoods and new healthy cities It is possible with some changes to increase the comfort of residents in the outer and inner spaces and reduce building energy demand for heating in winter and cooling in summer can be provided (Givoni, 1998). Table 2 presents the most important indicators of energy consumption from the physical and climatic perspective in urban form.

Table 1
General research process

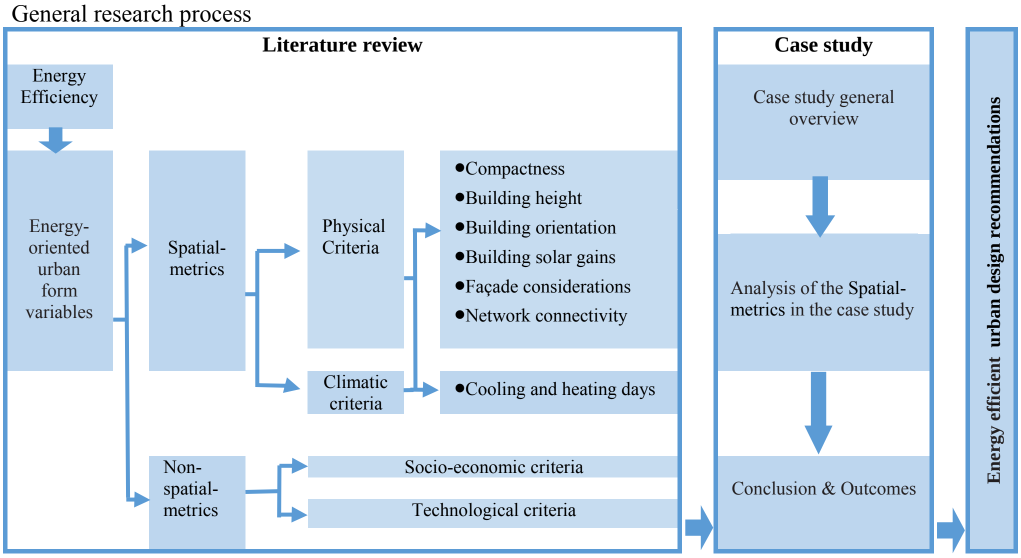


Table 2
Research spatial criteria.

Spatial key drivers	Criteria
physical criteria	• Compactness • Building height • Building orientation • Building solar gains • Façade considerations • Network connectivity
Climatic criteria	• Cooling and heating days

Compactness

Compactness does not generally have only one definition (Tsai, 2005), but is usually referred to in the context of high-density or monocentric development (Gordon & Richardson, 1997). The compact urban form impacts solar radiation, shadows, movement patterns, urban heat island effect and the efficiency of the infrastructure, which affects energy consumption directly and indirectly (Mahdy Youssef, 2013).
Several compactness indicators are used to assess the availability of solar potential in neighborhoods. This indicator explained as follows: (a) Volume-area ratio is the total building volume in a neighborhood divided by the total area of a neighborhood. (b) Site coverage is the total built area in a neighborhood divided by the total area of a neighborhood (Lee, 2016). (c) The plot ratio is the total floor area in a neighborhood divided by the total area of a neighborhood (Nault, 2015). (d) Building density is the total number of buildings in a neighborhood divided by the total area of a neighborhood (Wiginton,2010), (e) Population density is the total number of people living in a neighborhood divided by the total area of a neighborhood (Wiginton,2010). (f) The nearest-neighbor ratio is the average distance between buildings from centroids normalized by the total area of a neighborhood (Sarralde, 2015).

Building Height

The effect of building height on the energy demand of buildings is mainly due to its role as a practical obstacle in urban environments. In particular, building height not only shapes the skyline of a city and alters the amount of open space at ground level, but it also affects sunlight accessibility and solar gain (Aghili, 2017). Also, the distance between buildings is important in the urban areas where the area is scarce but the need for buildings is high. Leaving enough distance between buildings is considered in order to allow the wind to pass through all of the buildings. The distance of the buildings must be calculated using the solar data on the 21 st of December in which the sun is at the lowest angular value with the earth (Ratti, 2005).

Building Orientation

The orientation of a building is defined as the direction perpendicular to the main surface of the building. Clearly, the orientation of a building affects solar gain and energy demand by altering the incident angle and duration of sunlight. It is regarded as one of the most important parameters in housing design. Orientation is one of the most important variables in the energy efficiency of a building. When the orientation of a building is laid out correctly, the solar gain will be maximized, the building benefits from better quality daylighting, and the need for extra heating declines significantly (Aghili,2017).

