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Analyzing the Effects of Land Use and Transportation Network on Greenhouse Gas Emissions Based on Low-Carbon City Approach*

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ABSTRACT

Nowadays, the effects of climate change are too tangible that drawn the international community's attention. The spread of this phenomenon has caused an increase in greenhouse gas emissions. On the other hand, the low-carbon city is a concept, which has attracted the global community. Also, land use planning affects greenhouse gas emissions due to determining the usage of the urban lands and the demand to travel. Therefore, Therefore, this can be achieved by developing criteria for applying the principles of the low carbon city in the process of land use planning and transportation planning. Moreover, the concept of the new town was raised in 1989 in Iran. As a result of this policy, new towns were designed around Greater Tehran, the most important of which is Hashtgerd. Despite the various issues, including the lack of integrated transportation systems and proper land use planning, it could not successfully achieve its goals. The current study first viewed the theoretical foundations of low-carbon. Then, three scenarios were suggested for 35 hectares of pristine lands in Hashtgerd, and the greenhouse gas production was calculated by measuring the amount of greenhouse gas emissions using CommunityViz Software. Space Syntax was also applied to scrutinize the roads. Findings show that there is a direct relationship between the form of the road network, land use, and greenhouse gas production. By applying changes in the form of the road network, development of the integrated transportation, and changing the Landuse distribution, the greenhouse gas emissions in transportation can be reduced up to 41%.

Keywords: Greenhouse Gases, Low-Carbon City, Land Use Planning, Transportation Planning, 35-Hectares Area.

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1. INTRODUCTION

The cities have a great contribution to greenhouse gas emissions as half of the world population lives in the cities, and based on the predictions, its share will reach 70% in 2050. Cities consume 80% of the world's energy and equally cause greenhouse gas emissions of the world (World Bank, 2011, p. 15). Furthermore, evidence and documents of IPCC show that the increased consumption of carbon-based energy and, as a result, increased greenhouse gas emissions are the main reasons for the global warming and climate change significantly emitted in the cities. In cities, different activities are performed with more intensity, and therefore a large amount of energy is consumed. Reversing this trend requires a fast and essential change to low-carbon development. Any delay in this regard will make it more difficult and costly to solve the problem. Hence, making low-carbon cities and design strategies is essential for more sustainable and livable global and regional development; thus, diverse and sophisticated urban activities need policy tools to be able to effectively deal with the global warming issue. It is required to measure and analyze the current greenhouse gas emissions and absorption in the urban sector to estimate the effects of the policy tools on greenhouse gas emissions (IPCC, 700, 69). Increased greenhouse gas emissions are caused by human production, burning fossil fuels, and land-use changes (Ibid, p. 64). Also, scholars and policy-makers increasingly accepted that land use planning and development strategies could decrease fossil fuel consumption. For instance, a compact city can reduce the travel demands to decrease fossil fuel consumption, and mixed development can reduce energy consumption. On the other hand, since the decisions on land use are often made at the local level, local land use planning plays a significant role in reducing the impacts of climate change (Hussey &Wei, 2009). Local powers have better realized that the global climate changes have a “local aspect” (Betsill & Bulkeley, 2007, p. 12). The local efforts play a significant role in reducing greenhouse gas emissions, and the local rules can affect the consequences of climate change. However, making a low-carbon city is a purpose to achieve sustainability. Also, some global reports on the performance of the countries in climate changes indicate the poor performance of Iran and the declining trend of its environment. In a published report from the German Watch 3 Institute entitled climate change performance index, Iran’s rank among other countries of the world is extremely poor. With the downward trend of this rank, Iran gained the second rank from the last in the two recent reports of this institute.

Although Iran is not among the industrial countries and has less contribution to the greenhouse gas emissions, compared to the developed countries, statistics of the greenhouse gas emissions in the countries around the world show Iran's high share in greenhouse gas emissions in comparison to its current conditions and the industrialization rate (without comparing it with other countries), which is concerning. Hence, it can be said that cities of Iran, like many cities of the world, are exposed to climate change, and its destructive impacts; Industrial cities, metropolitans, and new towns around them are among these cities. The concept of new towns was raised in 1989. This policy was raised for providing housing for the low-income class, decentralizing the metropolitans, and developing pre-planned urban planning, especially in Tehran. As a result of this policy, new towns were implemented around greater Tehran, the most important of which was Hashtgerd. Despite various issues, including lack of integrated transportation systems and lack of proper land use planning, this new town could not successfully achieve its goals. However, despite the issues, due to its pristine and new lands, having a pre-planned development plan can play a significant role in reducing the speed and process of greenhouse gas production. Therefore, as one of the new towns around Tehran and Karaj metropolitans, Hashtgerd can be a proper context for applying the principles and criteria of the low-carbon city, in particular, in transportation and land use, to reduce greenhouse gas production (carbon dioxide, carbon monoxide, etc.), which is the main purpose of the current study. The present study aims to evaluate land use planning and transportation network planning, as two main and essential elements in the spatial organization of the form of the cities, on the greenhouse gas emissions. In this regard, 35 hectares of the pristine lands located in Hashtgerd (known for 35-hectare area) was selected to study and assess the effect of these factors to determine that two what extent the greenhouse gas emissions can be reduced in the case study by changing the form of the road network and increasing its integration and changing the land use system in proportion to the low-carbon city principles and criteria.

2. THEORETICAL FOUNDATIONS

Theoretical foundations play a significant role in the current study; because to determine the goals, criteria, and indicators of the low-carbon city, the theoretical foundations of the low-carbon cities were reviewed and analyzed. Based on their application, the current study aims to determine to what extent the application of these indicators in the 35-hectare pilot area can be effective in reducing greenhouse gas production and emissions. Thus, in the following, the abovementioned were explained and defined.

2.1. Low-City Carbon: Definitions and Concepts

Scholars believe that low-carbon cities include not only low-carbon energy and low-carbon production but also low-carbon consumption and low-carbon society. A low-carbon city is defined as an inclusive reflection of the low-carbon production, low-carbon consumption- low-carbon environment, and low-carbon urban planning. Quantitative development ideas and theories, such as Energy-efficient city, Transit-Oriented Development, have already used the principles of low carbon development (Reed & Wilkinson, 2009, p. 34). Some of these ideas focus on using renewable energy. Some other theories of low-carbon emission take spatial strategies in planning, such as the compact city and the eco-city. Other ideas emphasize practicing policies and rules to reduce carbon emission. Although many countries and regions have already helped control the carbon phenomenon, a low-carbon city is a novel and new concept, which there is no consensus on its definition. Cities must try to define a low-carbon city locally. The challenge is how to develop local social qualities in the framework of global sustainability (Roseland, 2012, p. 10).

Therefore, according to the definitions of a low-carbon city and its main and key purposes, principles of the low-carbon city can be summarized in a holistic view, as follows:

1. Reducing carbon emissions through re-organization of the urban activities in different sectors;
2. Change towards the compact urban structure;
3. Development and conservation of the green infrastructures (Bagheri, 2015, p. 2).

2.2. Low-Carbon City Aspects

Various aspects recognized by sustainable development include the aspects of the low-carbon city as well. However, they are different in analysis, focus, and strategy. Here, four aspects of the low-carbon and local green communities will be explained as follow:

- Harmony and Compatibility with Nature

Our ecosystem is an interconnected network, relating the being of the human with other creatures of the natural environment. In other words, human communities are a part of an ecosystem that must agree with environmental principles and conserve harmony and balance of the system. A low-carbon city is necessary for achieving harmony and compatibility with the natural ecosystems; a city, which its consumption is not more than nature, can produce energy or reuse it yet discharging its waste is at the minimum level (Cheng & Chang, 2012, p. 42). Moreover, a low-carbon adjusts the system to respond to the predicted and expected climate effects. The natural environment is a great capital, and reduction and compatibility strategies help conserve cleat weather, absorb carbon, and reduce draughts and floods (Golij & Sharifzadegan, 2014, p. 55).

