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Investigation and Analysis of the Effects of Land Use and Transportation Network Planning on Energy Consumption in the City; Case Study: "35-Hectare Area" in Hashtgerd New Town*

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ABSTRACT

The rapid and increasing growth of urbanization and the subsequent increase in population of cities have led to different consequences in various fields. Among the most important consequences is the increase in demand for energy resources, which can be considered from two aspects: first, limited renewable energy resources and second, environmental pollutions caused by the consumption of fossil fuels. On the other hand, public awareness of the above aspects has led to emergence of new approaches such as sustainable development, smart growth, etc. in urbanism and revealed the attention to the issue of energy efficiency in urbanism. The concept of energy consumption in the city is related to various components, one of which is street network and transportation, which in relation to the issue of land use, affect energy consumption in this sector (about 30% of energy consumption in cities). So far, several studies have been conducted in the field of energy consumption, but few quantitative studies have been done in Iran. In the present study, first the theoretical foundations in the field of energy and transportation planning are examined, and then the components affecting energy consumption in transportation sector are discussed. In the next step, three scenarios are proposed for a 35-hectares unbuilt area in Hashtgerd New Town (known as "35-Hectare Area" in the national documents), and at the end, for all scenarios, the energy consumption is evaluated by measuring the energy indices of transportation and land use using Communityviz software. To determine the degree of integration of passages, space syntax technique and Depth Map software are used. The results show that there is a direct relationship between the form of transportation network, urban land-use, and energy consumption such that by changing the form of transportation network, developing integrated transportation, and changing the land-use distribution, energy consumption in transportation sector can be reduced up to 35%.

Keywords: Sustainable Development, Energy Efficiency, Land Use Planning, Transportation Planning, Hashtgerd New Town.

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1. INTRODUCTION

The settlement of about 3.3 billion of the world's population (60% of the total population) in cities and rapid and increasing growth of urbanization, especially in developing countries, have had various economic, social, physical, and environmental consequences, one of which is the upward growth (about 20%) of energy consumption and demand in cities in the last three decades, and it is predicted that this trend will continue until 2035. This increase in energy demand and consumption has had major effects in two aspects. On the one hand, due to the limited resources to supply energy, it has caused a severe energy crisis, and on the other hand, since a high share of required energy (about 85%) is supplied from fossil fuels, much environmental pollution has been created due to the emission of greenhouse gases. To solve these problems, several movements have been formed in the field of urbanism, all of which emphasize the importance and necessity of paying attention to environmental considerations in cities, such as energy consumption. On the other hand, one of the important and influential dimensions in urban development and planning is the form of street network and integration of transportation network in relation to urban land-use. Urban land-use planning plays a role in the organization of urban system and the direction of its development by determining how to use urban lands, defining different densities, and providing appropriate access to different uses. Therefore, urban land-use planning, due to its direct relationship with urban activities, is completely related to and affects the issue of energy and its efficiency. The mutual effects of these two issues can be found in energy consumption in a variety of urban activities on the one hand and the energy consumed to access these activities, and thereby travels and energy consumption in these travels on the other hand.

Accordingly, given the current situation in the field of energy consumption in Iran, there is a need to develop criteria to be used in the urban land use and transportation network planning. Also, new towns, including Hashtgerd New Town, as the new models of urban development can have a significant contribution in attracting the population of other urban centers. These urban centers, despite the many criticisms of their formation by planners (they have not yet been able to attract the predicted population horizon) need proper planning and a suitable context for applying new principles and approaches such as energy efficiency. Applying the criteria for urban land use and transportation network planning with an approach to energy efficiency in this new town can be used as an opportunity to apply these criteria in other cities of Iran, create more sustainable urban development, and reduce energy consumption. The case study here is a 35-hectares unbuilt and uninhabited land located in the southern part of Hashtgerd New Town (known as “35-Hectare Area” in a national plan performed by Hashtgerd's New Towns Development Company in collaboration with a German group) where by applying energy efficiency criteria, the number of travels produced as a result of neighborhood, regional, and higher level commuting, and thereby energy consumption and greenhouse gas emissions can be greatly reduced.

2. THEORETICAL FOUNDATIONS

In this section, the theoretical literature along with the related models and theories are examined. Since the research topic is investigated with a holistic and macro perspective and also the related concepts are multidimensional, in this section, some of the most basic concepts are explained to make the totality of the research perceivable to the audience.

2.1. Concepts, Principles, and Origins of Attention to Energy Debate

Based on the above, numerous urbanism movements have emerged in response to the environmental crises since the 1960s, which promised better future and healthier and higher quality living environments. Among the most important of these movements are sustainable urban development, smart growth, and new urbanism. Each of these movements has its own goals and principles and has directly and indirectly emphasized the issue of energy and its efficiency in cities (Leitman, 1999, p. 41). Therefore, in this section the concepts and principles of these movements, as the origins of attention to the issue of energy and energy efficiency, are briefly reviewed.

According to the Agenda 21, there is a link between land use and planning, energy conservation, consumption management, and various other issues at the local level and local people participation; and in a separate chapter, the creation of sustainable settlements and the need to pay attention to the issue of energy and its sustainability in cities are emphasized (Haughton & Hunter, 1994, pp. 248-299).

In general, energy sustainability means providing energy in a way that the needs of the present generation are met without compromising the ability of future generations to meet their needs. In other words, energy sustainability means using resources that emit no threatening environmental pollutants, do not end up due to continuous consumption and also play no role in perpetuating major human health risks (Lantsberg, 2005, p. 12).