Building Solar Gains

Sun has several main functions in the energy-based studies of the urban environment since it is crucial for lighting and heating. Proper use of the solar radiation will decrease the heating loads in cold seasons, but effective protection from the sun is needed by sheltering or other ways in order to decrease the cooling loads. The magnitude and time of solar radiation directly affect the amount of heat gained by the building. The influence of the sun should be well estimated in land-use planning and housing design stages (Mert, 2014).

Facade Consideration

The façade plays a critical role in the exterior elements for building functionality. Façade as a barrier of a building that will impact the interior lighting and temperature, thus affect the energy use of buildings. Various façade types will lead to the various energy performance of buildings, especially in regard to energy consumption and thermal comfort. (Jia, 2013)

Network Connectivity

Connectivity is the primary goal of any transportation network; It relates the places that people want to move between them. Travel is commonly considered a "derived demand" – we travel mainly because we want access to other locations, not simply because we enjoy movement. Travel demand modeling generally assigns a cost to travel that includes the "cost" of time. All else being equal, shorter travel times are preferred. This is particularly true for bicycling and walking, which are usually slower than motorized travel (Dill, 2004). There are practical limits to how far a person will walk or bike. Increasing network connectivity can reduce travel distances for all modes, including walking and bicycling. Another benefit of increased connectivity for these modes has a wider range of routes to be selected from. A cyclist, for example, might choose a slightly longer route if he or she can use a bicycle lane, a street with less traffic, or a less steep hill (Dill, 2004).

A review of the planning and transportation literature found numerous measures of connectivity. Each measure is defined and described below.

Block length**:** is used in a different way to promote or measure connectivity. Several communities have adopted maximum block length standards for new development (Handy, 2003). Standards are usually between 91 and 182 meters and apply to each block, some of which are exceptional.

Block size**:** A handful of communities have adopted standards setting maximum block sizes, which capture two dimensions of the block, rather than the individual length of each side (Handy, 2003). This can be measured by the width and length, the area (e.g. acres), or the perimeter.

Block density: A few researchers have used block density as a proxy measure for connectivity (Frank, 2000). Used the mean number of census blocks per square mile. the authors assert that census block density is a good proxy for street connectivity since census blocks are typically defined as the smallest fully enclosed polygon bounded by features such as roads or streams on all sides.

Intersection density**:** Intersection density is measured as the number of intersections per unit of area, e.g. square mile. A higher number would indicate more intersections and, presumably, higher connectivity.

Street density**:** is measured as the number of linear miles of streets per square mile of land (or kilometers per square kilometer). A higher number would indicate more streets and, presumably, higher connectivity. Street density, intersection density, and block density are likely highly and positively correlated with each other.

Connected node ratio**:** The connected node ratio (CNR) is the number of street intersections divided by the number of intersections plus cul-de-sacs. The maximum value is 1.0. higher numbers indicate that there are relatively few cul-de-sacs and, theoretically, a higher level of connectivity.

Link-node ratio**:** is an index of connectivity equal to the number of links divided by the number of nodes within a study area. Links are defined as roadway or pathway segments between two nodes. Nodes are intersections or the end of a cul-de-sac. A perfect grid has a ratio of 2.5.

Grid pattern**:** Many researchers have measured the street network based upon whether it is a grid or not. For example, Greenwald and Boarnet and crane (2001) use the percentage of area in a one-quarter mile buffer zone that is covered by a grid street pattern, as measured by four-way intersections.

Pedestrian route directness**:** PRD is the ratio of route distance to the straight-line distance for two selected points. The lowest possible value is 1.0, where the route is the same distance as the "crow flies" distance numbers closer to 1.0 indicate a more direct route, theoretically representing a more connected network. PRD is the same as the "circuity factor" sometimes applied in logistics to approximate travel distances between cities (Ballou, 2002).

Effective walking area**:** EWA is used by the index model for Tampa, Florida. That is a ratio of the number of parcels within a one-quarter mile walking distance of a node to the total number of parcels within a one-quarter mile radius of that node. Values range between 0 and 1. A higher value indicates that more parcels are within walking distance of the pre-defined point, reflecting a more connected network.

Gamma index**:** is a ratio of the number of links in the network to the maximum possible number of links between nodes. The maximum possible number of links is expressed as 3 * (# nodes – 2) because the network is abstracted as a planar graph. In a planar graph, no links intersect, except by nodes (Taaffe and Gautheir, 1973). This feature represents a transportation network well. Values for the gamma index range from 0 to 1 and are often expressed as a percentage of connectivity, e.g. A gamma index of 0.54 means that the network if 54 percent connected.