- Health

This aspect is directly associated with the natural system and emphasizes the living conditions of people. Currently, we witness low relative density, automobile-oriented suburbs with high-quality housing and infrastructure. Such scattered development results in natural disasters, such as floods, hurricanes, increased temperature, air pollution, particularly increased greenhouse gas emissions (Frank, Engelke, & Schmid, 2003).

- Spiritual Wellbeing and Renewal

Human communities are essentially related to the natural systems and must seek the nature of renewing spiritual wellbeing. Technology-based life in the current age causes an essential disturbance and disorder, resulting in a reduction in the number of forests. Thus, low-carbon cities must be made to establish a relationship between human beings and the natural environment. Strategies, such as conservation of the native species against climate changes, making urban gardens to reduce urban heat islands and preservation of the stable temperature of the wetlands, increase the physical, spiritual, and mental health and provide a sense of commitment to the place in the residents (Beatley & Stephen, 2004, p. 65).

- Livable Built Environments

The aspect of Livable built environments emphasizes design characteristics of the physical land use, such as urban forms, density, and mixed land use in low-carbon urban planning. Livable built environments include urban design tools that are compatible with the required activities, lifestyle, and desires of the residents (Hester, 2006, p. 43). A low-carbon city must encourage the higher density development models, diverse transportation choices, green buildings techniques, and alike to support the sense of the place with the built attractive environmental landscape, such as walkable streets and delightful landscapes (Golij & Sharifzadegan, 2014, p. 56).

2.3. Principles of Low-Carbon City

There are generally four principles for the low-carbon city provided in the global theoretical literature and texts, summarized in the following.

2.3.1. Reducing Carbon Dioxide Emitted from Urban Activities and Structure

Reducing carbon dioxide emissions are two essential and fundamental steps to decrease global warming. Carbon dioxide emissions are often caused by energy consumption. Therefore, energy policy focuses on energy saving among the transportation, residential, industrial sectors and providing green renewable energy resources. The green belts around the urban complexes must be revitalized and developed to absorb carbon dioxide. Greening the urban space will create barriers against the phenomenon of heat islands in cities. As previously mentioned, it seems that urban restructure towards a compact urban form will have a favorable effect on the carbon dioxide emission level. Also, to reorganize urban activities and functions, open and public green spaces must be developed to reduce carbon dioxide emissions from various socio-economic activities (American Planning Association, 2008, p. 8).

2.3.2. Change Towards a Compact Urban Structure

A compact urban structure is perceived as an interconnected network of the central built region and other essential transportation hubs in the metropolitan area. The central hubs are centers for attractive urban functions and collecting population. These interconnected regions are effectively connected to the other neighborhoods in the metropolitan region by public transportation, providing better livability for the citizens and ensuring the sustainable development of the metropolitan region, as a whole (Ibid, p. 8).

2.3.3. Increasing Energy Efficiency in Different Sectors with a Focus on Land Use and Transportation

Making an urban energy system with high efficiency and low carbon emission is one of the main principles of a low-carbon city. Therefore, the urban restructure must be implemented in integration with the energy-related criteria. The mixed and compact land uses accumulated in the interconnected centers include high-rise buildings for residential and commercial purposes. The concentration of the energy demand in the integrated regions and equalizing the energy consumption in the transportation sector will be reduced, provided that the citizens of a metropolis dwell and work in a compact and responsive urban structure, and meet their daily needs; Because their daily travel distance will be reduced and the total demand for the transportation in the metropolitan region will be decreased (Zhang, 2011, p. 36). Reduction in the travel distance will encourage the changes from using personal vehicles to towards cycling and walking. When the traffic demand increases its density in the urban structure, the performance of the public transportation will be good enough to improve the frequency of the services and comfort, facilitating the change from the personal vehicle towards public transportation. Also, a recent survey about the climate change plans in 30 cities of the world showed that public transportation development (High-speed transportation systems), creating technology parks, improving non-vehicle transportation, and public awareness will be effective in reducing climate changes and greenhouse gas emissions in the transportation sector (United Nations, 2011, p. 28).

Table 1. Reducing Greenhouse Gas Emissions through the Built Environments (Transportation)

Design Type	Descriptions
New Low-Carbon Transportation Infrastructures	Plans to Reduce the Demand for Energy and Water Consumption and Garbage Collection
Renovating the Low-Carbon Infrastructures	Renovating and Improving the Transportation Infrastructures to Reduce Greenhouse Gas Emissions
Alternative Transport Fleet	Replacing the Fleet with Low-Carbon Energy-Efficient Vehicles
Changing the Fuel Type	Changing the Use of Fossil Fuels to Provide the Energy for the Fleet to the Low-Carbon or Renewable Energies
Increasing Energy Efficiency	Taking Measurements to Increase the Energy Efficiency of the Current Vehicles and Using Them
Demand-Reduction Measures	Taking Measures to Reduce the Demand for the Personal Motor Vehicle
Demand-Increase Measures	Taking Measures to Increase the Demand for Alternative Modes of Public Transportation, Walking, and Cycling.

(United Nations, 2011, p. 10)

2.3.4. Increasing Carbon Storage and Uptake

In this section, paying attention to the green space in urban regions is of great importance. Greenery is one of the key elements to be considered in designing a low-carbon urban structure. Plant life functions to eliminate carbon dioxide and reduces the destructive urban microclimates. Therefore, it indirectly helps reduce carbon dioxide emissions. In terms of biomass energy, vegetation will play a significant role in the urban structure. Developing the region and improving the quality of the green spaces both in the built regions and remote suburban, will positively contribute to developing the low-carbon metropolis. Also, it must be noted that urban management institutions often have a multi-purpose approach. For example, an increase in the coverage lot of the building and traffic volume are the signs of a growing city. It is fairly difficult for urban managers to make decisions comprehensively by balancing the need to support such an urbanization process with the need to reduce carbon emissions (American Planning Association, 2008, p. 14).

2.4. Research Theoretical Framework

As a result of reviewing the theoretical literature on low-carbon cities, it can be said that various criteria were presented in resources regarding land use planning, urban transportation, and urban planning, in general. Accordingly, in this section, as the most important achievement of the theoretical foundation of research, the final criteria of the urban planning affecting the greenhouse gas emissions and production and energy consumption were explained (due to the interdependency between energy consumption and greenhouse gas emissions, criteria of low-carbon city and energy-efficiency were used). Then, they were considered research criteria in the next step, and suggested scenarios were presented based thereon. Also, the achievement of the criteria of the low carbon city in the proposed scenarios in different fields, according to the studies conducted in the theoretical texts related to the research topic, has been compiled, which are discussed in detail in Table 2.

Table 2. Compiling the Influential Urban Planning Criteria on the Greenhouse Gas Emissions and Production Based on Low-Carbon City Approach (The Theoretical Foundation of the Research)