New urbanism movement is one of the other intellectual foundations supporting the issue of energy in the field of urban development. New urbanism, or neo-urbanism, is a movement in the United States that emerged in the early 1980s and challenged the uncontrolled expansion of cities by discussing the growth of suburbs in the form of creation of small towns and complexes. This movement does not reject the needs of modern and postmodern life in any way, but tries to find physical, technical, etc. solutions for them in accordance with human life and environmental

protection with an emphasis on the forgotten position of humans (and not automobiles) (Caves, 2005, p. 332).
In 2003, Steemers examined the relationship between energy and the city. In his study, by introducing the two sectors of construction and transportation as the sectors affected by urban planning, he has compared energy consumption in the two sectors and interpreted the relationship between them (Steemers, 2003).
Kwon and Leather, in 2006, have developed a technical report of transportation and energy efficiency in Asian cities for Asian Development Bank. In this report, the transportation sector has been introduced as one of the energy consuming and growing sectors in cities; and the main focus of this research has been to achieve policies to reduce energy consumption in this sector (Kwon & Leather, 2006). Also, in 2010, Okeil has researched on the optimal and efficient form of building in terms of energy consumption with a holistic approach. In this study, by emphasizing the differences in the forms appropriate for buildings at various latitudes and in different climates, he presented his proposed form for residential blocks. In general, the main and special emphasis of this study was on the building and its form as one of the factors affecting the amount of energy consumption in buildings (Okeil, 2010).
Rotterdam Energy Approach and Planning (REAP) has been developed in the Netherlands and Rotterdam City in order to reduce greenhouse gas emissions caused by energy consumption, and is one of the new methods in the field of energy efficiency in cities. One of the features of this method is its ability to be used in various scales, from building to city (Dobbelsteen Van den & Tillie, 2009).
The process of Sustainable Urban Energy Planning is another process related to energy in cities provided by the UN-Habitat. The program uses a ten-step process as a framework for local measures; and the role and participation of local groups in this process is very prominent. This process of economic, social, and environmental development of healthy communities aims to promote optimal use of energy resources in developing countries (UN-Habitat, 2009).
The Energy-Efficient Development model was developed by the American Planning Association in 2006 to achieve energy efficiency in cities. This model is important because in the content and stages of it, more attention is paid to the technical issues of urban planning and design and the suggestions are presented in this regard. This model introduces sustainable use of energy resources, ecological form and function of the community, community-based resource management, land use optimization, social equity, and economic vitality as the five basic principles to achieve a reduction in energy consumption in cities and presents some solutions in this regard (APA, 2006, p. 485).

2.2. Approach of Energy Efficiency in Cities

The Energy-Efficient Development model was developed by the American Planning Association in 2006 to achieve energy efficiency in cities. This model is important because in the content and stages of this model, more attention is paid to the technical issues of urban planning and design and the suggestions are presented in this regard. This model introduces sustainable use of energy resources, ecological form and function of the community, community-based resource management, land use optimization, social equity, and economic vitality as the five basic principles to achieve a reduction in energy consumption in cities and presents some solutions in this regard (APA, 2006, p. 485).
Urban planners have the best opportunity for promoting the economy, environment, and public health of their community in the form of optimal use of energy resources. The growing need of the society for clean resources and new and modern technologies optimizing energy consumption in services, business, as well as residential uses, along with new development models based on energy efficiency in the city, have provided a great opportunity for planners. The importance of increased greenhouse gases and energy demand has increased dramatically in global discussions. The world is watching an uncontrollable urbanization trend and consequently, increased energy demand for public, and private uses, and economic activity leading to increased greenhouse gas emissions. This expresses the urgent need to consider energy efficiency issues in urban planning and especially land use planning (Omer, 2008, p. 233).

2.3. Energy Consumption in Cities

In a general definition, human activities are the main factor of energy consumption in the world. Accordingly, by categorizing the mentioned activities, it can be stated that energy consumption in cities also takes place in different sectors. In different countries and based on different divisions, energy consuming sectors are different. In Canada, for example, the industrial, agricultural, residential, commercial-organizational, construction, and transportation sectors are the most important energy consuming sectors (Khalil, 2009, p. 10).
The review of theoretical studies also indicate that currently, in Germany, the major sectors of energy consumption are the industrial, residential, and transportation sectors. Also in the United Kingdom, according to the statistics provided by the Department of Energy and Climate Change in 2010, the residential, industrial, transportation, and service sectors have been introduced as the most important energy consuming sectors in this country.
Germany's Energiewende (“energy transition”) has been the most important step in Germany in order to manage energy and its consumption efficiency on a macro scale and includes all scales. It should be noted that this has not happened suddenly and without a plan. The existing infrastructures in this country have provided the ground for carrying out

this plan well. It is obvious that the urban planning system is one of the issues that have been considered in this plan. In general, the principles of German's energy policies are based on the three principles of sustainability, economic stability, and environmental energy resources. The energy transition plan is also based on the five principles of reduced greenhouse gas emissions, efficient construction sector, transportation, and renewable energies (Morris & Pehnt, 2016).

2.4. Energy Consumption in Buildings

Buildings are one of the most important sectors consuming energy in cities, which in different countries, due to their different characteristics, have different share in energy consumption compared to other sectors. In the United Kingdom, for example, buildings account for more than half of all energy consumption, while they account for 41% and 36% of total energy consumption in other EU countries and US, respectively. In fact, this difference in energy consumption in buildings in the United Kingdom compared to other sectors (transportation and industry) is due to the better conditions of public transport, more pedestrian-orientation, heavy traffic, and restrictions on parking. In London, for example, only 10 percent of the urban residents make their daily trips by private cars, while this is 40 percent worldwide (Steemers, 2003, p. 3).

Energy consumption varies depending on the type of buildings in the city. For example, in residential buildings, home heating, water heating, lighting, and cooking are of activities consuming energy in residential buildings. Among the abovementioned activities, the energy consumed for heating the interior accounts for about 60% of the total energy consumption in these buildings and has the largest share (Steemers, 2003, p. 6; Mitchell, 2005, p. 6).

2.5. Energy Consumption in Transportation Sector

Transportation sector is one of the other most important energy-consuming sectors, which, like the construction sector, based on different characteristics of countries, has various shares of total energy consumption in cities. In 2004, for example, the American Institute of Oil and Gas Technology reported the share of energy consumption in transportation to be 28 percent (APA, 2006, p. 484). This is while in the same year, the energy consumed in transportation sector in the United Kingdom was estimated to be about 20 percent (Mitchell, 2005, p. 3).