Alpha Index**:** is the ratio of the number of actual circuits to the maximum number of circuits and is equal to # links - # nodes + 1/2(# nodes) – 5

As with the gamma index, values for the alpha index range from 0 to 1, with higher values representing a more connected network. Both indices could be applied as measures of connectivity for bicycling and walking.

2.3.1.2. Local Climate

Climate is a factor in determining ultimate energy use, especially for heating and cooling demands. Its influence on energy use can be measured through the metrics of heating and cooling degree days, which, in combination with the thermal quality of buildings and settings for indoor temperature, determine energy use. Urban energy demand is, in principle, not markedly different in its climate dependence than that in non-urban settings or national averages, but it is structured by the influence of other variables, such as urban form, access to specific heating fuels, or income that can amplify or dampen the effect of climate variations on urban energy demand. Some studies illustrate the quantitative impact of climate variables on energy demand. For example, one research report differences in space heating energy use (measured as useful energy) normalized to heating degree days and square meters living space for seven industrial countries (Schipper, 2004). The relationship between climate and urban energy use is a two-way street: climate not only influences urban energy demand, but urban areas also influence their local climate through the 'urban heat island' effect. This effect can reduce the heat demand during winter, but also enhance the need for cooling in the summer (Dhakal, 2003).

Table 3
Energy key driver's checklist for urban design.

Field of action	Criteria	Sub-criteria
Urban design	Compact structure	Volume-area ratio, Site coverage, Plot ratio Building density, Population, Density, Nearest-neighbor ratio
	Passive use of solar energy	Building orientation, Façade consideration, shading by neighboring buildings, building height, Building solar gains
	Connectivity	Block length, Block size, Block density, Intersection density, Street density, Connected node ratio, Link-node ratio, Grid pattern, Pedestrian route directness, Effective walking area, Gamma index, Alpha index
Energy	Energy consumption	Cooling and heating demand

3. Methodology

The methodology is one of the most important components which influence the results of research, considerably dependent on the goal, nature, and tools of research and the assumptions and constraints. The following research is from the comparative type with the use of a descriptive-analytic method and with employing popular library tools along with field observations. This research was carried out the key criteria of spatial urban form in categories of physical and climatic are examined. The first step is to collect the necessary information. In this step, Compactness with 6 sub-criteria, measured by GIS version 10.5, Building Height, Building Orientation, Building Solar Gains and Façade Consideration measured by ECOTECT version 2011 and Network Connectivity with 12 sub-criteria measured by Auto CAD version 2016

$$x = \frac{1}{\tan \alpha}$$

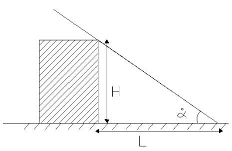


Fig .1. The angle of radiation and height of the building

by entering the number of people residing in each unit and thermal calculations performed by the software, based on are quantified with data fetched from publicly available information sources and Named software. To get the final figures for Compactness, Network Connectivity, we normalized figures and mean.

$$X_{norm} = x\text{-}min/max\text{-}min$$

Also, weather data from Meteonorm software has been used for calculating cooling and heating demands in order to determine the shading on 21 st of December, suns radius is 31.55 degrees (Rahnamai, 2003) at the time of the experiment. By exploitation of the formula illustrated in Fig. 1, as well as the assumption of 1-meter height for the length of the shadow, has found to be one meter. Due to the average height of buildings, the neighborhood shading assessed.

the amount of absorption of sunlight, the amount of energy demand to stay at 18 ° c -36° c is calculated. The second step is to compute the energy efficiency using the Analysis (ANP) method. Furthermore, choose energy-efficient neighborhoods with a higher value. To attain energy, use of buildings, the amount of buildings energy for heating and cooling are calculated. The criteria are straightly related to the absorption of solar radiation in residential units on the one hand and peripheral environment of residential units on the other.

4. Case Study

Two neighborhoods have been chosen in Sanandaj as case studies of this research. One of them is located in the 10 District of Sanandaj named Ghatarchyan and the other one in the 8 District, named Mobarakabad neighborhood. In this comparison, having the same number of inhabitants and approximately a similar size would be the main reason for the selection of these two neighborhoods (with the same population and very different physical characteristics). As comparison cases, energy demand in these two neighborhood is going to be analyzed based on key spatial criteria. Figures 2 show the Ghatarchyan and Mobarakabad site plan respectively. Based on Table 4, it is considered that both neighborhoods have approximately a similar size but a different land occupancy ratio. In Ghatarchyan neighborhood the land occupancy is about 78%, meanwhile, in Mobarakabad neighborhood, the land occupation is 65%.