Criteria	Polices to Achieve the Criteria
Compact and Dense Form (Sustainable)	- Locating the public facilities and service infrastructure in the integrated centers and attracting the residents to them. - Regular and permanent public transportation lines with a maximum temporal distance of 20 minutes (except for BRT and subway) (Cervero & Kockelman, 2017, p. 20). - Locating or relocating the great consumers of the heat in adjacent of the renewable and unused energy resources (Kim, 2018). - Shaping a metropolitan green network by increasing green surfaces in the built regions and protecting the green belts or the area in the remote regions.
Harmony and Compatibility with Nature	- Maintaining open spaces and increasing the green space share in each area (Kim, 2018). - Using shading trees in sidewalks and trails. - Using environmental-friendly technologies in the construction and transportation network.
The Mixture of Land Uses	- Diverse combination and mixture of the stores, administration centers, apartments, and houses; - The maximum walking distance from the closest center for supplying daily needs: 200 meters. - Conservation of the suburban lands. - Less vehicle dependency, less fuel consumption in the transportation section and encouraging the public transportation, more opportunity for walking. - Encouraging for social life and better surveillance and, as a result, increased public security. - Self-sufficient public transportation and reducing the car dependency and travels; - Decreasing the distances due to the mixed land uses and high population density; - Reducing the costs caused by global warming, as a result, compact urban form along with less fuel and pollution.
Walkability or Pedestrian-Orientation	- Providing pedestrian access to the entire area and land uses within the area; - Pedestrian access (maximum 10 minutes) to most local activities and land uses; - Designing pedestrian-oriented routes and, in some special cases, vehicle-free pedestrian roads. - Visually activation of the ground floor (Cervero & Kockelman, 2017, p. 20). - Ground floor physical permeability; - Proper shading on sidewalks to encourage walking and provide climatic comfort; - The length of sidewalks should be at least 1.8 meters (Ibid, p. 20).
Integrated and Efficient Public Transportation and Road Network	- Developing and improving roads connections to slow down vehicle traffic flows. - Northern-southern orientation of the vehicle access is recommended to use the maximum amount of sunlight in winter and southern win in summer. - Safe and proper pedestrian and bicycle lanes must be provided. - Reducing the vehicle width inside the neighborhood to enhance pedestrian safety. - Public transportation stations must have 250-meter radius coverage. - Neighborhood centers and units and public transportation stations must be located in compatible with each other. - Providing parking lot adjacent to the public transportation stations; - Reducing parking space in the area to reduce the vehicle-dependency - The maximum walking distance to the closest public transportation stations must be 1 kilometer. - The maximum walking distance to the closest direct transportation services to the public transportation station with high capacity: 500 meters (Cervero & Kockleman, 2017, p. 20). - All the parking lots must be considered off-street (Kim, 2018).

Criteria	Polices to Achieve the Criteria
Urban Divisions	- The area of different levels of divisions should be determined according to the radius of access to service centers to be accessible by walking and bicycle. - A balanced distribution of service centers in the area; - Providing service land uses for residents according to the access network hierarchy; - Determining the maximum and minimum population to distribute the population evenly in the area; - Composition and type of activities in the proposed distribution centers to increase the vitality and encourage the presence of residents; - Defining central elements for each division as an element whose radius of each division is determined by access to it.
Building Density and Height System	- Increasing the density and compactness of the settlement model. - Increasing the building density as much as possible. - The height and adjacency of the buildings to each other must be controlled to prevent shading by buildings. - Increasing building density in the adjacency of the Transit-Oriented Development. - The height of the buildings must be increased on the side of the prevailing wind in the winter.
Distribution of the Service and Travel Attracting Land Uses	- Locating the service land uses in the walking (150-250 meters) and bicycle distance (400-600 meters) (Cervero & Kockelman, 2017, p. 17). - The level of the mixed land uses must be increased horizontally and vertically and distributed in a scattered way. - Mixed land use levels should be increased vertically and horizontally in the area and distributed sparsely. - Service land-use hubs must be distributed sparsely. - Integrated locating of work and activity centers in the study area; - Establishment of regional and district land uses at the outer edges of the area.

3. METHODOLOGY

The current study was quantitative and applied research. In this regard, the research method was "planning", "simulation (Modeling)", and "documentation and analysis". Measurement models and methods of greenhouse gas emissions in the city have a very diverse range. On the other hand, nowadays, the role of software in urbanism is undeniable. Using software not only accelerates the planning process but also greatly increases the accuracy of the design in case of using proper tools. Therefore, different models for measuring the greenhouse gas emissions and production in the city provided the ground and basis for developing various software in this area.

3.1. Measurement Models and Methods of the Greenhouse Gas Emissions in the City

Measurement models and methods of greenhouse gas emissions in the city have a very diverse range. Thus, it is essential to recognize and investigate them to determine the required and compatible model and tool with this research. To this end, identifying, explaining the features and characteristics of measurement models and methods, and classifying them based on their features is an important step in the current research. Therefore, measurement models and methods of the greenhouse gasses have different classification as follow:

1. Classification based on the scope of function
- Single-sectors models
- Multi-sectors models
2. Classification based on the methodological nature
- Spatial/ non-spatial models
- Simulation/ provisional models
- Observation-based/ process-based models
3. Classification based on the scale

There is a variety of software related to the research subject (greenhouse gas emissions and its measurement), each of which has its specifications. The distinction between the software is generally summarized in the features of the applied model in them. In other words, the difference between this software is generally summarized in the features of the model used in them; In other words, based on the characteristics of each software in terms of key features of the model used (scale, methodological nature, and scope), its capabilities vary. It must be noted that one of the key factors distinguishing the analytical tools of the greenhouse gas emissions and production is the capability of using these tools in the urban planning process, which is effective in the influence and capability of using the software. Also, the research characteristics are the main and determining factor of the analytical tools used in the research. Also, the broadness of software available in this field and the different characteristics of each reveals the necessity to determine the basic research requirements to select the appropriate software.

3.2. Introducing Software

To measure the amount of the greenhouse gas emissions caused by the transportation sector, CommunityViz software was used as an analytical and measurement tool for the produced travels based on the type and way of the urban land use distribution, and consequently, the amount of greenhouse gas emissions. This software is one of the plugins of ArcGIS, which measures the number of travels based on the land use plan, or in other words, based on the distances between the service land uses (travel attraction) and residential land uses (travel production). Thus, based on the number of the produced travels and determining the travel distance, the annular amount of the greenhouse gas emissions in the transportation sector can be estimated and calculated. Given the research purpose, which is determining the relationship between land use, road network, and transportation, and the amount of greenhouse gas emissions and production, and since integrity is one of the influential factors in enhancing the walkability and integrated transportation development, and subsequently, reducing the personal travels and greenhouse gas emissions, Space syntax technique, and its software, DepthMap was applied in this regard. On the other hand, layers of ArcGIS and DepthMap were overlapped to accurately display and analyze the road network and land use, simultaneously to present the suggested land-use scenarios and locating the public transportation stations based on the land use system and roads integration. To this end, a mediating and flexible software called Mapinfo was also used (only for converting the format and transferring the information from DepthMap to ArcGIS), which was employed in the research process (analysis of findings), and analysis of each of the suggested scenarios.

3.3. Study Area

To evaluate the effect of the land use planning and transportation network components on the greenhouse gas emissions, a site with a 35-hectares area in New Town Hashtgerd was considered as the case study due to its pristine lands and the possibility of the pre-planned intervention and application of the principles and criteria extracted from the theoretical foundations. Hashtgerd is located in the southern hillside of the Alborz range, west of Tehran and between the Qazvin-Karaj highway. Its distance from Karaj, Tehran, and Qazvin are 60, 25, and 75 km, respectively. Hashtgerd, with an area of 4461 hectares, is located at latitude and longitude of 35 and 50 degrees, respectively. Also, according to the census of 2016, the population of this town was 16000 (About 11% of the prediction of the approved master plan for 2006) (Master Plan of Hashtgerd, 2005).

4. VALIDATION AND ANALYSIS OF DATA

After industry and construction sectors, the transportation sector is the largest consumer of energy and producer of greenhouse gasses in the cities. This sector is associated with the energy consumption in automobiles through which it is measured. In other words, by determining the number of the generated travels by the various land uses, the amount of the greenhouse gas emissions in the transportation sector in the cities can be indirectly measured.

4.1. Calculation Method

As previously mentioned, the number of the generated and attracted travels to various land uses was the main influential factor on the energy consumption and greenhouse gas emissions and production in the transportation sector. In other words, the land uses can be classified into two groups: origin (travel-generating) and destination (travel-attracting), based on which the number of the generated travels between the origin and destination, the amount of the greenhouse gas emissions, and production in the transportation sector can be determined. Assumingly, service land uses (such as educational, commercial, administration, health, etc.) are the travel-attracting, and residential land use is the travel-generating. On the other hand, if the distance between the travel attracting and travel generating land uses (origin and destination) is walking or cycling, vehicle travel will not occur. Therefore, the amount of greenhouse gas emissions and production can be obtained by determining the average distance between the travel origin and travel destination and comparing it in various scenarios. Accordingly, first, considering the number of the generated travel by all residential land uses, the amount of the greenhouse gas emissions in the transportation sector was calculated using CommunityViz software. Then, the average distance between the residential buildings and different service land uses on the local and district scales was calculated using the analytical tool of the common impacts (the averaged distance to the desired points). Finally, the initial amount of the greenhouse gas emissions was calculated and was multiplied by the percentage of the residential units the average distance of which to the service centers is more than 250 meters, and the amount of the generated greenhouse gas emissions in the transportation sector was calculated for different scenarios. It is noteworthy that the service centers in this analysis were considered on two local and district scales, and the distance was calculated for each.