Despite the high share of the construction sector in energy consumption, some reasons can be provided to clarify the necessity and importance of paying attention to energy consumption in transportation as follows:

• First, many local pollutions caused by transportation (air and noise) can be eliminated and solved much faster than pollutions caused by buildings.

• Second, the rate of replacement of old cars with new ones is much faster compared to buildings. In other words, transportation policies have a better chance of short-term profitability compared to building-related policies.

• Third, automobiles are not just associated with the environment, but they also are in relation to issues such as accidents, deaths, and social erosion, and this has led the debate to be highlighted in political circles (Steemers, 2003, pp. 3-4).

2.6. The Criteria for Urban Land Use and Transportation Planning with an Energy Efficiency Approach

As a result of the review of theoretical and practical literature on energy efficiency in cities, it can be acknowledged that various criteria have been provided for urban land use and urban transportation planning in references. Accordingly, in this section, as the most important final achievement of the theoretical foundations section of this study, the final criteria for urban land use and transportation network planning with energy efficiency approach are explained in order to be used in the subsequent sections of this study and provide the proposed plan based on them. Also, in order to achieve the above criteria in the scenarios proposed for the study area, given the review of literature and case studies conducted in developed and developing countries, some guidelines have been developed in various fields, as described in the table below.

Table 1. The Criteria for Urban Land Use and Transportation Planning with Energy Efficiency Approach

Criteria	Solutions Extracted from Theoretical Studies
Dense and Compact-ed Form (Sustainable)	- Closeness or central core of the city with a mix of houses, businesses, and sales centers - Regular and permanent public transport lines with a maximum time distance of 20 minutes (except BRT and metro lines) (Cervero, 2017, p. 28).
Mixed Uses	- A diverse mix of stores, offices, apartments, and houses - Maximum walking distance to the nearest base supply center: 200 meters - Protection of suburban lands (Cervero, 2017, p. 61). - Less dependence to automobiles, lower fuel consumption in transportation sector, en-couragement of public transportation, and more opportunity for walking - Encouragement of social life, better surveillance, and thus, increased public security - Creation of quality social relations and thus, increased population density - Self-sufficient public transportation, reduced dependence on automobiles, and reduction of the resulting travels - Reduced distances due to mixed uses and high population density - Reduction of the costs resulting from global warming as a result of dense urban form along with lower fuel consumption and lower production of pollution

Criteria	Solutions Extracted from Theoretical Studies
Centralized and Scattered Distribution	- Service uses in the planning process must be scattered as small concentrated groups across the entire area. - Human activities must be developed around the public transportation nodes. - Expansion of green spaces must be promoted in the city and the region.
Pedestrian-Orientation	- Providing pedestrian access to the entire area and the uses within the area in the land use planning process is one of the important criteria for achieving energy efficiency. - Providing pedestrian access to the entire area and the uses within the area in the land use planning process is one of the important criteria for achieving energy efficiency. - Pedestrian access (in maximum 10 minutes) to most local activities and uses (Cervero, 2017, p. 34) - Designing pedestrian-oriented passages and in some special cases, pedestrian paths free of automobile movement - Visual activation of the ground floor (Cervero, 2017, p. 38) - Ground floor physical permeability (Cervero, 2017, p. 38) - Provision of proper shading on sidewalks to encourage walking and provide climatic com-fort (Cervero, 2017, p. 41). - The length of sidewalks should be considered at least more than 1.8 meters (Cervero, 2017, p. 35).
Efficient and Inte-grated Public Trans-Portation Network	- Creating proper connection of the area to its surroundings through public transportation system - Automobile accesses are recommended to be in a north-south direction in order for max-imum use of sunlight in winter and south wind in summer. - Provision of safe and suitable pedestrian and bicycle paths - Reducing the width of the automobile paths within the neighborhoods to increase pedes-trian safety - Public transportation stations must have a coverage radius of 250 meters. - Neighborhood centers, neighborhood units, and public transportation stations should be located in coordination with each other. - Providing parking in the vicinity of public transportation stations - Reducing parking space in the area to reduce dependence on cars - The maximum walking distance to the nearest public transport station must be 1 km. - The maximum walking distance to the nearest service directly transporting to the high-capacity public transport station: 500 meters (Cervero, 2017, p. 20). - All the special surfaces for car parking should be considered as non-marginal.
Diversity	- A mix of land uses, building types, houses, and architectural styles in order to reduce en-ergy consumption in buildings and residential blocks
Amount of Open and Green Spaces	- Maintaining open spaces and increasing the share of green spaces in each area - Use of shading trees in pedestrian paths and sidewalks
Climatic Comfort	- Paying attention to the architectural and ecological design principles and criteria - Paying attention to the wind direction and orientation of the passages - Twisted orientation of passages in cold and dry climates in order to prevent the formation of wind tunnels in cold seasons
Urban Divisions	- The area of different levels of divisions should be determined according to the radius of access to service centers in order to be accessible on foot and by bicycle. - Balanced distribution of service centers in the area - Providing service uses for residents according to the access network hierarchy - Determining the maximum and minimum population in order for balanced distribution of population in the area - Combination of various types of activities in the proposed division centers in order to increase vitality and encourage the attendance of residents - Defining central elements for each of the divisions as an element based on access to which the radius of each of the divisions is determined.
Proportion of Residential Blocks	- Locating the residential lots densely and next to each other to reduce the building area and increase free space - Considering the effect of wind will reduce energy consumption in cold climates by 3 to 5 percent. - The depth of the building for passage of the south wind in summer must be less than 20 meters. - Use of rectangular form in residential lots and blocks. - Reducing the depth of residential lots to increase the use of sunlight - The shading of building blocks on each other should be reduced by determining the min-imum distance between the blocks according to the height plan in them. - The maximum length of the blocks should be about 110-150 meters (Cervero, 2017).