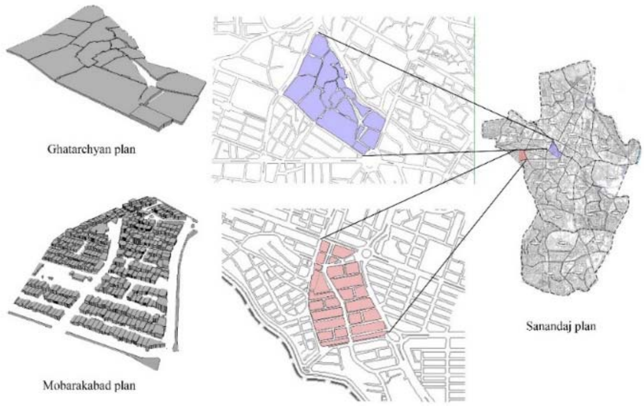


Fig.2. Ghatarchyan and Mobarakabad site plan

Table 4
General characteristics of case studies

Factors	Ghatarchyan neighborhood	Mobarakabad neighborhood
Area	404000 m^2	302000m^2
Land occupation	78%	65%
Population	8916 person	8657 person
Minimum floor	1 floor	1 floor
Maximum floor	5 floors	8 floors
Number of building units	1000 unit	355 unit
Mean residential area	80 m^2	120 m^2
Number of building blocks	17 block	24 block
Texture	Old	New

For the network connectivity criteria, 12 sub-criteria has been considered after calculating all the sub-criteria, the numbers are normalized. We considered the average of these figures for network connectivity number, which is obtained 0.12 for Ghatarchyan and 0.2 for the Mobarakabad so Mobarakabad has better connectivity than Ghatarchyan. Because of more intersections, shorter distances for travel, better walking area and there are more routes between places. Also, the street network pattern of this neighborhood is closer to the grid network.
For calculating cooling and heating demand Taking all of the spatial metrics and assuming 18°-36° Internal temperature we simulation was chosen neighborhoods in ECOTECT and obtained building cooling and heating demand for all year long, that showed in Table 5.

5. Findings and Discussion

The main focus of this research is on the neighborhood scale and the study of compactness, building height, building orientation, solar gains, facade consideration, network connectivity, and cooling and heating days at this level. The results of the physical and climatic criteria show that compactness were had been measured. 0.343 for Ghatarchyan and 0.275 for Mobarakabad, so we conclude a denser texture belong to Ghatarchyan neighborhood that because of unplanned texture. The recorded data shows an average of 7.285 meters for the building height in Ghatarchyan and 6.857 meters for the Mobarakabad neighborhood. About building height in Ghatarchyan that should be noted a few buildings change the average height while most of the buildings are in low height. The obtained shading for each building with a height of one meter assuming on 21 st of December is 1.64 meters. Based on the average building height in the mentioned neighborhoods, the shading rate in the neighborhoods of Ghatarchyan and Mobarakabad is 11.94 and 11.24 meters, respectively.
These results, in other words, determines the optimum distance between buildings to use the highest solar gains and reduce energy demand in the cold seasons on the facades with minimum shading. Also, the best position for block placement, in the orientation criteria, is the direction that receives the highest amount of energy in the winter and the lowest amount of energy in the warm season Due to the radiation angle. To determine the optimal orientation of the building, we used ECOTECT and the weather data of Sanandaj city, according to fig. 4. the blue

line shows the amount of sun radiation in the cold season and the red line indicating the amount of solar radiation in the warm season also the green line represents the amount of radiation throughout the year. The best orientation occurs at an angle where the maximum blue line value and the minimum redline value, this angle being seen with the yellow line in the figure. The ECOTECT application proposes an elongation of the building's in the east-west direction toward the south with a 2.5° spin toward the east. The results also indicate that the worst orientation is towards the east. The deviation of selected neighborhoods is from the optimal orientation for Ghatarchyan is 42.5° and for Mobarakabad is 12.5. Average solar gains for Ghatarchyan and Mobarakabad neighborhoods are 53.956 M Watts/km^2 per year and 58.852 M Watts/km^2 per year respectively. For the facade considerations criteria, with the field survey, we found out the dominant material and color for the Ghatarchyan is cream color concrete and for the Mobarakabad gray color travertine by simulations of neighborhoods with These facade properties in ECOTECT, the annual amount of solar gains for the Ghatarchyan is 0.0028 M Watts / m^2 and for Mobarakabad is 0.0039 M Watts / m^2, which indicates that the amount of absorption in the Mobarakabad building's façade is higher.