4.2. Required Data and Model Implementation Process in Software

The required data to use the analytical tool of the common impacts have the same format given that this software and ArcGIS have the same environment. Therefore, two information layers are required for each scenario. The first layer is the residential plots layer, including the spatial location of each plot and the number of households in the plot. The second layer is the desired places, including the land uses on the local scale, such as kindergarten, elementary school, local business, playground, mosque, library, and on the district scale, including the middle school, health, and administration land uses. Thus, first, by inputting the layer of the buildings of each scenario and its required information, the crude amount of the greenhouse gas emissions in the transportation sector was calculated. Then, the layer of the service land uses was also inputted into the analytical tool of the common impacts, and the average distance of buildings from these points was added to the buildings layer as an information column. Finally, by calculating the percentage of the more than 200-meter distances for the local land uses, and 500 meters for the district land uses, the final amount of the greenhouse gas emissions in the transportation sector was obtained for each scenario. It is noteworthy that the assumptions and consumption standards used in this software are adjusted with the global standards, the amount of which is different from the Iran and Hashtgerd standards. However, given that purpose of this measurement is the comparison between the suggested plans and the low-carbon city approach, the difference between the standards and initial assumptions will not disrupt the research process. As previously mentioned, in the second section, the space syntax method and DepthMap software were used to analyze the road network and determine its integration. The information layer required for this software is the blocking layer and the raw blocks in the AutoCAD software with DXF format, which is required for implementing the initial analysis. Then, after analyzing and determining the integration of the roads, MapInfo was used to transfer the spatial and descriptive data. The information resulted from the space syntax analysis was inputted in the software with MIF format, and was changed into Shape format, which is valid for ArcGIS software.

Table 3. The Required Data for Analytical Software of the Research

Software	Required Input Data	Output Data and Information	Output File Format
CommunityViz	Data related to the residential and service land uses (data with ShapeFile format)	Determining the annual crude amount of the greenhouse gasses based on the travel numbers between the residential and service land uses (travel-attracting)	Shape File GeoDataBase
DepthMap	The raw form of the blocking and the roads of the study area (DXF format)	Determining the integration of the road network based on the graphs theory	- MIF
MapInfo	Maps with different formats of MIF, SHP, and DBF	Transferring and converting the data from DepthMap to ArcGIS	- SHP - DXF - DBF

4.3. Analyzing the Amount of Greenhouse Gas Emissions and Generation in Scenarios

The first scenario, i.e., investigating the status quo, was evaluated based on the data in the review of the master plan of Hashtgerd town and based on its suggested land use plan and transportation. In the second scenario, which is the minimum intervention, the application of the theoretical framework extracted from the theoretical foundations through the least intervention and the most optimal intervention in the status quo was addressed. The third scenario is the maximum scenario (the maximum efficiency), that the maximum intervention in the status quo (suggested upstream plan) was considered to obtain the maximum reduction in the greenhouse gas emissions and generation in the study area. In the following, all the above mentioned were investigated in each scenario (status quo, minimum intervention, and maximum intervention) and the characteristics of each scenario were stated. Then, the top scenario was selected in terms of more compatibility with the environment of the study area. Finally, instructions and strategies were presented to achieve a low-carbon city or zero-carbon city in the study area and upstream planning.

4.3.1. Analyzing the Land Use and Integrity of the Transportation Network in the Status Quo

4.3.1.1. Principles and Instructions as the Criterion for Action

The standards and principles as the criterion for action in the scenario of the status quo are as follows:

4.3.1.1.1. Residential Land Use- Residential Blocks

The suggested per capita for residential land use is 18 square meters.
The minimum land area in the residential land use per unit in the medium density is 75 square meters, and in high density, is 40 square meters.
The minimum area for subdivision in the medium building density is 300 square meters.

4.3.1.1.2. Service Land Uses

Service land use per capita is suggested 10.5 square meters in total.
Service land uses are located linearly on the eastern side of the study area.

4.3.1.1.3. Road Network

The suggested hierarchy of the road network is a main arterial road, secondary arterial road, and main local access street, secondary local access street.
The width of the main arterial road is 45 meters, the secondary arterial is 35 meters, the main local access street is 24 meters, and the secondary local access street is 16 and 18 meters. Parking is provided for the service land uses.

4.3.1.1.4. Density and Height System

Medium and high density is suggested for the residential land uses in the area.
The coverage lot of the residential land use with a medium density of 180-240% is 60%, and with a high density of 280% is 40%.
In the status quo scenario, the recommendations of the Hashtgerd master plan review (2006) were analyzed and assessed. The recommendations for the land use of the study area are as follows:
Social facilities: kindergarten, elementary school, middle school, and cultural land uses.
Service and commercial/industrial land use with service characteristics: local stores, district stores, administrative and military.
Residential units.
Moreover, the population density for this area was suggested 223 people per hectare in the upstream plans. Therefore, the future population of the area is estimated to be approximately 7800, given its 35-hectare area. Also, the suggested land uses by the master plan for this area are residential, commercial, elementary school, high school, middle school, health, road network, green and open space, religious, military, parking lot, and sports. Residential land use with 43% has occupied the largest share of space. The road network, with about 30%, after residential use, has a high share of the proposed land uses of the current scenario. Also, connectivity and integration of the roads in the current study were analyzed to assess the presence of the pedestrian, walkability, distribution of the service, and travel-attracting land uses in the scenarios with maximum and minimum interventions. Therefore, in the scenarios of the status quo, the road network and access network model suggested in the master plan review of Hashtgerd were analyzed and assessed to determine the travel-generating pattern in the area. Thus, according to the space syntax analysis, the integrity in the road networks in most points of the 35-hectare site enjoyed low and very low integrity value (western, northern, and eastern roads), and parts of the central road of the area had high and very high integrity. In general, it can be said that the road network has medium downward integrity, indicating the low realization of the integrity principle of the road network, transportation, and compactness of the context, which is one of the main principles of the low-carbon city. Thus, as a result, the residents will be more encouraged to use a personal vehicle, and the travel generation rate and greenhouse gas emissions in the transportation sector will be raised.