Criteria	Solutions Extracted from Theoretical Studies
Building Density and Height Plan	- The density and compactness of the settlement model must be increased. - Increasing the area of open and green space - Increasing building density as much as possible - To prevent shading of buildings, the height and proximity of buildings to each other must be controlled. - Increasing building density in the vicinity of public transport stations (TOD) - The height of buildings in front of the prevailing wind must be increased in cold climates.
Distribution of Service and Trip-attracting Uses	- Locating service uses within walking distance of 150 to 250 meters and bicycle distance of 400 to 600 meters (Cervero, 2017, p. 17) - The areas of mixed uses should be increased vertically and horizontally in the area and they must be distributed in a scattered manner. - Centralized service use centers should be distributed sparsely. - Locating work and activity centers in an integrated way in the study area - Locating regional uses at the outer edges of the area

3. METHOD

The present study is quantitative-applied research carried out using "planning", "simulation (modeling)", and "documentation and analysis". The models and methods used for measuring energy consumption in the city have a very diverse range. On the other hand, today, the role of software programs in urban development is undeniable such that their use speeds up planning, and the accuracy of designs is greatly increased if the right tools are used. Therefore, various models used for measuring energy consumption in the city have provided the basis for the production of various software programs in this field.

In the present study, in order to measure the energy consumption in the transportation sector as accurately as possible, CommunityViz software was used as the tool to analyze and measure the number of trips produced and, consequently, the amount of energy consumed. This software is one of the extensions of ArcGis software and calculates the number of trips based on land use plan and in other words based on the distances between service uses (trip attractor) and residential uses (trip generator). Therefore, based on the number of produced trips and determining the average trip distances, the annual energy consumption of transportation sector can be estimated and calculated.

The present study aims to determine the relationship between three issues of land use, transportation network, and energy consumption. One of the most influential factors in increasing pedestrian-orientation, developing integrated transportation, and consequently, reducing personal travels and energy consumption is the degree of integration of street network. So, to investigate this issue, space syntax technique and its related software, DepthMap, were used. On the other hand, in order to more accurately display and analyze the street network and land use simultaneously to provide the proposed scenarios of land use and locate public transportation stations based on land use system and integration of streets, the layers of the two software programs of ArcGis and DepthMap were overlapped and combined. It should be noted that to do this, a very flexible intermediary software called Mapinfo was used in the section of result analysis and also to analyze each of the proposed scenarios.

4. RESULT ANALYSIS

In order to evaluate the influence of the components of land use and transportation network planning on energy consumption in transportation sector, the 35-hectare site in Hashtgerd New Town was selected as the case study because it was unbuilt and there was possible to apply predetermined development and intervention and also the principles and criteria extracted from the theoretical foundations. Hashtgerd New Town is located on the southern slope of the Alborz Mountains, west of Tehran province, and the middle of the Karaj-Qazvin road, and its distance from the cities of Karaj, Tehran, and Qazvin is 25, 60, and 75 km, respectively. The town with an area of 4461 hectares is located at latitude and longitude of 35 and 50 degrees, respectively. Also, according to the 2006 census, its population was about 16000 people (about 11% of the total population predicted in the comprehensive plan approved for 2006).

4.1. Analysis of Energy Consumption in Scenarios

The first scenario or the same status quo scenario, the proposed land use and transportation pattern was analyzed and assessed based on the data existing in the revised comprehensive plan of Hashtgerd New Town. In the second scenario, in the minimum intervention was considered, the theoretical framework extracted from the theoretical foundations was applied through the least and the most optimal intervention in the status quo. In the third scenario, in which the maximum intervention (maximum efficiency) was considered, the maximum amount of intervention in the status quo (the proposed national plan) was made to achieve the highest level of energy efficiency in the study area. In the following, all the items mentioned in each of the scenarios (status quo, minimum intervention, and maximum intervention) were examined, a vision was developed for each of the scenarios and the characteristics of each of them were discussed. Then, the superior scenario was selected considering its greater compatibility with the study area and some solutions and strategies for achieving sustainable energy consumption in the study area as well as higher levels of planning were proposed.

4.1.1. Analysis of Land Use Plan and Transportation Network Integration in the Status Quo Scenario

In the status quo scenario, the suggestions presented in the revised comprehensive plan of Hashtgerd New Town (2006) were evaluated and analyzed. The suggestions presented for land use plan in the study area were:

- Social facilities: kindergarten, elementary school, secondary school, and cultural uses.
- Service and commercial/industrial units with service features: local stores, regional stores, office land-uses, and military land-use.
- Residential units.

According to the national documents on the area, the population density proposed for this area was 223 people per hectare. Therefore, the future population of the area, considering the area of about 35 hectares, is estimated to be about 7800 people. Also, the proposed uses in the comprehensive plan for this area included residential, commercial, religious and sport uses, healthcare centers and hospitals, police office, elementary school, secondary school, high school, street network, green and open spaces, and parking. Residential use occupied the largest share of the area space (43%), followed by the street network (about 30%)

in the present study, the connection and integration of passages were investigated to measure the attendance of pedestrians, pedestrian-orientation, and distribution of service and trip-attracting uses in the proposed scenarios. Therefore, in the status quo scenario, the street network and the access network model proposed in the revised comprehensive plan of Hashtgerd New Town are examined and evaluated to determine travel generation pattern in the area. Therefore, using the space syntax technique, the integration of the street network and thereby the pattern of attendance and travel demand were examined in the status scenario, the results of which are as follows:

The results (Fig. 1) indicate that in the status quo scenario, generally, in most parts of the 35-hectare site, the street network (west, north, and east passages) has low and very low integration and only parts of the central passage have high and very high integration. In general, it can be said that the street network in the texture has intermediate to low integration, indicating low feasibility of the principle of integration of street network, transportation, and texture compaction which is one of the main principles of energy efficiency approach. Consequently, residents are more encouraged to use private cars and the rate of travel generation and energy consumption in the transportation sector increases.