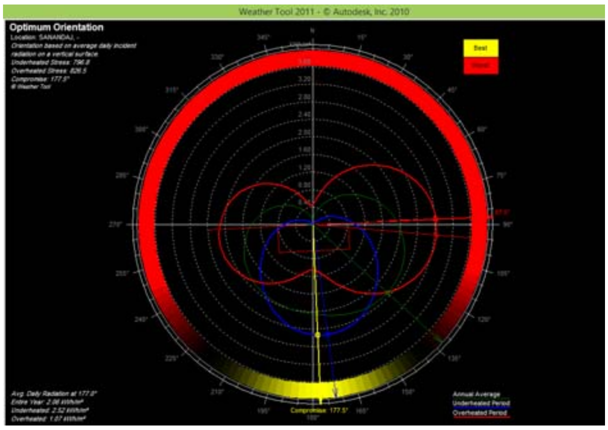


Fig. 3. Optimal building orientation in Sanandaj

Table 5
key spatial driver's status in quarters.

Criteria	Sub-criteria	Ghatarchyan neighborhood	Mobarakabad neighborhood
Compactness	Volume-area ratio	2.14	1.47
	Site coverage	0.78	0.65
	Plot ratio	0.66	0.46
	Building density	0.0024	0.0011
	Population Density	0.503	0.0500
	Nearest-neighbor ratio	0.79	0.70
Block height	Mutual shading	11.94	11.24
Block orientation		42.5 °difference with optimum	12.5 °difference with optimum
Façade considerations	Façade gains	0.0028 MW/m^2	0.0039 MW/m^2
Block solar gains		53.956 MW/km^2/year	58.852 MW/km^2/year
Network connectivity	Block length	134.51	79.56
	Block size	Perimeter 435.36	Perimeter 252.37
	Block density	0.1	0.2
	Intersection density	0.1	0.11
	Street density,	8	14.55
	Connected node ratio	0.34	0.86
	Link-node ratio	1.08	2.4
	Grid pattern,	0	1
	Pedestrian route directness	1.17	1.06
	Effective walking area	0.51	0.82
	Gamma index	0.37	0.97
	Alpha index	0.03	0.88
Energy	Cooling and heating demand	28076 MW per year	15105.7MW per year

5.1. Energy Analysis

Different methods have been used for comparison and analysis the most well-known multi-criteria decision-making method is the analytic hierarchy process (AHP) (Saaty, 1980). In that method, the decision-making problem is decomposed into a hierarchy. At the top of the hierarchy is the decision-making goal. The criteria are on the next level, which can be decomposed into the sub-criteria (and further decomposed to the lower levels). The last level is the alternatives. By using pairwise comparisons (to be explained later in this paper), local priorities of alternatives as well as criteria weights are calculated. Afterward, it is possible to calculate the global priorities of alternatives and make decisions. In the decision-making problem field, if influences/dependencies exist between criteria, which the AHP does not consider, using the AHP might lead to a decision that is less than optimal. In those cases, using the analytic network process (ANP) is more appropriate. By using the ANP, we can model the dependencies and feedback between the decision-making elements, and compute more precise weights of criteria, and local and global priorities of alternatives. The decision-making problems in the ANP are modeled as networks, not as hierarchies as with the AHP. The ANP is a generalization of the AHP. Figure 4 provides the structural differences between a linear hierarchy and a nonlinear network. The basic elements in the hierarchy and network are clusters (components; rectangles and ellipses in figure 4, nodes (elements in clusters, not specified in figure 4) and dependencies (arcs). The meaning of ‘depend on’ is the opposite of ‘have an influence on’ (Saaty, 1980).

In this paper based on the selection of the ANP method, Super Decisions Software has been used to analysis the spatial metric. Findings show that all the aforementioned criteria in different categories (physical and climate) affect urban energy use. While the results of the ANP analysis does not show a complete match, they rely on the real impacts regarding the importance of the criteria. Table 6 summarizes the spatial criteria which impact on energy use with their values in chosen neighborhoods.