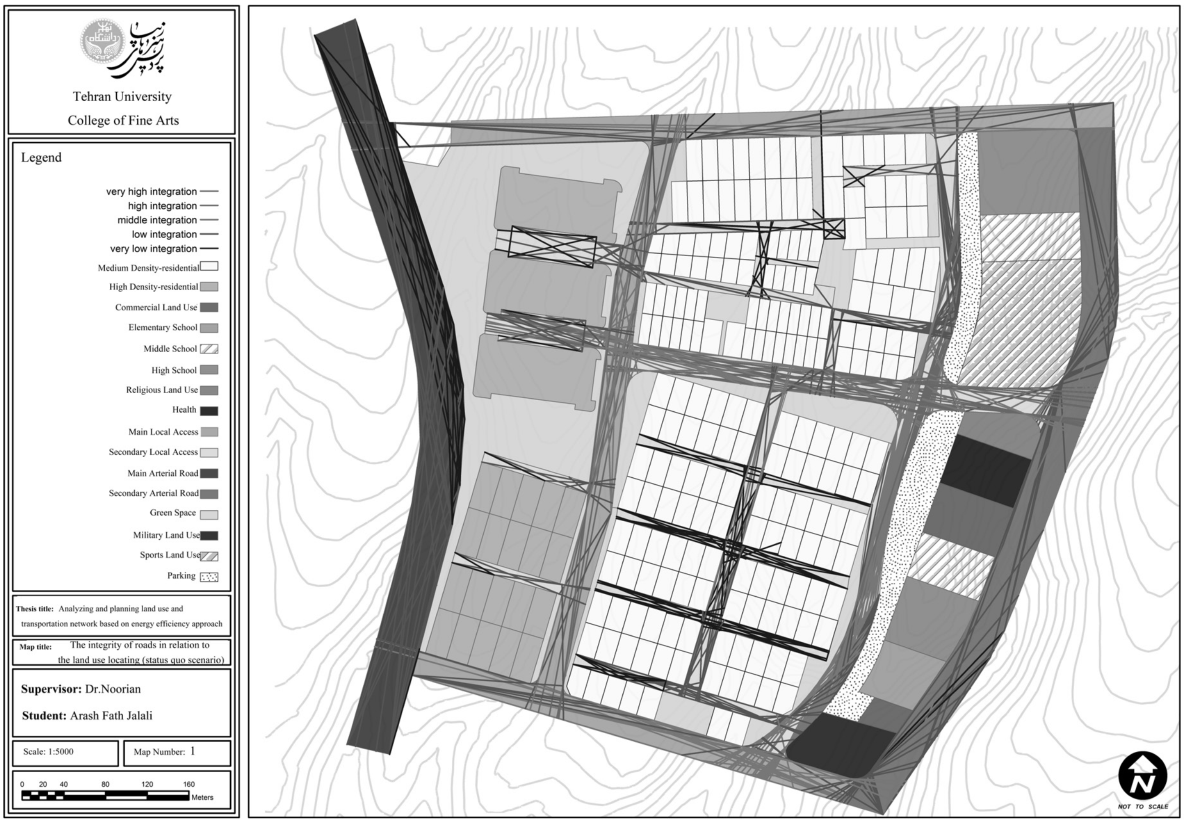

Fig. 1. Connectivity and Integrity of the Access Network Regarding the Land-Use System (Status Quo Scenario)

4.3.1.2. Analyzing the Land Use System and Greenhouse Gas Generation Based on the Distances between Residential and Service Land Uses

As previously mentioned in the methodology, CommunityViz software was used to calculate the number of travels and the amount of greenhouse gas emissions in the transportation sector. In this method, the service land uses are as the travel-attracting places and the travel begins from the residential land uses to these land uses. One of the reasons for generating these travels is the distance between the origin of the travel (residential buildings) and travel destination (service land uses). If this distance is less than the walking and cycling access (which was assumed 500 meters for district land uses and 200 meters for the local land uses), no travel will be generated. Accordingly, the average access of each one of the residential plots to the service land uses and the percentage of the plots that are located in more or less distance than this value was calculated for the suggested scenarios. Then by multiplying this percentage by the crude amount of the greenhouse gas emissions caused by the local and district travels, and by adding it to the crude amount of the greenhouse gas emissions caused by the urban travels, the total amount of the greenhouse gas emissions (CO, NO, CO_2, and hydrocarbons) in the transportation network was calculated for the suggested scenarios as follows:

Table 4. Calculating the Generated Greenhouse Gases in the Status Quo Scenario

Index	The First Scenario (Status Quo)
Crude Emission of CO_2 (kg/year)	13094278.86
Crude Emission of CO (kg/year)	296878.52
Crude Emission of NO (kg/year)	21891.33
Hydrocarbons Emissions (kg/year)	34024.16
Total (kg/year)	1662221.87

Therefore, according to the abovementioned, the diagrams obtained from the analyzes in the software environment and the relevant analytical model, it can be said that the amount of crude emission of carbon dioxide (CO_2) is 13094278.86 kilogram per year, based on the suggested master plan, i.e., status quo. Also, the crude emissions of carbon monoxide (CO), nitrogen monoxide (NO), and hydrocarbons in the study area are 296878.52 kg/year, 21891.33 kg/year, and 34024.16 kg/year, respectively.

4.3.2. Analyzing the Land Use and Integrity of the Transportation Network in the Minimum Intervention Scenario

4.3.2.1. Principles and Instructions as the Criterion for Action

The principles and standards in the minimum intervention scenario are as follows:

4.3.2.1.1. Residential Land Use- Residential Blocks

35-square meter per capita for residential land use is the criterion for action to provide environmental comfort for the residents, and the area of the residential plots is reduced to 150 square meters.

4.3.2.1.2. Roads Network and Public Transportation

The level of roads, especially its covered area, should be reduced in the area.

The vehicle and pedestrian routes must be suggested in compatibility with the counter lines of the area and slope of the status quo.

The northern-southern vehicle accesses are suggested.

Safe and appropriate pedestrian and bicycle roads are provided in the area and connect the residential blocks.

The width of the vehicle roads is reduced.

The priority in the main and secondary local access streets is given to the pedestrian and bicycle movement.

The road networks must be in line with the roads suggested in the master plan.

The bus and minibus stations must have a radius coverage of 250 meters.

The public transportation routes and stations must be in line with neighborhood centers and units.

Parking lots must be provided in the adjacency of the minibus stations (in the neighborhood).

4.3.2.1.3. Building Density and Height System

The maximum building density of the residential land use is increased to 320%.

The coverage lot of the residential land use is increased to 80%.

The maximum height of the residential buildings is 4 floors.

The value of the area and per capita of the green and open space must be increased.

The residential density was considered average for the whole area.

4.3.2.1.4. Service Land Uses

Kindergarten, children's playground, green space of the neighborhood unit, and mixed land use (in neighborhood unit) are considered the service land uses on the neighborhood scale.

Elementary school, religious, cultural, sports, and small-scale commercial land uses, and neighborhood parks are considered the service land uses on the neighborhood scale.

The service land uses are located within walking and cycling distance (200-500 meters).

The mixed land uses with the dominance of the residential land use are vertically distributed as mixed land use in the area.

Four accumulation centers of the service land use on the neighborhood unit scale are equally distributed.

The mixed land uses are distributed at the level of the centers of the neighborhood units.

The service land uses on a district scale are located on the external edge of the area.

To provide equal conditions to compare the suggested scenarios of the land use, population density, suggested population, and the area of service land uses was considered similar, and the changes were applied in their distribution. Therefore, in this scenario, with a population density of 223 people per hectare, the future population of the area was approximately considered 7800. According to the presented instructions in different areas, the proposed land-use plan includes the following land uses: residential, kindergarten, commercial, commercial-district, elementary school, high school, middle school, cultural, health, mixed land uses, mixed land uses with residential land use dominance, road network, green space of neighborhood unit, children's playground, religious land use, urban facilities, military land use, parking, sports, and open space among which, residential uses, road network, and open space, have the largest share. In the scenario of minimum intervention in the road network and the proposed access network model based on the principles and criteria in the theoretical framework, the minimum intervention has been made in the status quo to determine the travel generation model and presence in the area. According to the proposed instructions in the road network, in the study area, the proposed main arterial roads of the review plan were preserved around the area. Also, based on the topographical features of the site, two northern-southern vehicle roads (12-meter width and bicycle lane) were proposed within the area, and walking and western-eastern access to the building blocks are defined. As previously mentioned, in this scenario, the proposed road network and transportation is 250 meters based on the coverage radius, and distribution of the travel-attracting land uses (service land uses). Thus, considering that the location of the stations of the public transportation is determined based on the density of the travel-attracting land uses and more presence of the residents, the connectivity and integrity of the road network, and the presence and travel demand in the minimum intervention scenario were analyzed based on the space syntax analysis, the results of which are as follows:

The results show that in the minimum intervention scenario, due to respecting the low-carbon city principles and criteria, the integrity has been desirably increased to the status quo scenario, resulting in encouraging the residents to use their cars less. Therefore, as Figure 2 shows, the integrity of the southern-northern axis, western-eastern connecting axis located in the center of the site has been high and very high. As a result, considering the principles and criteria based on the public transportation and low-carbon city, the stations of the public transportation with access radius of 200-250 meters were located in the adjacency of the roads with high and higher integrity, and the building density reduces by taking distance from the stations. As can be seen in the ArcMap and DepthMap layer overlap, it was attempted to propose the access network in proportion to the distribution of the service land uses, travel-attracting land uses, and the status quo topography in the minimum intervention scenario; thus, while reducing the travel distances between the stations of the public transportation, they are located at the most optimal place and function integrated and concerning other transportation modes, such as walking and bicycle.