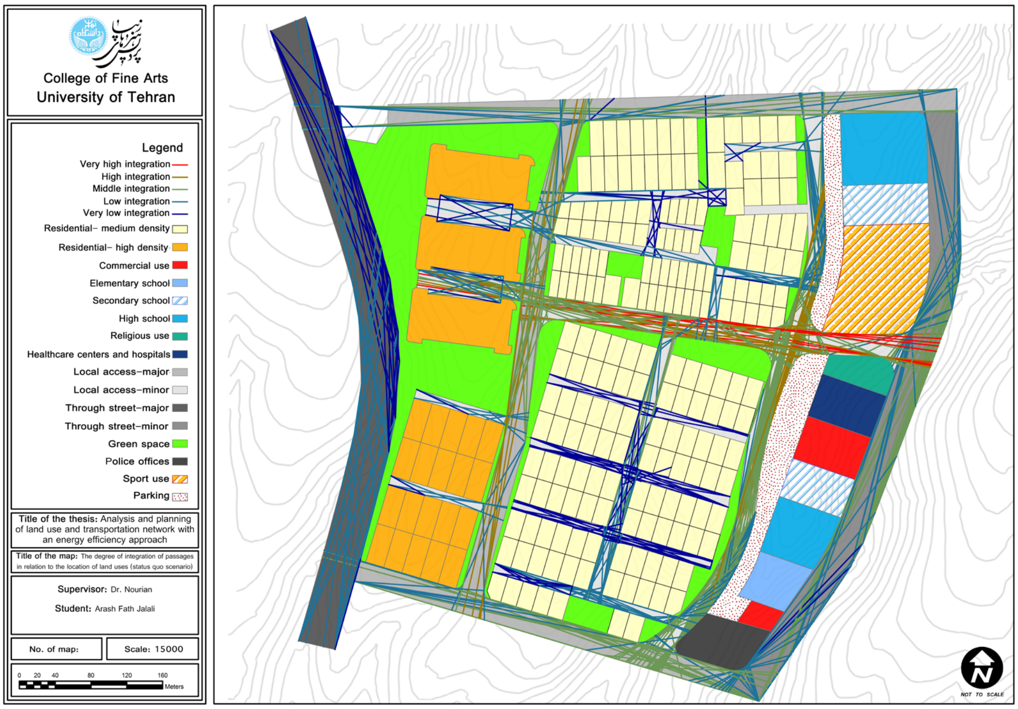

Fig. 1. The Degree of Connection and Integration of the Street Network in Relation to Land Use Plan (Status Quo Scenario)

4.1.2. Analysis of Land Use Plan and Energy Consumption Based on the Distances between Residential and Service Uses

In this section, as mentioned in the method section, CommunityViz software was used to calculate the number of travels and energy consumption in transportation sector. In this method, it is assumed that service uses are of places attracting trips and the flow of trip is formed from residential uses to them. One of the reasons for the existence and formation of these trips is the distance between the origin (residential buildings) and destination (service uses) trip. Therefore, if this distance is less than the reach of pedestrians and bicycles (which in this study is assumed to be 500 meters for district uses and 200 meters for local uses), no travel will take place. Accordingly, in this section, the average level of access of each residential lot to service uses and the percentage of the lots that are more or less distant from this amount were calculated for the proposed scenarios. Then, by multiplying this percentage by the amount of raw energy consumption due to local and regional trips and adding it to the amount of raw energy consumption due to urban trips, total amount of energy consumption in transportation sector was calculated for the proposed scenarios. The results are as follows:

Table 2. Calculation of Energy Consumption in the Status Quo Scenario

Indicator	First Scenario (Status Quo)
Annual raw energy consumption due to local trips (liters)	3321658.53
Annual raw energy consumption due to regional trips (liters)	3321658.53
Annual raw energy consumption due to urban trips (liters)	3321658.53
Percentage of residential lots at a distance of between 200 to 500 meters to service uses (local travels)	41.10
Percentage of residential lots at a distance of more than 500 meters to service uses (regional)	40
Total annual energy consumption due to local trips (liters)	1365201.43
Total annual energy consumption due to regional trips (liters)	1328663.41
Total annual energy consumption due to urban travels (liters)	3321658.53
Total annual energy consumption in the transportation sector (liters)	6015523.37

Therefore, as can be seen in the table above, the total annual energy consumption in the transportation sector (liters) based on the average access distance to the uses attracting trips or the same commercial-service uses was 6015523.37 liters per year in the status quo scenario which was obtained based on the proposed land use, street network and transportation plan.

4.1.3. Analysis of Land Use Plan and Transportation Network Integration in the Minimum Intervention Scenario

In order to provide same conditions for comparing the proposed scenarios, the same land-use types, population density, proposed population, and area of service uses were considered in them, and their distributions were changed. Therefore, in this scenario, the population density was considered 223 people per hectare and the future population of the area around 7800 people. According to the guidelines provided in various fields, the proposed land use plan included residential, commercial, regional commercial use, mixed, mixed (with the dominance of residential use), religious land-uses, kindergarten, elementary school, high school, secondary school, , street network, local green space, children's playing space, hospitals and healthcare centers, urban facilities, police offices, parking, sport centers, and open space, among which residential uses, street network, and open spaces had the largest share.

Regarding the proposed street and transportation network, it can be stated that in the minimum intervention scenario, the street network and the proposed access network pattern were provided based on the principles and criteria set out in the theoretical framework section and the least intervention in the status quo to determine the pattern of trip generation and attendance in the area. Based on the proposed guidelines in the field of street network, in the study area, the through streets proposed in the revised plan were preserved, and within the area, based on the topography of the site, two automobile paths (12 meters width and with bicycle path) were proposed in the north-south direction, and access to the building blocks were proposed in west-east direction and on foot.