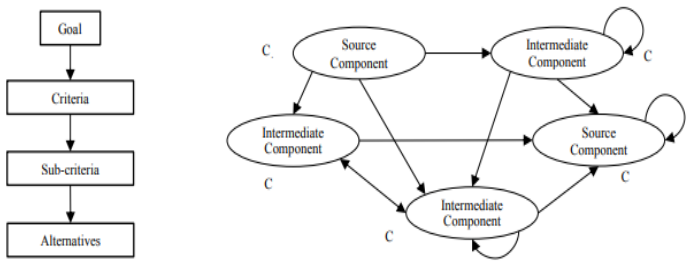
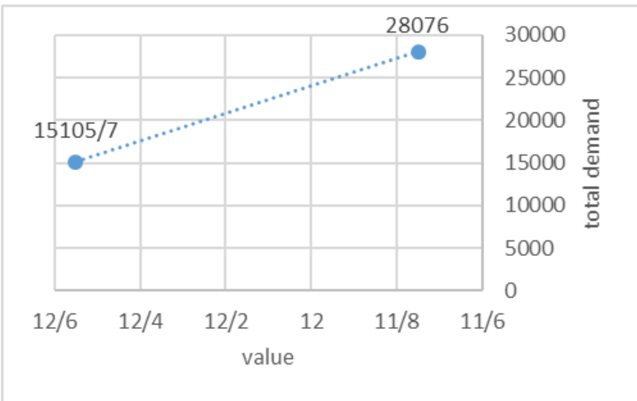


Fig .4. The structural difference between hierarchy and network (adapted from [Saaty, 2006])

Table 6
Neighborhoods value based on spatial metrics.

Criteria	Ghatarchyan neighborhood	Mobarakabad neighborhood	Weight	Amount	
Compactness	0.343	0.275	0.202	A 0.069	B 0.055
Block height	11.94	11.24	0.150	1.79	1.68
Block orientation	42.5 °difference with optimum	12.5 °difference with optimum	0.164	0.124	0.152
Façade considerations	0.0028MW/m^2	0.0039MW/m^2	0.181	9.76	10.65
Block solar gains	53.956 MW/Km^2	53.956 MW/km^2/year	0.075	0.0002	0.0003
Network connectivity	0.12	0.16	0.123	0.0147	0.0196
				Total A 11.75	Total B: 12.55
Cooling and heating demand			A	Max Heating:16.6MW Max Cooling:16.6MW Total:28076MW per year	
			B	Max Heating:8.7MW Max Cooling:5.3MW Total:15105.7MW per year	

6. Conclusions

Energy efficiency is one of the key concepts of urban design today. Based on this, urban designers are trying to provide optimal solutions for improving energy performance indicators. This study measured spatial metrics (physical and climatic criteria) to evaluate the relation between urban form and energy performance. Six key variables (compactness, block height, block orientation, façade considerations, block solar gains, network connectivity) that related to urban form energy performance has been assessed. Although we used the network analysis process to calculate realistic estimates of the average value of each neighborhood. By applying this approach, it is found that physical structure and local climate have an impact on energy efficiency. ECOTECT software helped us assess the cooling and heating demand and block orientation in the real-world environment. The results of the evaluation in two neighborhoods with different forms show that there is a negative correlation between spatial metrics and energy use, so if the spatial metrics amount of each neighborhood increases, neighborhood energy demand will decrease. Due to the compactness, it is clear that distance between buildings is low and building shading is high also building orientation and connectivity pattern is not absolutely Suitable, all of these criteria affecting on solar gains and reduce it which will increase energy demand in old texture. So this study provides an insight into how urban designers can respond to development and policy shifts in energy fields. In general, terms, to improve energy efficiency, urban design recommendations based on the spatial structure are presented.

The main recommendations are summarized as follows:

- Enclosure based on the maximum fit with the annual solar irradiation pattern of building blocks.
- Decreasing site coverage tends to increase the solar potential of the buildings.
- Coordination of height and distance between blocks to avoid overshadowing.
- Establishment at 272.5 ° (the best orientation is 2.5 ° southward to the east and east-west elongation) in order to get the maximum winter light and get the lowest solar energy in the summer.
- The Use of the facade with a suitable absorption coefficient regard to the local climate.
- Reduce the size and length of building blocks in the design, to integrate the pedestrian path and expand the walking area
- Open the dead ends of old texture as much as possible and Create more intersections.

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[i] In terms of kilograms, the equivalent of crude oil for a dollar of GDP is fixed at constant prices (2005 = 100).

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