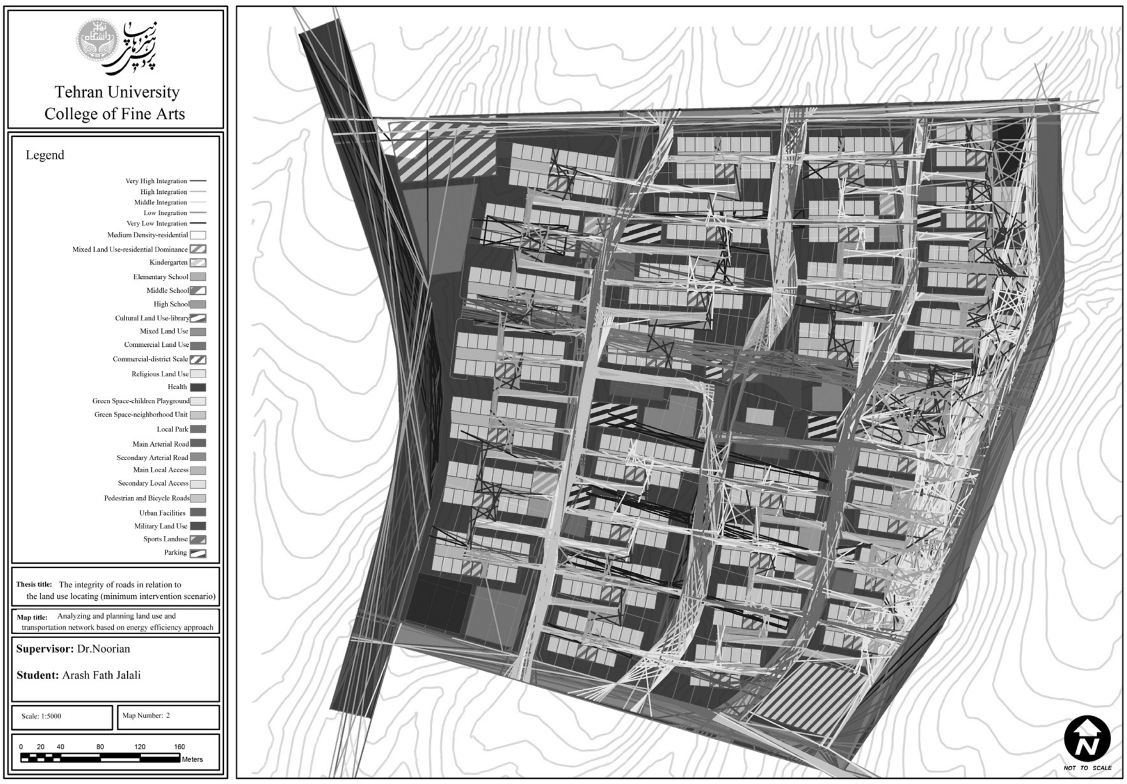

Fig. 2. Connectivity and Integrity of the Access Network Regarding Locating the Service Land Use (Minimum Intervention Scenario)

4.3.2.2. Analyzing the Land Use System and Greenhouse Gas Emissions Based on the Distances between the Residential and Service Land Uses in the Minimum Intervention Scenario

In the minimum intervention scenario, it was tried to reduce the travel distance (average distance to the service land uses) and greenhouse gas emissions in the study area by changing the distribution of the service land uses on local and district scales to the status quo scenario. In the current scenario, the percentage of the residential land uses located 200-500 meters away from the service land uses (local travels) was reduced to 67.5%. Also, the percentage of the residential land uses located more than 500-meters distances from the service land uses (district travels) was reduced to 38.6%, reducing the greenhouse gas emissions in the study area. Also, its numerical value was reduced to 981726.84 kg per year, which is a noticeable reduction to the status quo scenario.

Table 5. Calculating the Generated Greenhouse Gases in the Minimum Intervention Scenario

Index	The Second Scenario (Minimum Intervention)
The Amount of Generated CO2 Emission (kg/year)	772251.84
The Amount of Generated CO Emission (kg/year)	175087.90
The Amount of Generated NO Emission (kg/year)	12910.69
The Amount of Generated Hydrocarbons Emission (kg/year)	20066.18
Total (kg/year)	981726.84

4.3.3. Analyzing the Land Use and Integrity of the Transportation Network in the Maximum Intervention Scenario

4.3.3.1. Principles and Instructions as a Criterion for Action

Principles and standards of the criterion for action in the maximum intervention scenario are as follows:

4.3.3.1.1.Residential Land Use-Building Blocks

35-square meter per capita for residential land use is the criterion for action to provide environmental comfort for the residents. The building plots with 120, 150, and 200 square meters are proposed.

4.3.3.1.2. Building Density and Height System

The maximum building density for residential land use is increased to 300-600 %.
The coverage lot of the residential land use is increased to 100%.
The maximum and minimum height for the residential buildings is 3 and 6 floors, respectively.
The area and per capita of the green and open spaces must be increased.
The building density is considered medium for the whole area.

4.3.3.1.3. Service Land Uses

Kindergarten, green space at neighborhood unit, and mixed land use (neighborhood unit) are considered service land uses at the neighborhood unit scale.
Elementary school, religious, cultural, sports, and small-scale commercial land uses, and neighborhood parks are considered the service land uses on the neighborhood scale.
The service land uses (including neighborhood, local, and district) are located within walking and cycling distance (200-500 meters).
The mixed land uses with the dominance of the residential land use are vertically distributed as mixed land use in the area.
Four accumulation centers of the service land use on the neighborhood unit scale are equally distributed.
The mixed land uses are distributed at the level of the center of the neighborhood units.
The service land uses on the district scale were provided as mixed land uses on the district scale to reduce the access distance to the district land uses.
Mixed land uses are located on the external edges of the area.
Similar to the second scenario, the current scenario was also proposed based on the low-carbon or zero-carbon city approach. However, in the second scenario, the changes applied in the status quo scenario was trivial; in the minimum intervention scenario, the practiced changes were changing area, orientation and dimensions of the plots, building densities, and the distribution of the service land use, especially on the local scale. However, in comparison with the second scenario, (maximum intervention), the applied changes were more in the current scenario. The most important changes in this scenario are as follows: the change in the layout of the residential plots, height system, dimensions, area, the orientation of the residential plots, and the distribution of the service land uses on the district, local, and neighborhood scales. As mentioned in the previous scenario, the population density was also considered 223 people per hectare in this scenario, and the future population was taken 7800. Also, based on the presented instructions in different areas, the proposed land use plan includes the following land uses: residential land uses, kindergarten, commercial land use, elementary school, cultural land use, mixed

neighborhood unit, mixed land use on district scale with the domination of the residential land use, the road network, greenspace on the neighborhood unit scale, children's playground, religious land use, urban facilities, parking, sports land use, and open space, among which, the residential land uses, roads network, and open space has the maximum share. As the name of this scenario implies, it has experiences the maximum changes in the road network and transportation compared to the model of the road network, the distribution of land uses, and the transportation network in the status quo scenario. A main arterial axis in the western part of the site, a secondary arterial axis in the eastern side of the site, two important axes of the access road and local collector road were proposed. The integrated and interconnected pedestrian and bicycle roads were considered between the residential blocks and service land uses regarding the other public transportation modes to improve the walkability in the area. Therefore, as integrity shows (Fig. 3), the roads located on the western, southern, and northern edges enjoy more integrity value than the previous scenarios and high have a very high connectivity level. Above all, in this scenario, the axis located on the eastern edge of the area is also improved in terms of integrity and has high connectivity. In general, the context of the area has relatively desirable integrity and connectivity in terms of the road network connectivity, the value of presence in the space, and improved walkability, increasing the walkability and reducing greenhouse gas emissions in the study area. To evaluate the appropriate location and placement of service land uses, the overlap analysis of the integration layers of the road network and the proposed land uses in the maximum intervention scenario has been used. As Figure 3 shows, mixed land uses and service land uses are based on the principles and criteria of the low-carbon city, and standards of the Transit-Oriented Development are located in the vicinity of the edges with high and very high integrity. Therefore, based on the information obtained from the figure above, the building density in the vicinity of the roads and by taking distance from the roads and edges with high and very high integrity, this amount is reduced to 300% with 100% coverage lot (three floors).