In this scenario, as mentioned before, the proposed street and transportation network are based on the distribution of trip-attracting used (service uses) and access radius or coverage radius of 250 meters. Therefore, since public transport stations are located based on the density of trip-attracting uses or higher level of resident attendance, using the space syntax technique, the degree of integration and interconnectedness of the street network and thereby the attendance pattern and travel demand model were investigated and analyzed in the minimum intervention scenario, the results of which are as follows:

The results indicate that in the minimum intervention scenario, due to the observance of the principles and criteria of energy efficiency, in general, the level of integration has increased to a relatively desirable level compared to the status quo scenario, leading to more encouraging the residents to less use personal automobile. Therefore, as shown in Figure 2, the three north-south axes and the east-west connecting axis, which is located in the center of the site, have high and very high integration. Therefore, according to the principles and criteria of public transportation- and energy efficiency-based development, in the vicinity of streets with high and very high integration, public transport stations with an access radius of 250 meters were located and established and the building density decreases with the increase in the distance from the stations. It should be noted that public transportation stations are located based on the distribution of service uses and as can be seen in Figure 2, in the minimum intervention scenario, it was attempted to propose the street network in proportion to the distribution of service uses attracting trips as well as the existing topography so that while reducing travel distances, public transport stations would be located in the most optimal location and also operate in an integrated manner and in connection with other modes of transport such as pedestrians and bicycles.

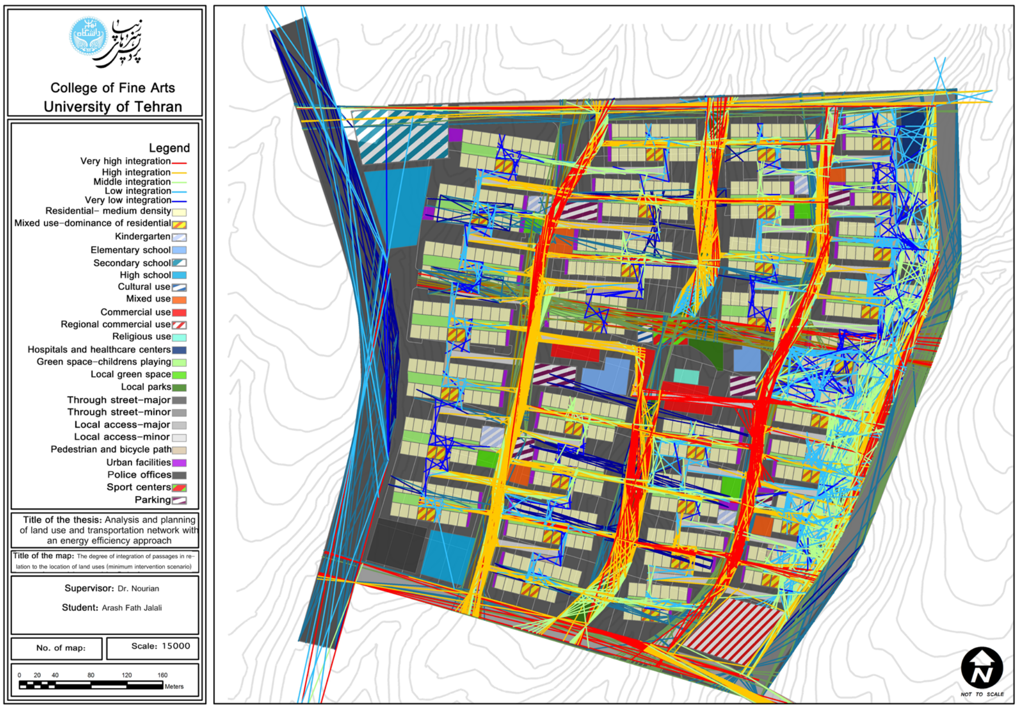

Fig. 2. The Degree of Connection and Integration of the Street Network in Relation to the Location of Service Uses (Minimum Intervention Scenario)

4.1.4. Analysis of Land Use Plan and Energy Consumption Based on the Distances between Residential and Service Uses in Minimum Intervention Scenario

In the minimum intervention scenario, compared to the status quo scenario, by changing the distribution of service uses at local and regional level, it was attempted to reduce travel distances (average distance to service uses) and consequently energy consumption in transportation sector and greenhouse gas emissions in the study area. In the present scenario, the percentage of residential lots located at a distance between 200 and 500 meters from service uses (local trips) was reduced to 5.67 percent and the percentage of residential uses located at distances more than 500 meters from service uses (district trips) was reduced to 38.6 percent, leading to a significantly reduced energy consumption in the study area (its numerical value was reached 4792156.75 liters per year) compared to the status quo scenario.

Table 3. Calculation of Energy Consumption in the Minimum Intervention Scenario

Indicator	Second Scenario (Minimum Intervention)
Annual raw energy consumption due to local trips (liters)	3321658.53
Annual raw energy consumption due to regional trips (liters)	3321658.53
Annual raw energy consumption due to urban trips (liters)	3321658.53
Percentage of residential lots at a distance between 200 to 500 meters to service uses (local trips)	5.67
Percentage of residential lots at a distance of more than 500 meters to service uses (regional trips)	38.6
Total annual energy consumption due to local trips (liters)	188338.03

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Indicator	Second Scenario (Minimum Intervention)
Total annual energy consumption due to regional trips (liters)	1282160.19
Total annual energy consumption due to urban trips (liters)	3321658.53
Total annual energy consumption in the transportation sector (liters)	4792156.75

4.1.5. Analysis of Land Use Plan and Transportation Network Integration in the Maximum Intervention Scenario

This scenario, like the second scenario, was proposed with an energy efficiency approach and the difference was that in the third scenario, the greater amount of changes were made in the status quo. Thus, in the minimum intervention scenario, the made changes were limited to those in the area, direction, and dimensions of lots, building densities, and distribution of service uses, especially at local level, but in this scenario (maximum intervention), more changes were made. The most important changes made in this scenario included changes in the syntax of residential lots, height plan, dimensions, area and direction of residential lots and distribution of service uses at the regional, district, and local scales. Based on the contents presented in the previous scenario, in this scenario, the population density and the future population of the area were also considered 223 people per hectare and about 7800 people, respectively. Also, according to the guidelines provided in different fields, the proposed land use plan included residential, commercial, regional commercial use, mixed, mixed (with the dominance of residential use), religious land-uses, kindergarten, elementary school, high school, secondary school, street network, local green space, children's playing space, hospitals and healthcare centers, urban facilities, police offices, parking, sport centers, and open space uses among which, residential, street network, and open space had the largest share. As the name of this scenario suggests, it includes the most changes in the street network pattern, distribution of uses and transportation network as compared to the status quo scenario. In this scenario, a through street (major) in the western part of the site, a through street (minor) in the eastern part as well as two local collectors were proposed. To promote the grounds for pedestrian-orientation in the area, pedestrian and bicycle paths, in an integrated and interconnected manner, were considered between the residential blocks and service uses in connection with other modes of public transportation.

Therefore, as shown in the integration map (Fig. 3), in this scenario, the passages located at the western, southern, and northern edges have a very high integration level which is higher than the previous scenarios. Most importantly, in this scenario, the axis located at the eastern edge of the area has been enhanced in terms of integration level and has a high value of integration. In general, the texture of the area has relatively favorable integration in terms of integration of the street network and value of attendance in space and consequently the promotion of pedestrian-orientation grounds. In order to evaluate the location of service uses, the two layers of the street network integration and the proposed land-use plan were overlapped and, the resulted layer was analyzed. As shown in Figure 3, mixed and service uses are located are located in the vicinity of edges with very high and high integration according to the principles and criteria of energy efficiency-and public transportation-based development. Therefore, according to the information obtained from the map above, building density in the vicinity of passages with very high and high integration is 600% with 100% building area (6 floors).By distancing from passages and edges with high integration, this value is reduced to 300% considering 100% building area (3 floors).

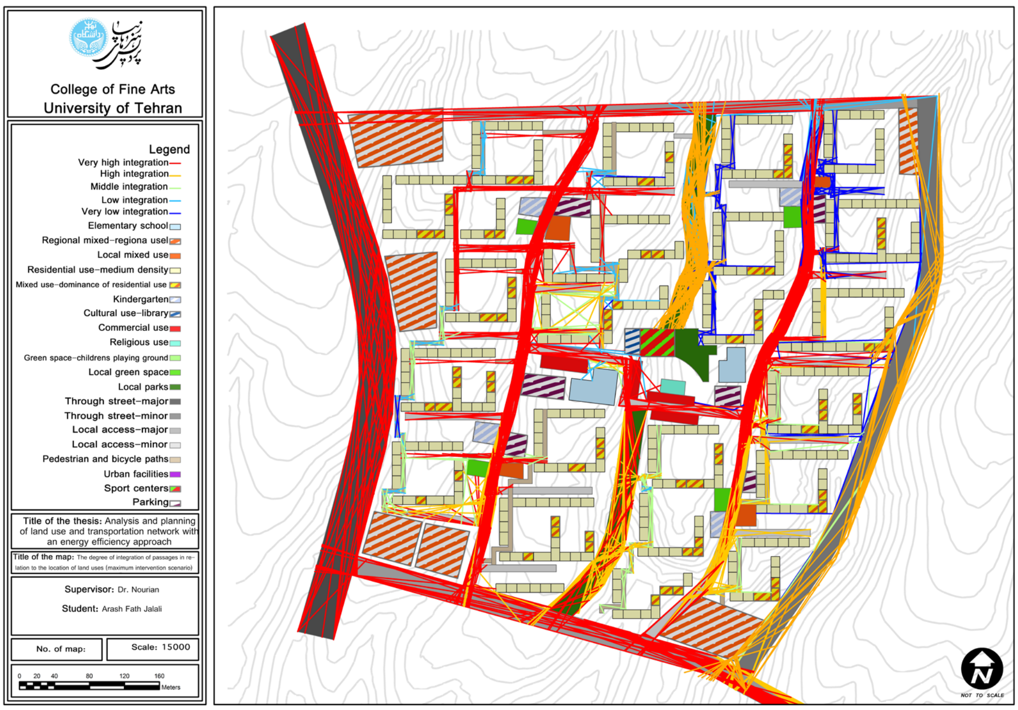

Fig. 3. The Degree of Connection and Integration of the Street Network in Relation to the Location of Land Uses (Maximum Intervention Scenario)

4.1.6. Analysis of Land Use Plan and Energy Consumption Based on the Distances between Residential and Service Uses in the Maximum Intervention Scenario

In the maximum intervention scenario, compared to the status quo scenario, by changing the distribution of service uses at the local and regional level, it was attempted to reduce travel distances (average distance to service uses) and consequently energy consumption in the transportation sector and greenhouse gas emissions in the study area. In the present scenario, the percentage of residential lots located between 200 and 500 meters from service uses (local trips) was reduced to zero percent, and also the percentage of residential lots located at distances more than 500 meters from service uses (regional trips) was reduced to 16.2 percent, leading to a reduction in energy consumption in the study area (its numerical value decreased to 3859767.12 liters per year). It has in a more favorable condition than the status quo scenario.

Table 4. Calculation of Energy Consumption in the Status Quo Scenario

Indicator	Third Scenario (Maximum Intervention)
Annual raw energy consumption due to local trips (liters)	3321658.53
Annual raw energy consumption due to regional trips (liters)	3321658.53
Annual raw energy consumption due to urban travels (liters)	3321658.53
Percentage of residential lots at a distance between 200 to 500 meters to service uses (local trips)	0
Percentage of residential lots at a distance of more than 500 meters to service uses (regional trip)	16.2
Total annual energy consumption due to local travels (liters)	0
Total annual energy consumption due to regional trips (liters)	538108.68
Total annual energy consumption due to urban travels (liters)	3321658.53
Total annual energy consumption in the transportation sector (liters)	3859767.12

5. DISCUSSION AND CONCLUSION

In the present study, based on the theoretical framework provided and the characteristics of the status quo of the study area (being uninhabited, unbuilt, , and having favorable opportunity for making changes and optimal modeling), three scenarios (status quo, minimum intervention, and maximum intervention) were developed for the area according to the principles and criteria developed based on energy efficiency and transportation-oriented development standards and then, they were evaluated using analytical methods described. . Moreover, the amount of energy consumption was calculated using CommunityVizsoftware). Accordingly, in each of the proposed land use scenarios, the uses were divided into two categories of residential and service uses. Then, based on the distance between service uses (as trip attractor) and residential uses (trip generation), the number of produced travels (annually) and then, the raw energy consumption (annually) were calculated using the analytical software (CommunityViz). In the next step, in order to study more accurately, separate local, regional, and urban trips, and extract the final annual energy consumption in each of the proposed scenarios, the percentage of residential lots at a distance between 200 and 500 meters (assuming that the trip is generated at a distance more than 200 meters) to service uses for local trips, and the percentage of residential lots at a distance of more than 500 meters to service uses for regional trips were identified and then, by multiplying this percentage by the value obtained for the raw energy consumption, the total annual energy consumption in the transportation sector was calculated for each scenario and used as the criterion for evaluation.