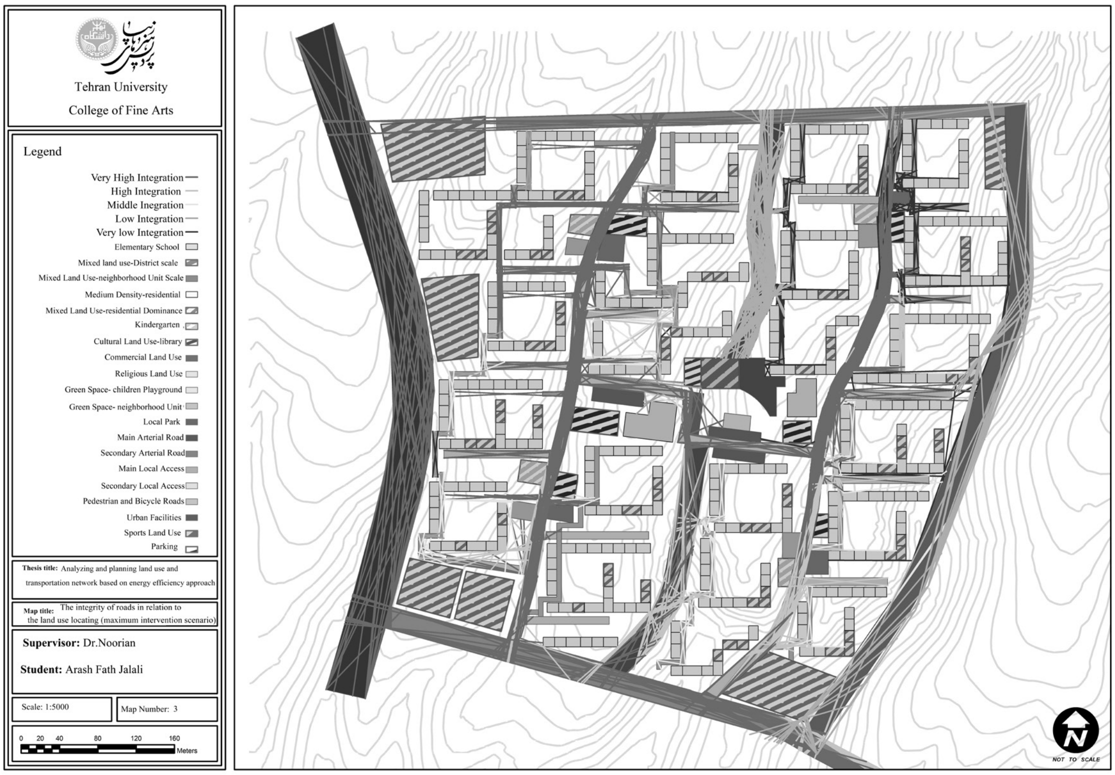

Fig. 3. Connectivity and Integrity of the Access Network Regarding Locating Land Use (Maximum Intervention Scenario)

4.3.3.2. Analyzing the Land Use System and Greenhouse Gas Emissions Based on the Distances between the Residential and Service Land Uses in the Maximum Intervention Scenario

In the maximum intervention scenario, it was tried to reduce the travel distances (average distance from the service land use) and, as a result, reduce greenhouse gas emissions and generation in the transportation sector in the study area by changing the distribution of the service land uses at local and district levels in the status quo scenario. In the current scenario, the percentage of the residential plots located within 200-500-meter distance from the service land uses (local travels) was reduced to zero percent. Also, the percentage of the residential land uses located more than 500-meter distances from the service land uses (district travels) was reduced to 16.2%, which resulted in reducing the greenhouse gas emissions in the study area. The value of the greenhouse gas emissions has been reduced to 336179.69 and enjoys a more desirable situation than the status quo scenario.

Table 6. Calculating Generated Greenhouse Gas Emissions in the Maximum Intervention Scenario

Index	The Third Scenario (Maximum Intervention)
The Amount of Generated Crude Emission of CO2 (kg/year)	264828.1
The Amount of Generated Crude Emission of CO (kg/year)	60042.84
The Amount of Generated Crude Emission of NO (kg/year)	4427.46
The Amount of Generated Crude Emission of Hydrocarbons (kg/year)	6881.29
Total (kg/year)	336179.69

5. DISCUSSION AND CONCLUSION

Since the 1970s, the world has had to deal with the complicated and sophisticated issues caused by the threats of the energy consumption resources, and subsequently, greenhouse gas emissions and generation due to the reduced resources and emergence of the constraints. In the meantime, fossil fuels and extensive use of them were the origins of these threats. Today, greenhouse gas emissions have been raised as a result of the extensive use of non-renewable energy resources, and in general, a serious problem. This phenomenon is affected by the economic and natural factors and all the incidents caused by human being's interventions in their surrounded environment. Emerging some issues and some actions, such as deforestation, desertification, and extensive human casualties, decline and disintegration of the global economy, reduction in natural water resources, air, water, and soil pollution, and global warming, are among the influential factors on exacerbating the greenhouse gas emissions and its consequences. On the other hand, the information indicates that the urbanization trend and its energy consumption are increasing. By 2030, 60 percent of the world's population is projected to live in cities, 73 percent of the world's energy is consumed by cities, and 76 percent of the world's greenhouse gases are emitted by cities. Hence, given the above problems and its increasing trend, it is significantly necessary to control the way and amount of the energy consumption, and subsequently, solve these issues in the urban communities. Indeed, there are various attitudes on the approaches in this regard. In the meantime, the close relationship between urban planning and the greenhouse gas emissions and generation, and achieving the principles of the low-carbon city in the cities are some of the controversial subjects. Therefore, studying the relationship between the different sectors and involving and integrating the low-carbon principles in the urban planning processes require numerous studies and investigation. The current study attempted to address these relations. To this end, first, three scenarios were determined for the study area based on the provided theoretical framework and the features of the current situation of the study era (uninhabited, pristine, and a desirable opportunity to apply changes and desirable modeling). Thus, in all the proposed scenarios-minimum intervention scenario, maximum intervention scenario, criteria of the compact and dense form- harmony with the nature, mixed land use, walkability, transportation, and efficient and integrated road network, urban divisions, building density, and distribution of the service land uses were the criteria for the planning (all the details of the low-carbon city planning and design were explained in describing scenarios and displayed in the proposed road network and land use plans). Then, the greenhouse gas emissions were calculated and considered using its analytical model and related software. In each scenario of the proposed land use, the land uses were classified into non-residential and residential. Then, based on the distance between the service land uses (travel attracting land use) and residential land uses (travel generating land use), the number of the generated travels (annually) and then the crude amount of the greenhouse gas emissions (annually) were calculated in CommunityViz software. The percentage of residential plots within a distance of 200-500 meters (assuming that the travel takes place at a distance of more than 500 meters) for local travels was determined to study accurately and separate travels by local, district, and urban scales and extract the annual greenhouse gas emissions in each of the proposed scenarios. Also, the percentage of residential plots with a distance of more than 500 meters for district travel was estimated. By multiplying this percentage by the crude number obtained, the annual greenhouse gas emissions of the transportation sector were calculated evaluated for each scenario. In this regard, based on the reviewed theoretical foundations, the results of evaluating and measuring the production and emission of greenhouse gases, land-use scenarios, and analyzing the proposed road network, it can be concluded that by changing the land use system and access network in Hashtgerd, the amount of the greenhouse gas emissions were significantly changed in the study area (Hashtgerd, neighborhood unit). In other words, the change in the layout of the service land uses, distribution of the urban facilities, and characteristics of the residential land use, as the contexts of the urban land use planning and change in the road network form and integration of the transportation network, have been increasingly influential in the amount of the greenhouse gas emissions in the area. The results of studying different compiled criteria in the research process indicate that there is a necessary relationship between land use, its distribution, road network, transportation, and the amount of greenhouse gas emissions. Thus, by making changes in the land use, road network form, and various transportation modes, a maximum of 79% reduction and a minimum of 41% reduction in greenhouse gas emissions can be achieved at the neighborhood unit level in Hashtgerd city.