Table 5. Comparison of Energy Consumption in the Proposed Scenarios

Indicator	First Scenario (Status Quo)	Second Scenario (Minimum Intervention)	Third Scenario (Maximum Intervention)
Annual raw energy consumption due to local trips (liters)	3321658.53	3321658.53	3321658.53
Annual raw energy consumption due to regional trips (liters)	3321658.53	3321658.53	3321658.53
Annual raw energy consumption due to urban trips (liters)	3321658.53	3321658.53	3321658.53
Percentage of residential lots at a distance between 200 to 500 meters to service uses (local trips)	41.1	5.67	0

Indicator	First Scenario (Status Quo)	Second Scenario (Minimum Intervention)	Third Scenario (Maximum Intervention)
Percentage of residential lots at a distance of more than 500 meters to service uses (regional trips)	40	38.6	16.2
Total annual energy consumption due to local trips (liters)	1365201.43	188338.03	0
Total annual energy consumption due to regional trips (liters)	1328663.41	1282160.19	538108.68
Total annual energy consumption due to urban trips (liters)	3321658.53	3321658.53	3321658.53
Total annual energy consumption in the transportation sector (liters)	6015523.37	4792156.761	3859767.212
Percentage of changes compared to the first scenario	-	20.34	35.84

But the point to consider in this regard is to pay attention to the feasibility of the plan which greatly affects the superiority of the scenarios and selection of the better scenario. In this regard, based on the theoretical foundations on the one hand, and the results of evaluation and measurement of energy consumption in land use scenarios as well as the analysis of the proposed street networks on the other hand, it can be concluded that by changing the land use plan and street network in Hashtgerd New Town, a significant change in the amount of energy consumption in the study area (a neighborhood unit in Hashtgerd New Town) took place. In other words, the change in the space syntax of service uses, distribution of urban facilities, and characteristics of residential uses, as the grounds for urban land use planning, as well as the change in the form of street networks and integration of the transportation network have greatly affected the amount of energy consumption in the area. Therefore, the examination of various indicators developed in the research process show the important point that there is a relationship between land use, its distribution, street network, transportation, and energy consumption; and by making changes in land use and street network form and various transportation modes, a maximum of 36% reduction and a minimum of 21% reduction in energy consumption at local level in Hashtgerd New Town can be achieved.

It should be noted that the present study was conducted only in a 35-hectare in Hashtgerd New Town and has resulted in about 36% savings in annual energy consumption. Therefore, tf the guidelines for reducing energy consumption are applied in the land use plan and street network of all cities of Iran, this value will be very large, indicating the necessity of attention to this issue more than ever. Therefore, it is suggested to develop some guidelines for reducing energy consumption in the transportation sector in the field of urban planning and design to use as standards in various urban development projects.

REFERENCES

- American planning Association (APA)(2006). Planning and Urban Design Standard, London: John Wiley & Sons, Inc.
- Caves, R. (2005). The Encyclopedia of the City, London: Routeldge.
- Cervero, R., & Kockelman, K. (1997). Travel Demand and the 3Ds: Density, Diversity, and Design. *Transportation Research Part D: Transport and Environment*, 2(3), 199-219. https://doi.org/10.1016/S1361-9209(97)00009-6
- Dobbelsteen Van den, A., & Tillie, N. (2009). Towards CO2 Neural City Planning and Low-energy Redevelopment-Presenting the Rotterdam Energy Approach and Planning, Fifth Urban Research Symposium.
- Haughton, M., & Hunter, M. (1994). Sustainable Cities, London, Kingsley Press.
- Khalil, H.A.E.E. (2009). Energy Efficiency Strategies in Urban Planning of Cites, American Institute of Aeronautics and Astronautics, 7th International Energy Conversion Engineering Conference, August, Denver, Colorado. https://scholar.cu.edu.eg/?q=hebakhalil/publications/energy-efficiency-strategies-urban-planning-cities
- Kwon, E., & Leather, J.A. (2006). Urban Transport Energy Efficiency, Technical note, Regional and Sustainable Development Department, Asian Development Bank (ADB).
- Lantsberg, A. (2005). Sustainable Urban Energy Planning, A Roadmap for Research and Funding, California, California Energy Commission.
- Leitman, J. (1999). Sustaining Cities: Environmental Planning and Management in Urban Design, London: McGraw-Hill.
- Mitchell, G. (2005). Urban Development, Form and Energy use in Buildings: A Review for the Solutions Project, EPSRC.
- Morris, C., & Pehnt, M. (2016). Energy Transition the German Energiewende. Heinrich Böll Foundation, Available form: http://energytransition.de/wp-content/themes/boell/pdf/en/German-Energy-Transition_en.pdf (Accessed 21 August 2015)
- Okeil, A. (2010). A Holistic Approach to Energy Efficient Building Forms. *Energy and Buildings*, 42, 1437-1444. https://doi.org/10.1016/j.enbuild.2010.03.013
- Omer, A.M. (2008). Energy, Environment and Sustainable Development. *Renewable and Sustainable Energy Reviews*, 12(9).
- Steemers, K. (2003). Energy and the City: Density, Buildings and Transport. *Energy and Buildings*, 35(1), 3-14. DOI: 10.1016/S0378-7788(02)00075-0
- TOD Standards. (2017). R.cervero and Colleagues, Institue for Transportation Developent and Policy.
- UN-Habitat. (2009). Sustainable Energy Planning, ICLEI, Available at: http://www.unhabitat.org/content.asp?typeid=19&catid=555&cid=5607

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