Table 7. Comparing the Changes of the Greenhouse Gas Emissions in the Proposed Scenarios

Indicator	First Scenario (Status Quo)	Second Scenario (Minimum Intervention)	Third Scenario (Maximum Intervention)
The Amount of Generated Crude Emission of CO2 (kg/year)	1309427.86	772251.84	264828.1
The Amount of Generated Crude Emission of CO (kg/year)	296878.52	175087.9	60042.84
The Amount of Generated Crude Emission of NO (kg/year)	21891.33	12910.69	4427.46
The Amount of Generated Crude Emission of Hydrocarbons (kg/year)	34024.16	20066.18	6881.29
Annual Generated Greenhouse Gas Emissions in the Transportation Network (kg/year)	1662221.87	981726.84	336179.69
Total (kg/yea)	-	41%	79%

In this section, to select the top scenario based on the criteria extracted from the theoretical framework, Multi-criteria decision-making methods (Analytic Hierarchy Process) were used. Thus, first, the criteria were compared in pairs and prioritized to select the top scenario. Then, the proposed scenarios in proportion to the criteria were compared in pairs to select the top scenario. It is noteworthy that the criterion for the comparison was L Saaty's 1-9 scale of pairwise comparison. The results obtained from the pairwise comparison of the criteria were presented in Figure.

Table 8. Saaty's 9-Scale for Pairwise Comparison of the Items

Score (Intensity of The Preference)	Definition
1	Equal Preference
3	Moderate Preference
5	Strong Preference
7	Very Strong Preference
9	Extreme Preference
2, 4, 6, 8	Medan Preferences (When There are Median Modes)

(Zebardast, 2001, p. 15)

According to the values and weights displayed in the figure, it can be said that the integrity criteria of the transportation and roads networks were the priority with the weight of 0.187. The mixture of the land uses was the next priority with the weight of 0.143. Distribution of the service and travel-attracting land uses was the third priority with the weight of 0.128. Then, compact and dense form, walkability, building density, harmony, and compatibility with nature, and urban divisions with 0.123, 0.114, 0.110, 0.104, 0.091 weights ranked next, respectively, for the planning and designing scenarios. In the following, each of the criteria related to the proposed scenarios was compared in pairs. Then, after calculation, the following results were obtained in terms of application of the criteria in the scenarios: maximum intervention scenario with a weight of 0.518 ranked first, minimum intervention scenario with the weight of 0.347 ranked second, and keeping the status quo scenario with the weight of 0.135 ranked third. Therefore, in general, the maximum intervention scenario was determined as the top scenario in terms of more application of the low-carbon city criteria. The criterion for the validity of the assessments was the inconsistency coefficient, which was 0.06 in all steps. If this value is less than 0.1, it will indicate the validity of the calculations and assessments. However, in holistic review and regardless of evaluation, which is based on the application of each of the extracted criteria from the theoretical foundations in the study area, it can be claimed that the maximum intervention scenario requires considerable financial and infrastructural expenditures in the short term despite having maximum criteria of the low-carbon city. In the case of implementation, this scenario will have lower economic efficiency than the minimum intervention scenario. Therefore, in terms of implementation and realizability and the short term, the minimum intervention scenario with a 41% reduction in the greenhouse gas emissions can be a moderate option in terms of execution and application of the low-carbon city criteria.

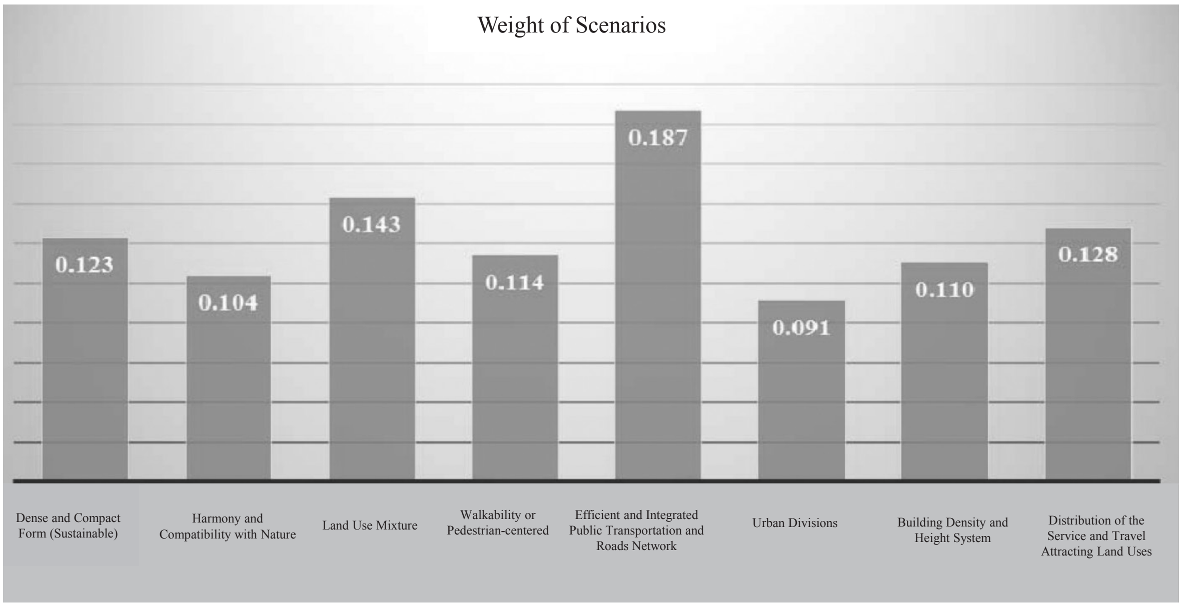

Fig. 4. Comparing the Criteria Related to the Purpose (Final Weights of the Criteria Related to the Purpose)

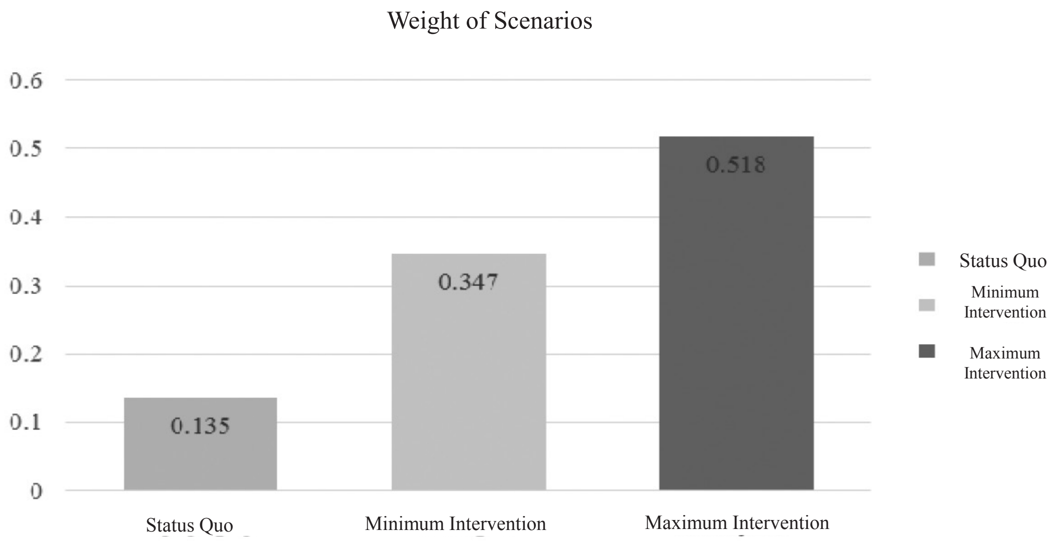

Fig. 5. Comparing the Scenarios Concerning the Criteria (Final Weight of the Scenarios)

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